Buckinghamshire Strategic Transport Model

Local Model Validation Report

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Buckinghamshire Council

BC

Buckinghamshire Strategic Transport Model

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Executive Summary

Jacobs are framework consultants to the Transport for Buckinghamshire Alliance (TfB) between Ringway Jacobs and Buckinghamshire Council (BC). Under the terms of this contract, Jacobs are commissioned to undertake transport planning, modelling and appraisal projects on behalf of BC. As part of this study, Jacobs has been commissioned to develop the Buckinghamshire Strategic Transport Model (BSTM), in partnership with Systra.

The model has been developed with the following uses in mind:

- Evidence for Local Plan development and hearings (and cumulative impacts once Local Plans are in place);
- Ability to understand and mitigate impact of external influences e.g. Housing allocations, Highways England schemes;
- Evidence to support Business Case submissions (to Strategic Outline level) to secure Government funding for new infrastructure and maintenance;
- Provide evidence to support responses to Government department or company consultations;
- Support the Development Consent Order (DCO) and town and country planning process on key schemes;
- Understand suitable phasing of maintenance and utilities work to manage congestion impacts;
- Optimisation of the performance of the existing transport network using technology; and
- Accessibility planning for key land uses.

It was originally intended that the model would have a 2020 base year using new survey data collected in that year, however, due to the impacts of COVID-19, no new traffic data has been collected, and Journey Time data and Mobile Network Data (MND), which is continually collected regardless, has been collected from 2019. The lack of new traffic survey data (i.e. traffic counts) has been overcome through the use of pre-existing data from multiple sources which pre-date 2020, and with the scope changed to develop a model with a 2019 base year.

The model is based in VISUM, v2021. The zoning system and network for the model was based on that of the existing Countywide Model, but with a detailed review and update, informed by other models developed within Buckinghamshire, and with more spatial detail added in urban areas just across the County border, such as Milton Keynes, Bicester, Slough, and Uxbridge. The model comprises approximately 900 zones, around 700 of which are in the area of detailed modelling covering the county and adjacent built up areas.

The model is highway based but does not exclude the possibility of a Public Transport element being added later if required. It has also been developed to allow for full Variable Demand Modelling, using 24-hour Production-Attraction matrices. It covers an AM peak hour, PM peak hour, and average interpeak hour, of an average neutral weekday in 2019; thereby covering all key time periods during which significant impacts on the transport network would occur. Whilst the assignment model allows for different route choices for commuting, business, and other trip purposes, the demand model is segregated further into four home-based and two non-home-based trip purposes.

The model was developed following the Department for Transport's (DfT's) Transport Analysis Guidance (TAG) for highway assignment modelling and matrix development. Accordingly, the model has gone through a rigorous process of network checking, calibration and validation, and route choice calibration. The trip matrices were derived from a fusion of observed travel patterns from Mobile Network Data, with synthetic data calibrated against Census journey to work and National Travel Survey (NTS) Data. Trip matrices were subject to appropriate verification checks, as well as calibration and validation. Finally, the highway assignment was calibrated and validated and demonstrated to replicate observed traffic data to an appropriate level of tolerance given the intended uses of the model.

However, any application of the model for a specific purpose should always first assess the suitability of the model for that task. No specific application has yet been identified; however, the model is considered to be an excellent starting point for the areas of application mentioned above. However, further local revalidation in specific areas may be required once specific applications and uses have been identified. For example, more detailed submissions at Outline and Final Business case stages would likely require a more detailed local model or a local revalidation of the BSTM, along with (potentially) a Variable Demand Model (VDM) and (possibly) a Public Transport (PT) model, depending on the requirements of the individual scheme. The BSTM is currently considered fit for strategic transport planning assessments, such as Local Transport Plan 5, however, in absence of further review and (most likely) local revalidation the model should not be considered fit for more detailed assessments of development impacts such as for development management purposes.

As with all strategic models, the impact of uncertainty on the model results will need to be carefully considered through a range of sensitivity tests when applying the model. The BSTM has been developed using the latest pre-COVID-19 pandemic data and is calibrated against 2019 conditions. While the pandemic had a profound impact on travel demand by all modes in 2020, and is continuing to affect conditions in 2021, it is not yet clear how it will affect longer term trends. This does not undermine the validity or usefulness of the model set up based on 2019 data because these are temporary effects driven by external factors rather than fundamental changes in the travel choice processes that the model is calibrated to reproduce. If there are to be long term effects, these will be driven by the input assumptions used to derive future travel demand rather than changes in the behaviour represented by the model's algorithms.

At this stage, the likely long-term impacts of the pandemic can only be understood through scenario testing and our recommendation is that such scenarios should be run through the BSTM to examine the potential range of outcomes. Such scenarios should be developed through discussion and consultation with key stakeholders and may be informed by the scenarios postulated by the Office for Budget Responsibility (OBR) who maintain a set of upside, central and downside forecasts.

1. Introduction

1.1 Background

As framework consultants to Buckinghamshire Council (BC), Jacobs has been asked to develop a strategic transport model of Buckinghamshire.

A previous strategic transport model of Buckinghamshire, known as The Countywide Transport Model, was commissioned in November 2013 through the Transport for Buckinghamshire framework and is therefore reaching the end of its usable life. Acknowledging this, BC have requested Jacobs develop a new model, the Buckingham Strategic Transport Model (BSTM). Aside from the age of the older Countywide model, the update will also address the following:

- Base year travel demand was entirely synthetic – the update will include the incorporation of observed demand based on mobile network data.
- The detailed area of the model covered Buckinghamshire County, but not beyond – the update will extend the detail into neighbouring built up areas, such as Slough and Thame.
- The model had calibration and validation statistics which did not meet all of the recommended criteria in DfT's Transport Appraisal Guidance (TAG) – the update will improve on this and aim to achieve a standard closer to the full TAG guidelines.

It was acknowledged at the time that the 2013 model would be built with regards to TAG, but not to TAG standards in every aspect (for example, as listed above, matrix and assignment validation criteria and development of entirely synthetic trip demand). The model was developed such that more detailed models could be developed from it, as the need arose, with the expectation that those models could be used for Outline and Full Business Case appraisal, amongst other purposes. This led to the development of a number of sub-area models which have been generated from the original Countywide Model since its development, these are detailed in Table 1-1:

Model	Base Year
A355 Beaconsfield	2015
Updated Aylesbury	2017
Iver	2019

Table 1-1: Sub-Area Models Developed from the 2013 Countywide Model

These sub-area models were built to be able to provide an evidence base for full business case submissions (subject to appropriate forecasting assumptions and techniques), this means that additional count surveys were carried out, and the models underwent a more detailed process of matrix and assignment calibration and validation. The BSTM adopted the increased levels of network detail in those sub-area models within its network development.

As well as updating to a new base year (2019), the model also utilised new technology by incorporating observed OD data from mobile network data. The model has been developed in the latest version of VISUM software (VISUM version 2021) and incorporated network improvements made as part of developing local models (e.g. the Aylesbury, Risborough and Iver Models) and improvements to the original Countywide Model already undertaken as part of local plan modelling. Consistent with the 2013 Countywide Model, the updated version includes AM and PM peak hours, and an average interpeak hour.

1.2 Report Structure

The remainder of this report is set out as follows:

Chapter 2 - Details the proposed uses of the model and key design considerations;

Chapter 3 - Identifies the aspired standards to which the model was built;

Chapter 4 - Describes the key features of the model;

Chapter 5 - Details the data used for model calibration and validation;

Chapter 6 - Describes the processes used in developing the modelled network;

Chapter 7 - Describes the checks carried out on the network calibration and validation;

Chapter 8 - Describes the checks carried out on the route choice calibration;

Chapter 9 - Describes the processes used in developing the modelled demand (i.e. trip matrices);

Chapter 10 - Provides information on the calibration and validation of the trip matrices;

Chapter 11 - Provides information on the overall calibration and validation of the assignment; and

Chapter 12 - Provides a summary of the model development and of the standards achieved.

2. Proposed Uses of the Model and Key Design Considerations

2.1 Proposed Use of the Model

The model has been developed initially to assist in the production of the new Unitary Local Plan for Buckinghamshire, Local Transport Plan 5, and the subsequent assessment of any associated transport schemes.

The model may, with suitable updates or refinements, be required to serve a number of other purposes including but not limited to those listed below.

- Ability to understand and mitigate impact of external influences e.g. Housing allocations, National Highways schemes;
- Evidence to support Business Case submissions to secure Government funding for new infrastructure and maintenance;
- Provide evidence to support responses to Government department or company consultations;
- Support the Development Consent Order (DCO) and town and country planning process on key schemes;
- Understand suitable phasing of maintenance and utilities work to manage congestion impacts;
- Optimisation of the performance of the existing transport network using technology; and
- Accessibility planning for key land uses.

It should be noted with regard to business case submissions that the model would only be suitable for Strategic Outline Business Cases (SOBC). More detailed submissions at Outline and Final Business case stages would likely require a more detailed local model or a local revalidation of the BSTM, along with (potentially) a Variable Demand Model (VDM) and (possibly) a Public Transport (PT) model, depending on the requirements of the individual scheme.

Given the wide coverage of the BSTM, it may not be possible to achieve a consistency of validation standards across the whole model area, and therefore it is possible that in some particular local areas, the level of validation may fall below that of the model as a whole. For this reason, the validation of the model within a relevant study area should always be reviewed, and a revalidation in that local area be considered. Unless and until an appropriate review takes place, the model should only be considered appropriate for strategic modelling purposes and <u>not</u> appropriate for development management purposes.

The model covers only highway modes, and does not currently include any representation of PT. The model does not currently include a VDM component. This allows limited resources to be focussed on the most pressing need, which is to assess the impact of road infrastructure schemes and land use development impacts on the highway. However, the model was designed such that the inclusion of PT modelling and VDM can be facilitated at a later date if required.

2.2 Key Model Design Considerations

In order for the BSTM to be used for the proposed purposes above it is important that the model accurately reflects movements throughout the county, and also key areas within the county, including; Aylesbury, High Wycombe, Buckingham and Iver. Additional to these areas within the county, it is also important to reflect movements in the ‘bulge’ areas around the county border as this will determine accurate movements of vehicles across the county borders. These ‘bulge’ areas include:

- Milton Keynes

- Bicester
- Slough
- West Drayton

It is important that the interaction between the local routes in the model and the strategic road network are well represented. The core study area and the bulge areas mentioned are shown in Figure 2-1 on the next page.

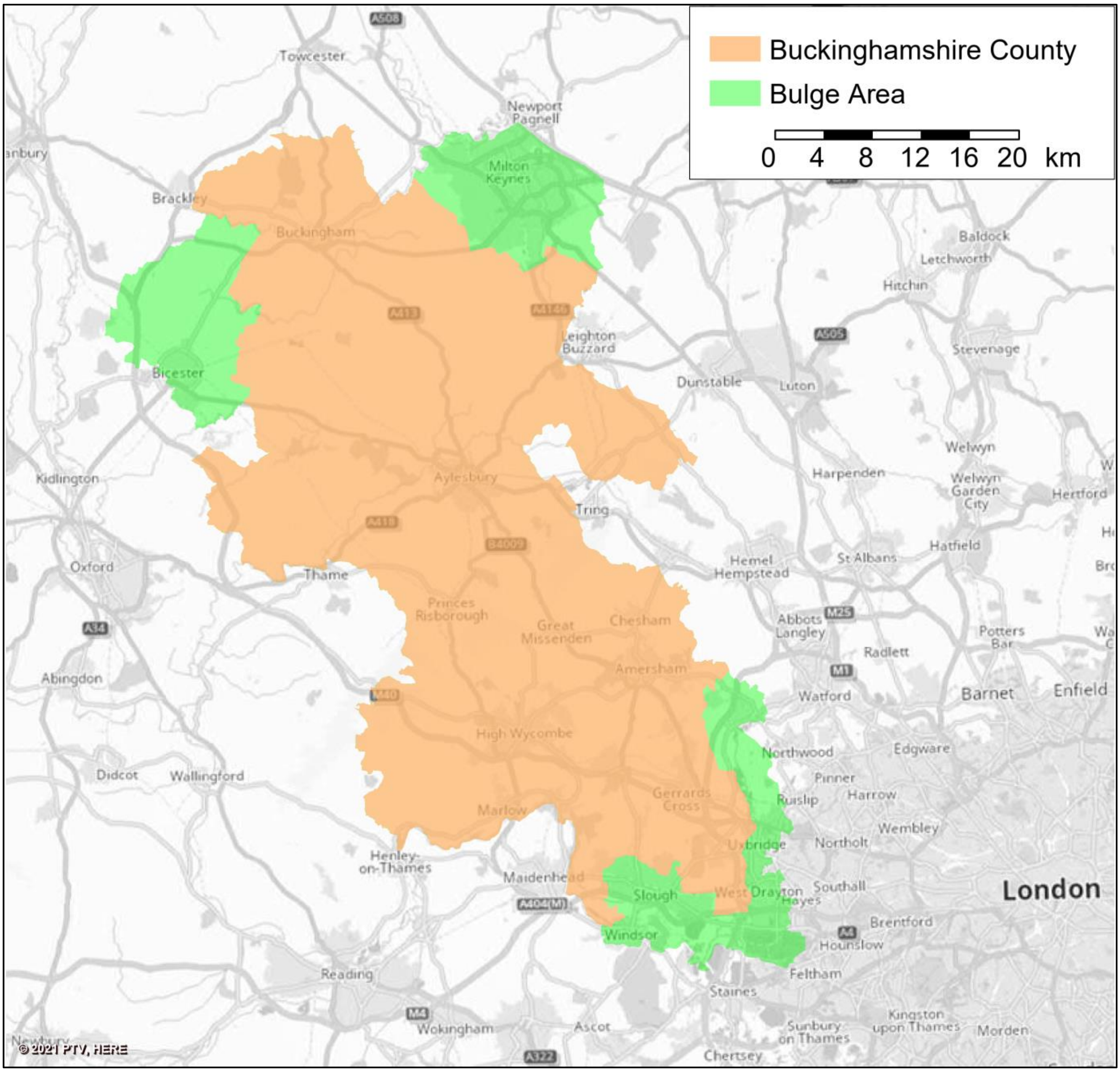


Figure 2-1: Study Area (Buckinghamshire County and Bulge Area)

The model will be used to inform potential Business Case appraisals for a range of highway schemes. To reflect the impact that these schemes might have during the busiest parts of the day, morning peak and evening peak models were developed. Schemes may have an impact during less busy times of the day and therefore an average inter-peak hour was also modelled.

Although some schemes may impact both public transport trips and highway trips, it is beyond the scope of the current commission to develop a full PT model. Should the need to develop a PT model arise in the future, the required functionality can be added to the highway model.

3. Model Standards

3.1 Validation Criteria and Acceptability Guidelines

The adequacy of the BSTM for its proposed uses (see section 2.1) has been measured against the criteria set out in TAG Unit M3.1. The TAG guidance sets out measures to compare the base year model against observed independent data to quantify the level of fit. The validation of the highway assignment model included comparisons of the following criteria which have been taken from TAG unit M3.1, paragraph 3.3.5:

- 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.

Base matrix validation is defined as the percentage differences between modelled flows and counts at screenline level within the model, the criteria to meet is set out in Table 3-1 below:

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%)

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

TAG specifies the following criteria for screenlines, within unit M3.1 paragraph 3.3.8:

- *Screenlines should normally consist of five or more links;*
- *The comparison of modelled and observed flows for screenlines containing high flow routes (such as motorways) should be presented both with and without such routes;*
- *The comparison should be presented separately for:*
    - *Roadside interview screenlines;*
    - *Other screenlines used as constraints in matrix estimation; and*
    - *Screenlines used as independent validation.*
- *The comparison should be presented by vehicle type, i.e. for car, Light Goods Vehicles (LGV) and Heavy Goods Vehicles (HGV) traffic.*
- *The comparison should be presented separately for each modelled period.*

Further information is given in Section 10, but due to the relatively small study area, it was difficult to draw up screenlines consisting of more than five links in all cases, and the screenlines used consisted of between three to ten links.

In addition to validation of total screenline flows, TAG Unit M3.1 also contains guidelines on the validation criteria for individual links or turning movements. Link flow validation was based on the following measures:

- *The absolute and percentage differences between modelled flows and counts, and;*
- *The GEH statistic, which is a form of the Chi-squared statistic that incorporates both relative and absolute errors. The GEH statistic is detailed below:*

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

where:

GEH is the GEH statistic;

M is the modelled flow; and

C is the observed count.

The validation criteria and acceptability guidelines for link flows are defined below in Table 3-2. For the representation of modelled flow on a link to be considered valid against the observed flow, it must satisfy at least one of the two criteria[1] in the table below.

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

Table 3-2: Link Flow and Turning Movement Validation Criteria and Acceptability Guidelines

TAG guidance unit M3.1 paragraph 3.3.12 states that the above comparison of modelled and observed flows should be applied to link flows and turning movements, although acceptability may be difficult to achieve for turning movements. The comparisons should be presented for total vehicle flows and for car flows, but not for LGV and HGV flows unless sufficiently accurate link counts have been obtained. In addition, the above information should be presented by modelled time period.

Data collection sites used in the validation of the base year, as well as those sites used in the development of the base year model, are presented within section 5.2.

TAG also contains acceptability guidelines for the validation of journey times. The journey time validation will be presented separately for each modelled period for all vehicle types together. The measure which will be used is the percentage difference between modelled and observed journey times, subject to an absolute maximum difference. The acceptability criterion for journey time validation is given below in Table 3-3:

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

Table 3-3: Journey Time Validation Criterion

Independent validation as specified above quantifies the ability of the model to replicate base year travel conditions within the model area. To check that these conditions have a sound basis, TAG provides guidance as to the acceptability of changes to the highway 'prior' matrices that result from the application of matrix

[1] TAG Unit M3.1 Paragraph 3.3.10 states that these two measurement criteria are “broadly consistent and link flows that meet either criterion should be regarded as satisfactory”.

estimation. The purpose of matrix estimation is to refine trips, but it is important that the effects of matrix estimation are minimised. The changes brought about by matrix estimation should be carefully monitored by the following means:

- *Scatter plots of matrix zonal cell values, prior to and post matrix estimation, with regression statistics (slopes, intercepts and R^2 values);*
- *Scatter plots of zonal trip ends, prior to and post matrix estimation, with regression statistics (slopes, intercepts and R^2 values);*
- *Trip length distributions, prior to and post matrix estimation, with means and standard deviations; and*
- *Sector to Sector level matrices, prior to and post matrix estimation, with absolute and percentage changes.*

The changes brought about by matrix estimation should not be significant. The criteria by which the significance of the changes brought about by matrix estimation may be judged are given in Table 3-4:

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

Table 3-4: Significance of Matrix Estimation Changes

TAG Unit M3.1 paragraph 8.3.16 states that all exceedances of the above should be noted and assessed as to their importance to assess the scheme. In addition, paragraph 8.3.17 states that the independent validation of the model as set out in Table 3-1, Table 3-2, and Table 3-3, should not be achieved at the expense of matrix estimation as presented in Table 3-4. In some models, particularly models of large congested areas, it may be difficult to achieve the link flow and journey time validation quality guidelines without matrix estimation bringing about changes greater than the limits shown in Table 3-4. In these cases, the limits set out should be respected, the impacts of matrix estimation should be reduced so that they do not become significant, and a lower standard of model validation reported. In other words, matrix estimation should not be allowed to make significant changes to the prior matrices in order to meet the validation quality standards.

3.2 Convergence Criteria and Standards

In order for the outcomes of the modelling to be reliable, the stability of the modelled flows needs to be confirmed at the appropriate level. The importance of achieving convergence is related to providing stable, consistent, and robust model results. This increases confidence that, when modelling a scheme, any flow changes which occur do so directly as a result of the scheme, rather than as a result of random flow changes due to poor convergence.

Sufficient iterations should be carried out to achieve an acceptably low value for %GAP (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). GAP is the single most valuable indicator of overall model convergence and the method for calculating GAP (denoted δ) is outlined below with the guideline for GAP being 0.1% or less.

$$\delta = \frac{\sum T_{pij}(C_{pij} - C_{ij}^{*})}{\sum T_{ij} C_{ij}^{*}}$$

where:

T_{pij} is the flow on route p from origin i to destination j;

T_{ij} is the total travel from i to j;

C_{pij} is the (congested) cost of travel from i to j on path p; and

C_{ij}^{*} is the minimum cost of travel from i to j.

Source: TAG Unit M3.1 paragraph C.2.4

In addition, the model should converge to a point in which routes obey Wardrop's First Principle of Traffic Equilibrium which unit M3.1 paragraph 2.7.3 defines as: "*Traffic arranges itself on networks such that the cost of travel on all routes used between each OD pair is equal to the minimum cost of travel and all unused routes have equal or greater cost*."

This relates to how close the model is to a particular converged solution, which varies depending on the preferences of the user or software package being used.

The gap value therefore represents the excess cost incurred by failing to travel on the route with the lowest generalised cost (Section 4.9) and is expressed relative to that minimum route cost. The excess cost is summed over each route between each OD pair and multiplied by the number of trips between each OD pair. This is divided by the minimum cost summed over each route between each OD pair, also multiplied by the number of trips between each OD pair.

For the model to be considered sufficiently well converged, the GAP value must be less than 0.1%. A full summary of the most appropriate convergence measures (of proximity and stability) for a model of this type, and the values generally considered acceptable for use in establishing a base model, is expressed in Table 3-5:

Measure of Convergence	Base Model Acceptable Values
Delta and % GAP	Less than 0.1% or at least stable with convergence fully documented and all other criteria met
Percentage of links with flow change (P) < 1%	Four consecutive iterations greater than 98%
Percentage of links with cost change (P2) < 1%	Four consecutive iterations greater than 98%

Table 3-5: Summary of Convergence Measures and Base Model Acceptable Values

Within the model, the “Assignment with Intersection Capacity Analysis (ICA)” methodology will be used where, within each outer iteration, a Linear User Cost Equilibrium (LUCE) assignment, which does not include flow metering, is run to convergence before flow metering and blocking back is then applied. Subsequent iterations then consider the delay caused by flow metering and blocking back when choosing routes. This process therefore includes the “inner iterations” of the equilibrium assignment and the “outer iterations” of the assignment with flow metering and blocking back. This assignment methodology is described in more detail in Section 4.8.

4. Key Features of the Model

4.1 Summary

The BSTM has been developed with a base year of 2019. As will be outlined later, the origin-destination data collected from Mobile Network Data (MND) to inform the matrix development was collected in September 2019.

The key characteristics of the model are described in Table 4-1 :

Characteristic	Model Coverage
Model Structure	Highway assignment model
Software platform	VISUM version 2021
Assignment methodology	VISUM Assignment with ICA using the LUCE algorithm
Time periods	AM peak hour, Average interpeak hour, PM peak hour
Trip Matrices (Private Transport Modes)	Car Commute, Car Business, Car Other, LGV, HGV
Trip matrices (Public Transport Modes)	None (but software platform allows future inclusion of public transport)
Base Year	2019
Forecast Year	2040
Calibration/Validation	Following TAG

Table 4-1: Key Model Features

4.2 Fully Modelled Area and External Area

TAG Unit M3.1 states that the geographic coverage of highway assignment models generally needs to allow for the strategic re-routing impacts of interventions; enable areas outside the main area of interest, which are potential alternative destinations, to be properly represented; and enable the full lengths of trips to be represented for deriving costs.

The modelled area therefore needs to be large enough to include these elements, but within the modelled area the level of detail should vary as follows:

- Fully Modelled Area:
    - Area of Detailed Modelling; and
    - Rest of the Fully Modelled Area.
- External Area.

It is to be noted that the method to capture delays in the 'Bulge Areas' (see Figure 2-1 below) is similar to the Rest of the Fully Modelled Area. However, the network density in the 'Bulge Areas' (which fall right outside the Area of Detailed Modelling) is higher compared to the Rest of Fully Modelled Area. The emphasis in the 'Bulge Areas' was to accurately reflect movements to and from these areas into Buckinghamshire and quantification of model performance within these bulge areas is out of the current scope.

The Area of Detailed Modelling is contained within the Buckinghamshire County boundary. Additional links beyond the county boundary have been modelled to provide a sufficient buffer around the county to enable demand to route into the Area of Detailed Modelling correctly. These additional links comprise the "Rest of the Fully Modelled Area". The External Area of the model comprises the rest of the Model outside the Area of Detailed Modelling and Rest of Fully Modelled Area, which is not explicitly modelled. Figure 4-1 below shows the Fully Modelled Area (Area of Detailed Modelling, 'Bulge Areas', and Rest of Fully Modelled Area):

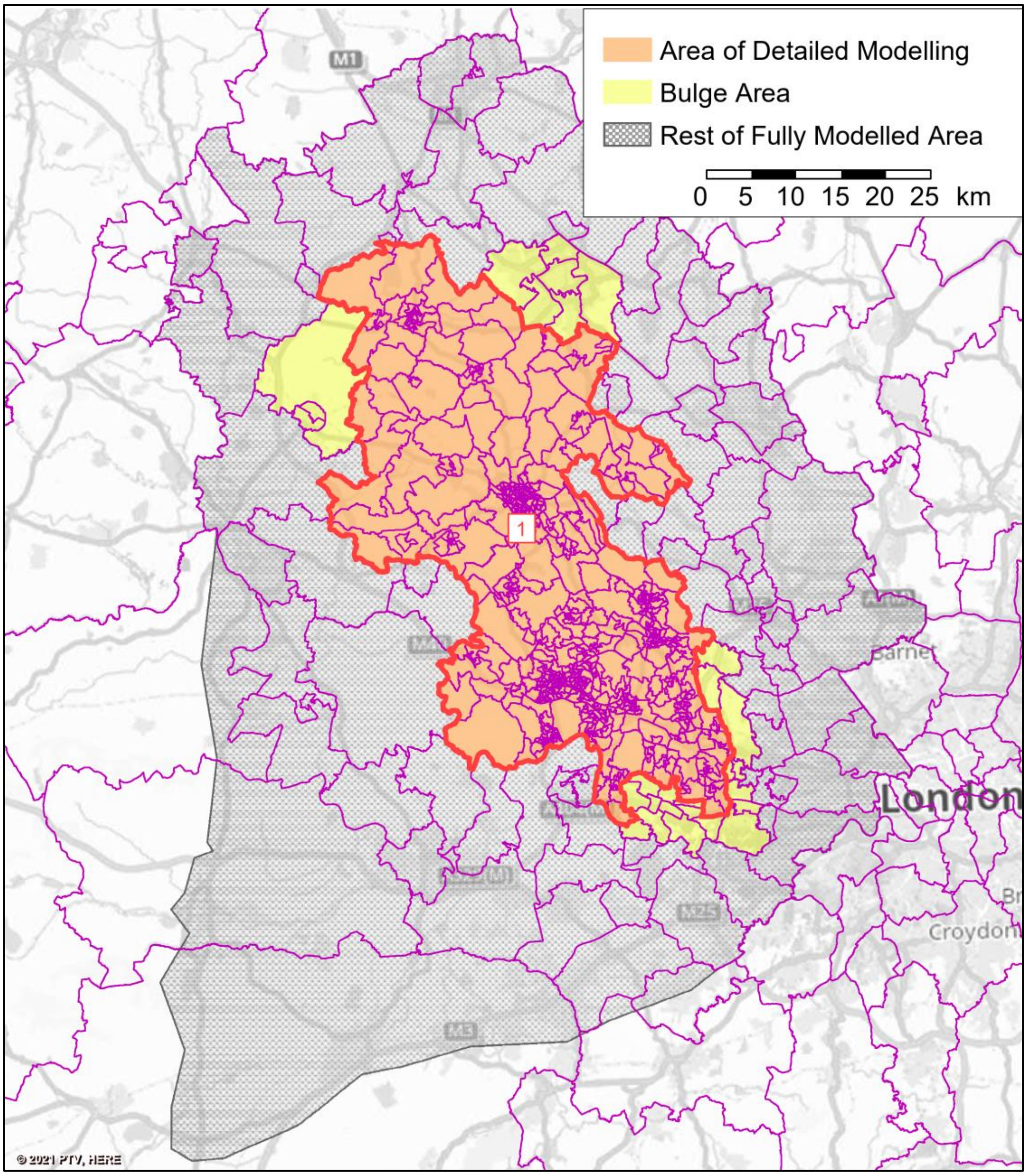


Figure 4-1: Fully Modelled Area

4.3 Zoning System

The zone system used in the model was similarly adapted from the 2013 version of the Countywide Model.

The zone system within the BSTM is hierarchical with higher levels of detail within the county, decreasing in detail as distance from the county increases. Within the county, zone boundaries were built up from aggregations of output areas. In urban centres, the greater levels of detail required necessitated splitting up one output area into several zones. Table 4-2 (below) and Figure 4-2 (on the next page) show the zone system used for the BSTM:

Area of Model	Number of Zones
Area of Detailed Modelling	696
'Bulge Areas'	28
Rest of Fully Modelled Area	84
External	62
Total	870

Table 4-2: BSTM Zone System

It should be noted that it may be necessary to add new zones to subsequent forecast models in order to fully represent future year land developments.

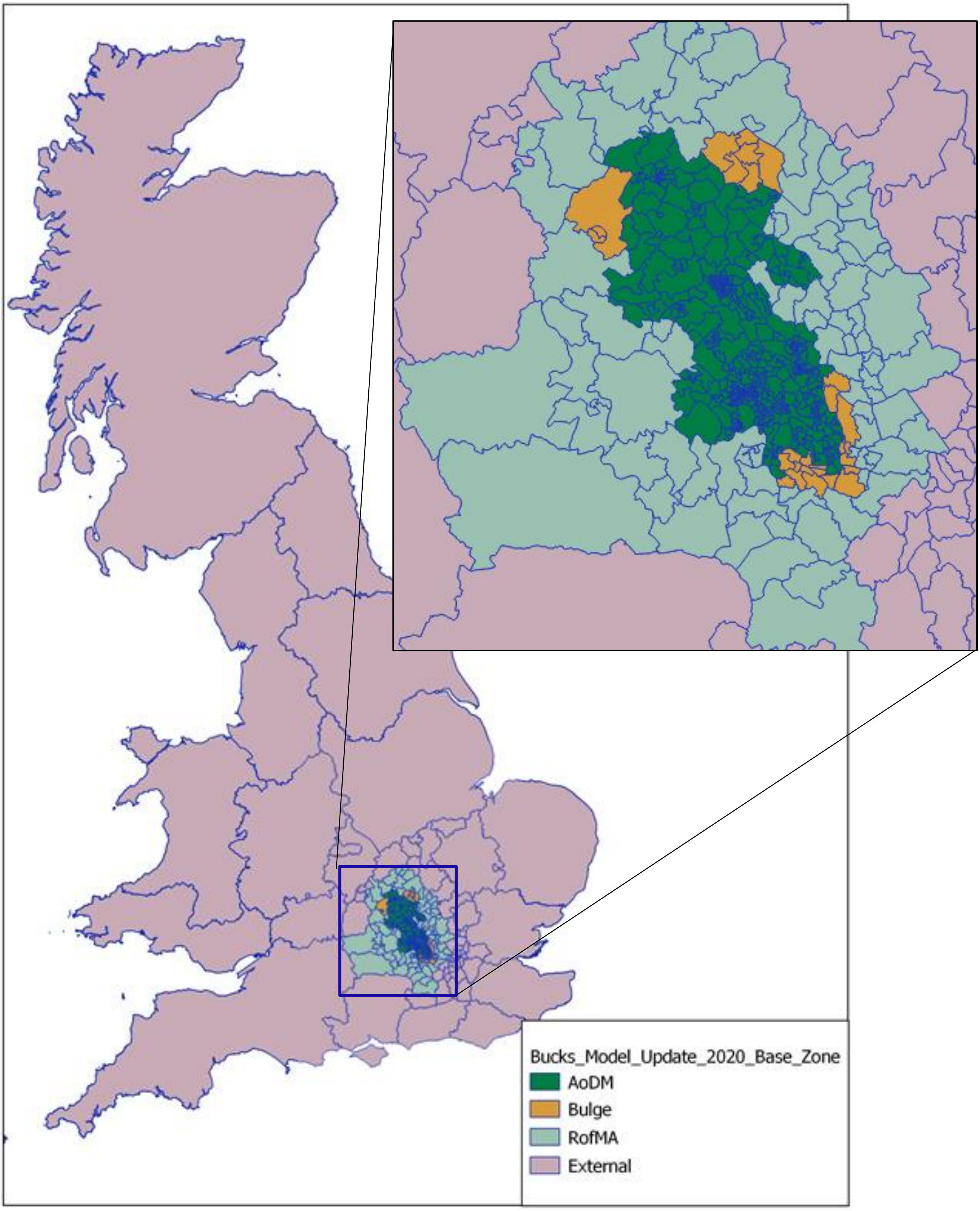


Figure 4-2: Buckinghamshire County Model Zone System

4.3.1 Zone Sectoring

To assist with matrix manipulation analysis and reporting, a 48-sector system was developed, as shown in Figure 4-3. It is noted that sectors are at a greater level of aggregation in the external areas, becoming more disaggregate in the core study areas and are compatible with Middle Layer Super Output Areas (MSOA) and district boundaries. The sector numbering system is detailed in Table 4-3 on the next page.

Figure 4-3: BSTM Sector System

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

Table 4-3: BSTM Sector Numbering System

4.4 Centroid Connectors

Trips to and from zones are loaded onto the network from the zone centroid using specialised links known as centroid connectors. Zone connectors will connect to the highway network at access points via junctions. The points at which these connectors load on to the network have been chosen to reflect actual access points and to avoid major junctions.

In line with TAG Unit M3.1 Section 2.4, the number of centroid connectors will be minimised. In general, each model zone will have one centroid connector, but there are likely to be exceptions to this where zones require multiple centroid connectors to accurately represent the loading points to/from the zone. For example, some zones in town centres will have multiple connectors due to the high detail and connectivity. In the case of multiple centroids, traffic will be split by estimating fixed trip proportions by centroid, the “by shares” tool in VISUM will be used to distribute the trip ends to better represent the distribution of the demand.

Zone connectors coding will be reviewed and if necessary refined during the model calibration process. Figure 4-4 on the next page shows examples of zone connector coding in the BSTM, in this case in the town of High Wycombe.

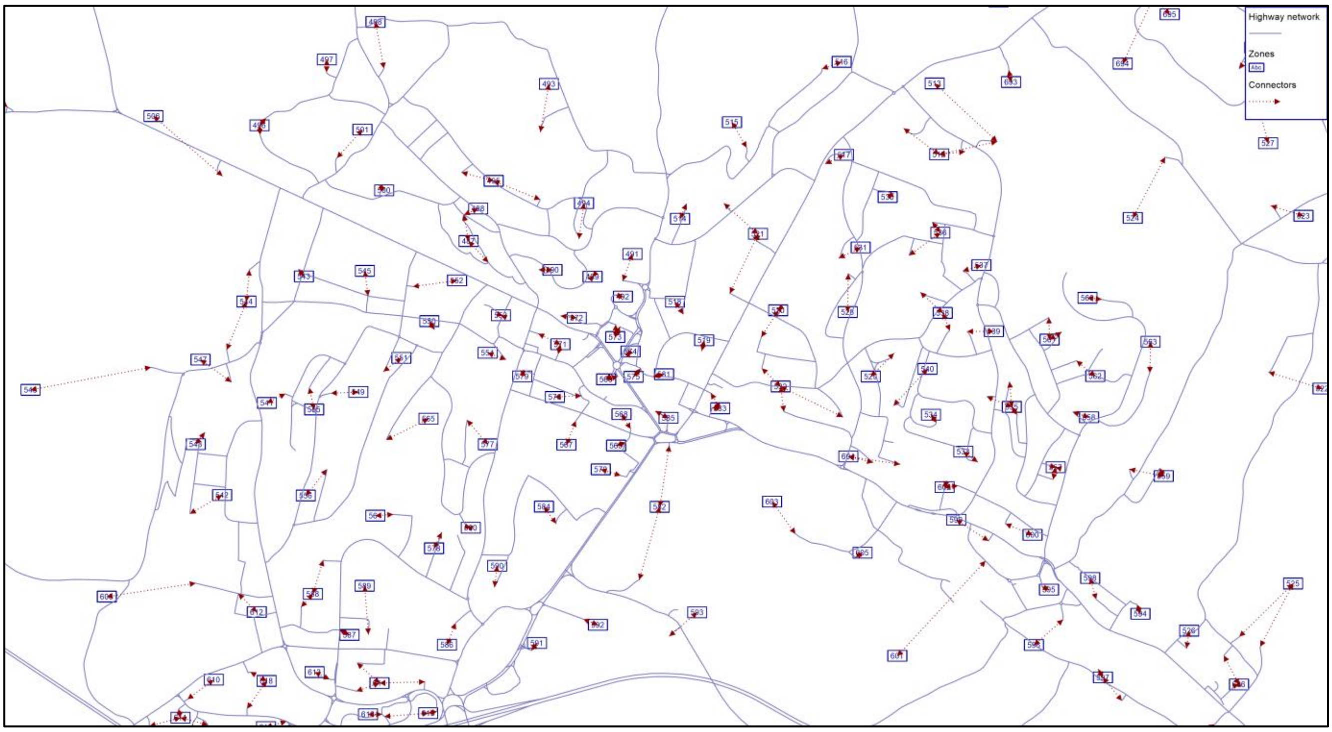


Figure 4-4: Zone Connectors in High Wycombe

4.5 Network Structure

The highways network inside the Buckinghamshire County border (and 'Bulge Areas') includes all major and minor roads. There is proportional treatment of local roads with due regard to the importance of such roads in facilitating access to major trip generating areas or for providing routes to through traffic. The highways network outside of the Buckinghamshire County border (and 'Bulge Areas') was represented by major roads only.

The basis of the model highway network is digital mapping databases, which were converted to model network using GIS functions. For areas within Buckinghamshire the ITN digital map layer was used, for outside this boundary the Meridian open source digital maps were used.

As part of the previous Countywide Model and subsequent sub-area models the network has previously been extensively checked. The following highways classes were developed:

- Motorways;
- A Roads;
- B Roads;
- Minor Roads;
- Local Roads (residential streets etc…) – partial coding; and
- Ancillary Roads (walkways, bus links etc…) – partial coding.

Figure 4-5 below shows the level of detail of network coding:

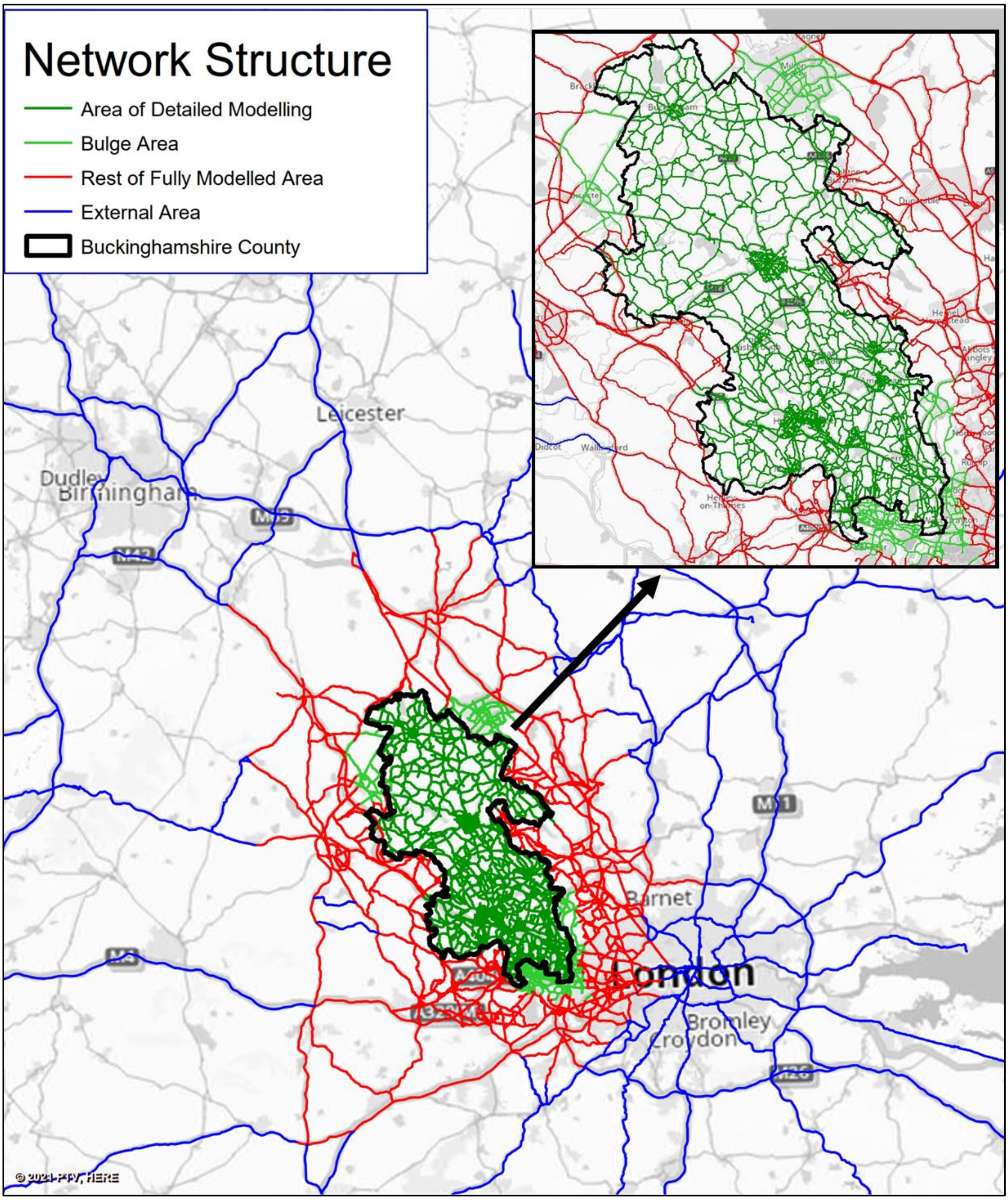


Figure 4-5: BSTM Network Structure

Additional network, including the A33 and A339 to the south west of the study area, were included in the Rest of the Fully Modelled Area, taking Highways England's feedback on the network structure into consideration.

4.6 Time Periods

The model was built to represent three time periods, presented in Table 4-4. The modelled hours were derived by analysis of traffic counts throughout the study area to ascertain which hours contained the highest overall volume of traffic and the hours where the traffic volume was observed to be the highest at the majority of survey locations. Evidence on the selection of the specific hours for the time periods is provided in the related Data Collection Report for this model.

Time Period	Temporal Coverage
AM peak hour	08:00 – 09:00
Average hour in the interpeak	10:00 – 16:00
PM peak hour	17:00 – 18:00

Table 4-4: Modelled Time Periods

4.7 User Classes

In line with TAG unit M3-1, the modelled car trips were subdivided into Commute, Business and Other trip purposes in the assignment. In addition to this, separate user classes were used for LGV and HGV trips. Additional trip purposes are used in the demand model, with non-home-based car trips incorporated into the Business and Other trip purposes during the assignment. The segmentation is summarised in Table 4-5:

Assignment Mode	Assignment User Class	Demand Model Trip Purpose	Vehicle Class
Private Transport (PrT)	Car Commute	Home-Based Work (HBW)	VC1
	Car Employers' Business	Home-Based Employers' Business (HBEB)	
		Non-Home-Based Employers' Business (NHBEB)	
	Car Other	Home-Based Other (HBO)	
		Home-Based Education (HBED)	
		Non-Home-Based Other (NHBO)	
	LGV	LGV	VC2
	HGV	HGV	VC3

Table 4-5: Purpose/User Class/Vehicle Class Correspondence

Link flow validation was performed at the level of vehicle class flows. The trip purpose and user class definitions are consistent with the guidance contained in TAG Unit M3.1.

Vehicle classes 1 and 2 (cars and LGVs) were assigned a Passenger Car Unit (PCU) factor of 1.0. HGVs were given a PCU factor of 2.0. This is consistent with guidance in TAG unit M3.1 appendix D, which advises use of this factor on road types other than motorways and dual carriageways. Some consideration was given to the use of a PCU factor of 2.5, corresponding with guidance regarding HGVs on motorways, and discussion on this issue was had with Highways England. It was concluded that because the majority of the network comprises local roads, a factor of 2.0 would be used, but when flows from the model are used for local junction modelling on the Strategic Road Network, a factor of 2.5 would be used within those junction models.

As previously stated, the purpose and proposed uses of the BSTM means there are no expected changes to the Public Transport System, therefore no specific Public Transport assignment component has been employed in the model.

4.8 Assignment Methodology

The assignment methodology used in this model is known as "Assignment with ICA". This was consistent with the approach used on the 2013 Countywide Model. This means that, when generalised costs are calculated for the purposes of route choice, junction delays are calculated using Intersection Capacity Analysis (ICA) and are included within the generalised cost. In all other VISUM assignment methods, junction delays are calculated using volume-delay functions (VDFs), and the ICA is only brought into effect when the assignment is completed.

The "Assignment with ICA" method also enables flow metering (known as blocking back) to be calculated. For the assignment with ICA, the LUCE assignment can be used as a subordinate assignment procedure with the advantage that there is stable route distribution, the calculation of blocking back is considerably faster than using the paths of other assignment methods, and (due to the stable route distribution over routes) the blocking back result is more stable and convergence is reached much faster. The fundamentals of the LUCE assignment is that, for any node, a user equilibrium shall be reached on all forward edges for the local route choice of drivers heading to a destination zone[2].

Blocking back occurs when the volume on a link upstream of a junction exceeds the capacity of that junction (or more specifically, the capacities of the turns at the junction) creating a bottleneck in which traffic volumes in excess of the capacity are 'metered'; the modelled flow downstream of the junction is equal to the upstream junction (or turn) capacity. The excess traffic (which is metered) forms a queue on the upstream link. In cases where the queue length exceeds the length of the link, then 'blocking back' occurs in which the queue 'blocks back' through the next upstream junction. This consequentially leads to a reduction in the junction capacity. Within the model, it is assumed that one PCU takes up 7.0 metres of road space when in a queue.

This approach is consistent with the latest TAG guidance on highway assignment modelling.

4.9 Generalised Cost Formulation and Parameter Values

The values of time (VoT) used in the model were taken from the TAG Data Book, (July 2020 version), which was the latest version of the data book available at the time the model was developed. Similarly, vehicle operating costs (VOC) were based on formulations and parameters within the TAG Data Book (when calculating the VOC, an average network speed of 40kph was assumed and a 50:50 ratio between OGV1 and OGV2).

The generalised cost is defined below (taken from TAG unit M3-1):

$$GC = T + \frac{VOC \times D}{VoT} + \frac{M}{VoT}$$

where:

GC = Generalised cost;

VOC = Vehicle Operating Cost;

VoT = Value of Time;

T = time;

D = distance; and

M = is monetary charge.

[2] PTV VISUM 17 Manual, 2017 PTV AG, Karlsruhe, Germany

In this case the variable '**M**' will be set to zero as there are no toll roads or user charging in the modelled area.

Generalised cost is therefore a time value. Parameters have been calculated separately for each user class (business, commute, other, LGV and HGV). Overall, the generalised costs for LGVs and HGVs have a higher emphasis on the distance component than is the case for cars. The VoT and VOC values used in the base model are presented in Table 4-6:

Time Period	User Class	2019 Base Year (From July 2020 TAG Databook)	
		VoT p/min	VOC p/km
AM	UC1 (Commute)	20.81	5.90
	UC2 (Business)	31.03	12.45
	UC3 (Other)	14.36	5.90
	LGV	22.49	14.03
	HGV	44.79	40.64
IP	UC1 (Commute)	21.15	5.76
	UC2 (Business)	31.79	12.15
	UC3 (Other)	15.29	5.76
	LGV	22.49	13.86
	HGV	44.79	39.49
PM	UC1 (Commute)	20.88	6.02
	UC2 (Business)	31.47	12.71
	UC3 (Other)	15.03	6.02
	LGV	22.49	14.20
	HGV	44.79	41.65

Table 4-6: Generalised Cost Parameters

Note, the values of time differ for the same purpose across different time periods; this reflects changes in average vehicle occupancy, which are based on TAG.

For HGVs, TAG Unit M3.1 Paragraph 7.2.2 states that:

"It is often the case that the routes based on generalised costs given in TAG for heavy goods vehicles do not appear to take full account of the attractiveness of motorways and trunk roads and the unattractiveness of local roads."

Paragraph 2.8.8 also states that:

"The value of time given in TAG Unit A1.3 for HGVs relates to the driver's time and does not take account of the influence of owners on the routeing of these vehicles. On these grounds, it may be considered to be more appropriate to use a value of time around twice the TAG Unit A1.3 values".

Following this advice, and based upon previous experience and professional judgement, the HGV VoT values used in the model have been doubled and HGV routing given special consideration during model route choice sense-checking and calibration.

4.10 Capacity Restraint Mechanisms

4.10.1 Links

Delays along links will be calculated according to volume-delay functions, which regulate how average travel speeds on a link change with respect to traffic volume. Capacity restraint on links is modelled through the use of speed flow curves. However, in models where there is a high level of congestion and many parallel routes, the use of volume-delay functions in urban areas can cause difficulty in assignments reaching convergence. However, this was not found to be a problem in this case. Volume-delay functions for specific link types are shown in section 6.3.

4.10.2 Junctions

As previously mentioned in section 4.8, the assignment methodology will use “Assignment with ICA” which enables capacity restraint at junctions to be modelled using VISUM’s Intersection Capacity Analysis functionality.

4.11 Relationship with Other Models

4.11.1 Existing Traffic Models

The development of the modelling strategy began with a review of existing modelling tools. The existing 2013 Buckinghamshire Countywide Model and the sub-area models developed from it were used as the basis for the modelled network. The updated model has a similar (expanded) geographic coverage but an uplifted base year (from 2013 to 2019) and includes additional network detail in the ‘bulge’ areas around the county border, including Milton Keynes, West Drayton, Bicester and Slough.

The South East Regional Transport Model (SERTM), with a base year of 2015, will inform the development of prior matrices for LGV and HGV. These matrices will be converted to the BSTM zone system and uplifted to 2019, the base year for the BSTM.

4.11.2 Buckinghamshire Models

The 2013 Countywide transport model was commissioned in November 2013 through the Transport for Buckinghamshire framework. It was acknowledged at the time that the model would be built following TAG but not to full TAG standards in every aspect (for example, matrix and assignment validation criteria and development of entirely synthetic trip demand). The model was developed such that more detailed models could be developed from it, as the need arose, with the expectation that those models could be used for Outline and Full Business Case appraisal, amongst other purposes. This led to the development of several sub-area models which have been generated from the Countywide Model since its development. The full list of existing models used in the development of the BSTM is below.

Model	Base Year	Intended Use
Countywide Model	2013	Starting point for model network and zone system. Also provides the initial land use assumptions, which were further updated for local area models (as below).
A355 Beaconsfield	2015	Contains more detailed network refinements in the area of Beaconsfield, to be carried across into the BSTM.
Chiltern and South Bucks models	2015	Contains more detailed network refinements in the Chiltern and South Bucks districts, to be carried across into the new BSTM (except from the area covering Iver which is taken from the Iver Model).
Updated Aylesbury	2017	Contains more detailed network refinement in the area of Aylesbury, to be carried across into the BSTM.

Model	Base Year	Intended Use
		Updates land uses from the 2013 Countywide Model to 2017, using planning data, which will be taken forward for the BSTM.
Iver	2018	Contains more detailed network refinement in the areas of Iver and Slough, which will be taken forwards to the Countywide Model update. Updates the land uses from 2017 to 2018, which will be taken forward for the BSTM.

Table 4-7: Existing Models Used in the Development of the BSTM

It is anticipated that the BSTM may be similarly used to produce new sub-area models within Buckinghamshire and these could in turn be used for any possible future update of the BSTM, and so on.

4.11.3 SERTM

The South East Regional Traffic Model (SERTM) was developed for Highways England (HE) and includes coverage of Buckinghamshire. It is intended to be used as the basis of goods vehicle (GV) demand for the BSTM. However, it is noted that it has a base year of 2015 and has a more aggregate zonal coverage of Buckinghamshire. Therefore, the SERTM matrices require conversion to a 2019 base year, and also between the SERTM zone system and the BSTM zone system. The conversion between zones systems requires the SERTM trips to be split into the more detailed BSTM zone system. This was facilitated through the use of land use data (primarily employment data, which generates the bulk of GV trips). The conversion from 2015 to 2019 base years was informed by DfT regional traffic trends and by traffic count data.

4.11.4 Use of Existing Model Information

The risks associated with using the existing model as a basis for the new model were also considered; highlighted in Table 4-8 below are the general risks associated with using previous models and the mitigation methods that have been put in place for this project.

Risk	Mitigation
Parts of the network might be outdated	Modelled network was updated with information on changes in the highway network since 2014.
Errors in the model carried forward	The network coding was checked in detail.
Zoning system might not be suitable	Reviewed the zoning system and assessed its suitability for the purposes to which the new model will be put. Identified areas around the county border which lacked sufficient detail in the zoning system and split the zones to provide the required level of spatial detail.
Changes in trip patterns for GV trips	Finalised GV matrices were checked against independent data sources and count screenline flows.

Table 4-8: Risks Associated with Existing Models and Mitigation Methods Put In Place

5. Calibration and Validation Data

5.1 Overview

This chapter discusses the observed data used in the calibration and validation of the 2019 traffic model. This includes the link flow observations used in calibration and validation of the modelled flows within the highway assignment and the observed journey time data used for the validation of the modelled times.

This chapter should also be read in conjunction with the Traffic Data Collection Report (18th January 2021).

It was originally intended that the model would have a 2020 base year using new survey data collected in that year. However, due to the impacts of COVID-19, no new data has been collected apart from Journey Time data and Mobile Network Data which is continually collected regardless. Existing data from different sources will be used in the model development and the scope has been changed to develop a model with a 2019 base year.

The validated 2013 Buckinghamshire Countywide Model was used as the basis for developing the 2019 traffic model. The development of the modelling strategy began with a review of existing modelling tools. The existing Buckinghamshire Countywide Model and the sub-area models developed from it were used as the basis for the modelled network. The updated model has a similar (expanded) geographic coverage but an uplifted base year (from 2013 to 2019) and includes additional network detail in the 'bulge' areas around the county border, including Milton Keynes, West Drayton, Bicester and Slough.

This section briefly describes the traffic data sources used to develop the 2019 model. Several different types of data have been collected including volumetric/flow, vehicle classification, and Teletrac GPS journey time data.

5.2 Traffic Counts

WebTRIS is Highways England's Web-based Traffic Information System and contains traffic flow information for the Strategic Road Network (SRN). This provides classified continuous data in 15-minute time intervals; however, whilst producing accurate figures, the data availability can be sporadic due to the counters failing. Where there is enough data available at a location, WebTRIS data can be used. There are several WebTRIS sites along sections of network within the modelled area. Traffic flow information was obtained from WebTRIS for the 18 sites (9 locations, each in two directions) shown in Figure 5-1 on the next page. In the following plots, some count locations may be hidden behind overlapping counts.

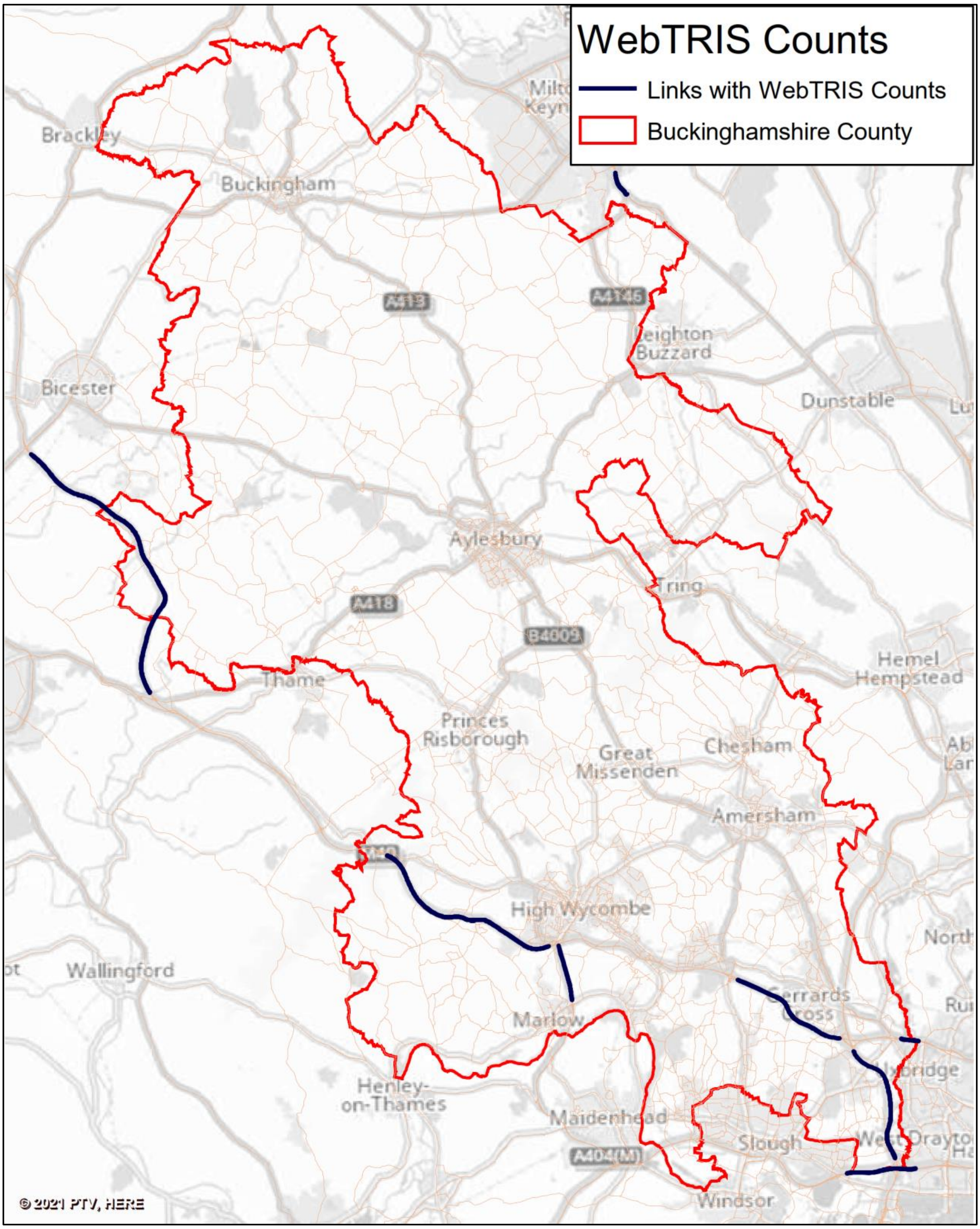


Figure 5-1: WebTRIS Locations

Data was obtained for 2019. The data for neutral weekdays (Tuesday to Thursday) in a neutral month has been used (June and October, avoiding half term holidays). 18 WebTRIS counts were used. Consistency checks were carried out to check and remove any anomalous results found in the count data (e.g. missing data due to road closure), as detailed in the Data Collection Report.

Automatic Traffic Counts (ATCs) are counts where flows are compiled automatically without constant human supervision. This allows for a longer duration of survey period in which counts are collected continuously over a period of one or two weeks, providing a more reliable estimate of average flow. The counts which are referred to as ATCs for the data in this model use two pneumatic tubes laid across the road to count traffic flows and to detect the direction in which the traffic is travelling. They can also count the number of axles on each vehicle, although there are limits to how accurate they are at this. ATCs are effective for counting total flows but are not reliable for providing vehicle type classifications.

ATCs can also produce inaccurate counts at locations where traffic is moving particularly slowly. The extent of this can be checked against classified link count data collected on days in which both are in use and, if necessary, a factor can be used to correct the ATC count.

ATC data was acquired from a variety of sources to obtain volumetric data on local roads. In most cases ATCs cover a longer period of time, typically a minimum of two weeks, which gives a more reliable average volume of traffic than a survey covering a shorter period.

The sources of ATC data (185 in total) include:

- BC ATC monitoring Counts (125 counts) - permanent or long period ATC counts controlled by BC;
- Iver ATC counts (20 counts) - permanent or long period ATC traffic counts were collected for the purposes of developing BC's Iver Model and procured from BC's count database;
- OxCam ATC counts (26 counts) - permanent or long period ATC traffic counts were collected for the Oxford Cambridge corridor study and made available for the modelling via BC;
- ATR ATC counts (10 counts) - existing traffic counts within Buckinghamshire, on file with the survey company 'ATR' and made available to the project team;
- Tracsis ATC counts (2 counts) - existing traffic counts within Buckinghamshire, on file with the survey company 'Tracsis' and made available to the project team; and
- A355 ATC counts (2 counts) - permanent or long period ATC traffic counts which were obtained by Jacobs in 2015 to support the A355 Relief Road Business Case.

Most of the ATC data was collected during 2018 and 2019. However, because it was not possible to commission new counts for this study, it was necessary to use data from 2015 to 2017 and 2020 (pre covid-19) for screenlines that could not be completed with 2018 and 2019 data. The data extracted from all ATC sites was for neutral weekdays in neutral months and adjustments were made to check and normalise the flows to be representative of 2019.

The collected ATC data locations are shown in Figure 5-2 on the next page. For each site, the average hourly count for Tuesday to Thursday was calculated. Mondays and Fridays were explicitly excluded from the average as some traffic flows on these days can deviate from that of a typical weekday.

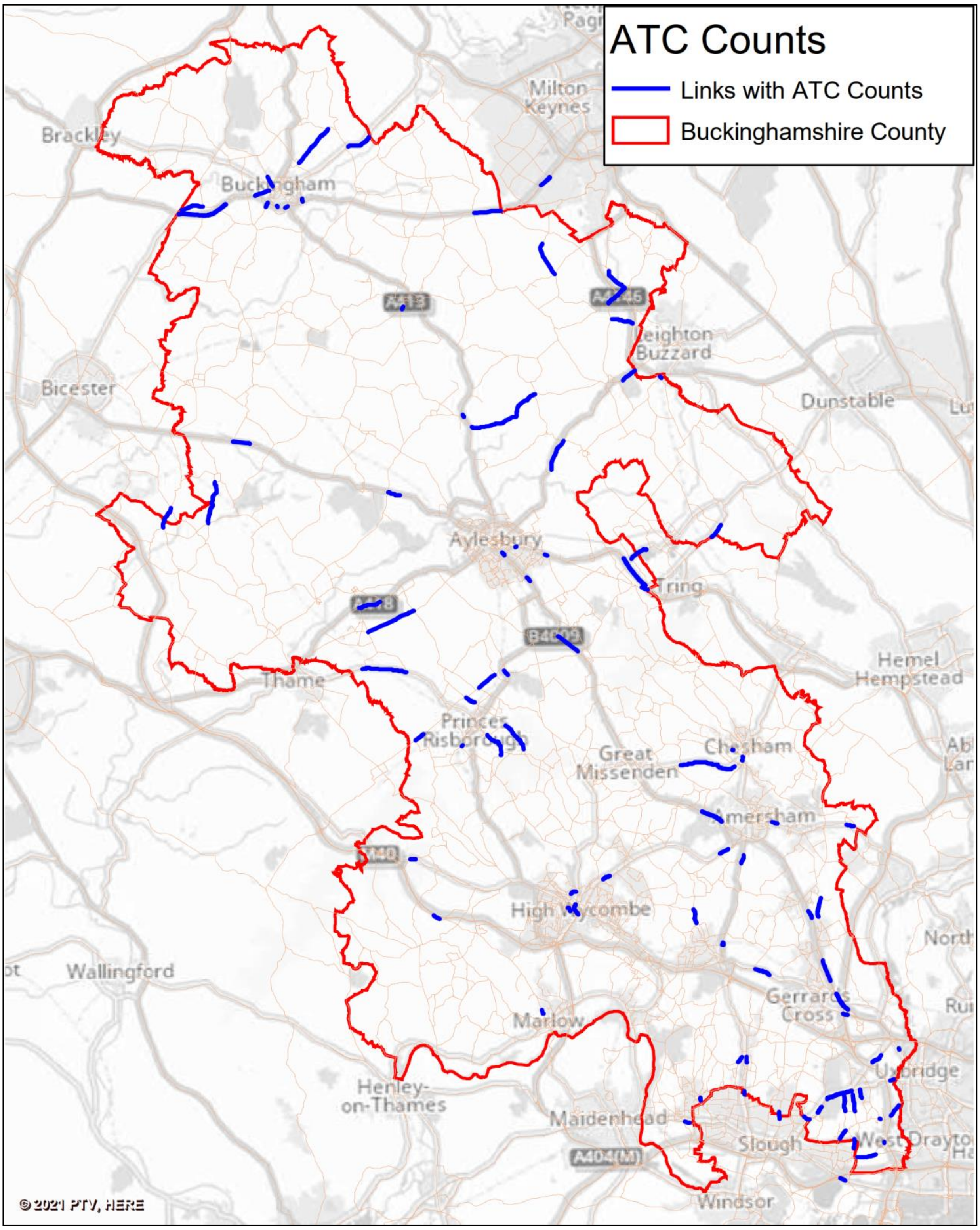


Figure 5-2: ATC Locations

The Department for Transport (DfT) collects traffic data to produce statistics on the level of traffic on roads in Great Britain. This data is made available on the DfT website and contains traffic flow information for count locations on major and minor roads. This provides classified data in hourly time intervals; however, DfT counts are only collected for one day each year and therefore it is not possible to determine an average traffic flow over a number of weeks. There are 7 DfT counts (3x2 directions and 1x1 direction) along sections of network within the Area of Detailed Modelling. Traffic flow information was obtained from DfT for the sites shown in Figure 5-3:

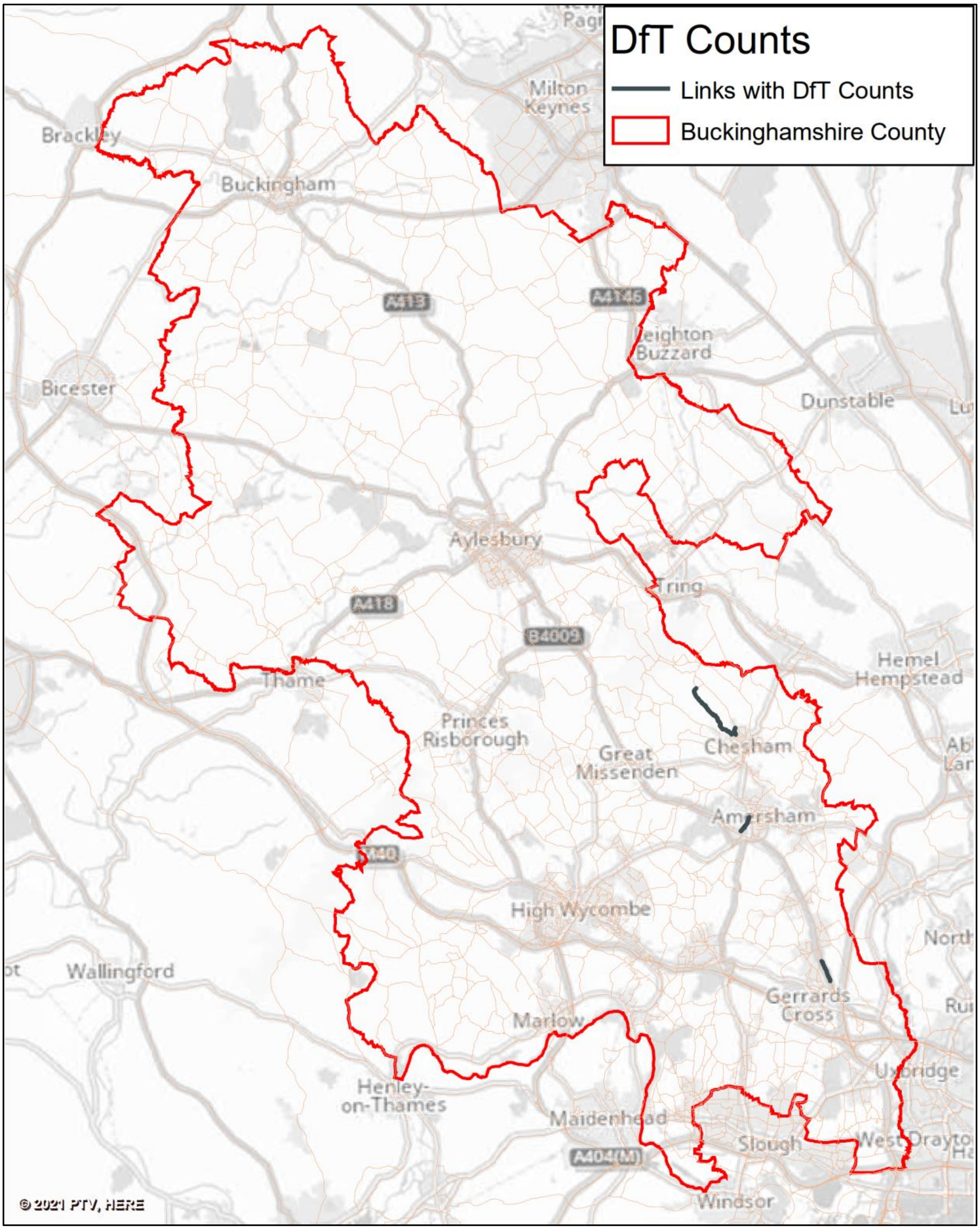


Figure 5-3: DfT Count Locations

DfT data was obtained for neutral weekdays (Tuesday to Thursday) in neutral months in 2018 and 2017.

Manual Classified Counts (MCCs) are counts which are completed via video recording, usually over a period of one day. Enumeration from video is considered to be the most accurate, but also the most expensive, method for collecting data on vehicle classification. A total of 158 MCC counts were processed (150 BC MCCs, 6 counts obtained from the A355 Relief Road Business Case, and 2 independent). These were used to infill gaps on screenlines where ATC data from existing surveys was not available and also to identify vehicle type proportions to apply to the ATC dataset. Classified counts can come in the form of a Link Count (LNK) which counts vehicles travelling in each direction of a single road, or a Junction Count (JCT), which counts all turning movements at the junction.

The MCCs collected were undertaken between Monday to Thursday during neutral months in 2018 and 2019. Vehicle classes were categorised according to the types shown in Table 5-1:

Vehicles	Classification Group	Length/Chassis Identifiers	Descriptive Identifiers
Cars	**CAR**	2-axle 4-tyre Rigid chassis Trailers included	Three or four wheeled vehicles Non-commercial pick-ups Cars with trailers & caravans Light ambulances & caravanettes Non-commercial 4x4s
LGV1 (car-based)	**LGV1**	Under 1.5t 2-axle, 4-tyre Rigid chassis Trailers included	Car-size chassis Inc. Astra vans, Escort vans, etc Sign-written commercial pick-up vehicles
LGV2 (Transit-type)	**LGV2**	1.5t - 3.5t 2-axle, 4- or 6-tyre Rigid chassis Trailers included	Mercedes Sprinter, Ford Transit No reflective plates on rear
Medium goods	**MGV**	3.5t - 7.5t 2-axle, 6-tyre Rigid chassis Trailers included	Twin tyres on rear axle No reflective plates on rear Single or no support bar between axles Rigid chassis, deep-dish rear wheels
Heavy goods rigid	**HGV**	Over 7.5t 2-axle, 3-axle 6 or more tyres Rigid chassis No trailers	Twin tyres on rear axle(s) Reflective plates on rear Double support bar between axles Rigid chassis only
Heavy goods articulated		Over 7.5t 4-axle or more Rigid chassis (plus trailer) Articulated chassis	Twin tyres on rear axles Reflective plates on rear Double support bar between axles Rigid or articulated chassis
Buses & coaches	**PSV**	2-axle, 3-axle 6 or more tyres Rigid chassis	Single or double decker All coach-built passenger carriers All school & scheduled routes Inc. non-scheduled coaches

Table 5-1: Vehicle Classes Aggregated to Analysis Classes

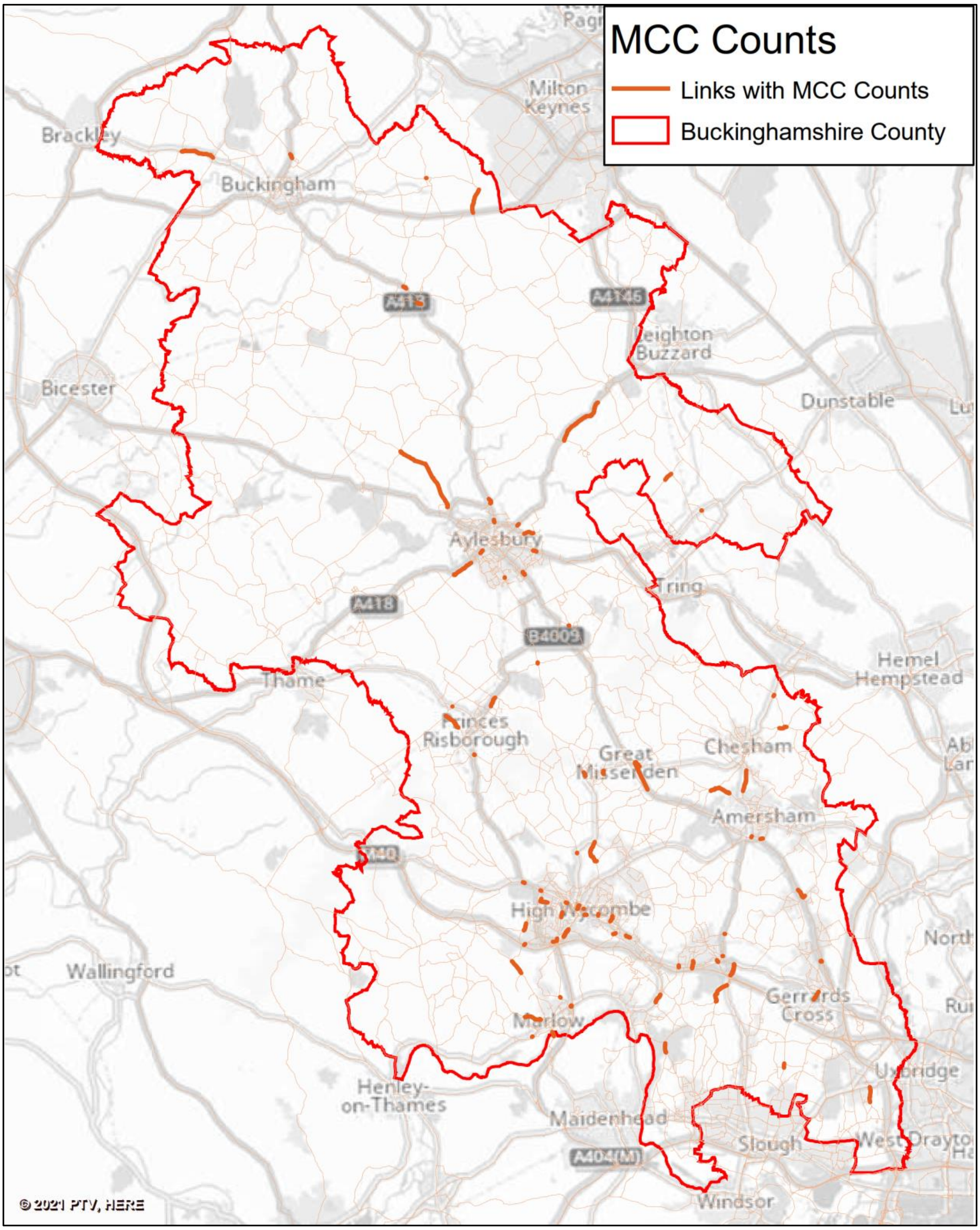


Figure 5-4: MCC Locations

All MCC data was checked for anomalies and incorrect assignment of direction. It was found that there were no significant anomalies which required data to be discarded. However, there were a small number of sites for which data was taken from an alternative time period rather than the nominated peak hour of the model. This is considered a pragmatic approach which retains data for use in model calibration. These are identified in Table 5-2 on the next page.

Count	Location	Issue	Resolution
MCC 47_EB	A41 Tring Road/Regent Road junction.	Possible closure between 8-10am.	AM Peak flows based on the 07:00 to 08:00 am flows.
MCC 98_EB	A40 Abbey Way/Easton Street.	PM 18-19 flow is significantly higher than peak hour flow.	PM Peak flows based on 18:00 to 19:00 flows.
MCC 120_SB	Desborough Avenue/Deeds Grove junction.	AM 7-8 flow is significantly higher than peak hour flow.	AM Peak flows based on 07:00 to 08:00 flows.
MCC 104_SB	Hatter's Lane/Clarendon Road.	PM 18-19 flow is significantly higher than peak hour flow.	PM Peak flows based on 18:00 to 19:00 flows.
MCC 31 A413_NB	A413/B4442 junction (Chalfont St Giles)	PM flow is almost double compared to the AM NB or SB flow, which is slightly suspicious	PM flows were also high between 16:00-17:00 and 18:00-19:00, so the 17:00-18:00 observed flows were retained (count data to be used with caution)

Table 5-2: MCC Data Anomalies

The total number of counts taken forward for use in model development is presented in Table 5-3. Note that in giving the number of counts, this refers to single-direction counts. The vast majority of individual count sites had two directions, i.e. two counts for each site. There was a small number of one-way sites which only had a single count.

Count Source	No. of Survey Counts by Collection Year						
	2020 (pre-lockdown)	2019	2018	2017	2016	2015	Total Number of Counts
WebTRIS	0	17	1	0	0	0	**18**
Survey – ATC	10	105	59	7	2	2	**185**
Survey – MCC	2	78	70	2	0	6	**158**
DfT	0	0	4	3	0	0	**7**
Total	**12**	**200**	**134**	**12**	**2**	**8**	**368**

Table 5-3: Summary of Volumetric Dataset

Figure 5-5 (on the next page) then shows the location of the complete data set.

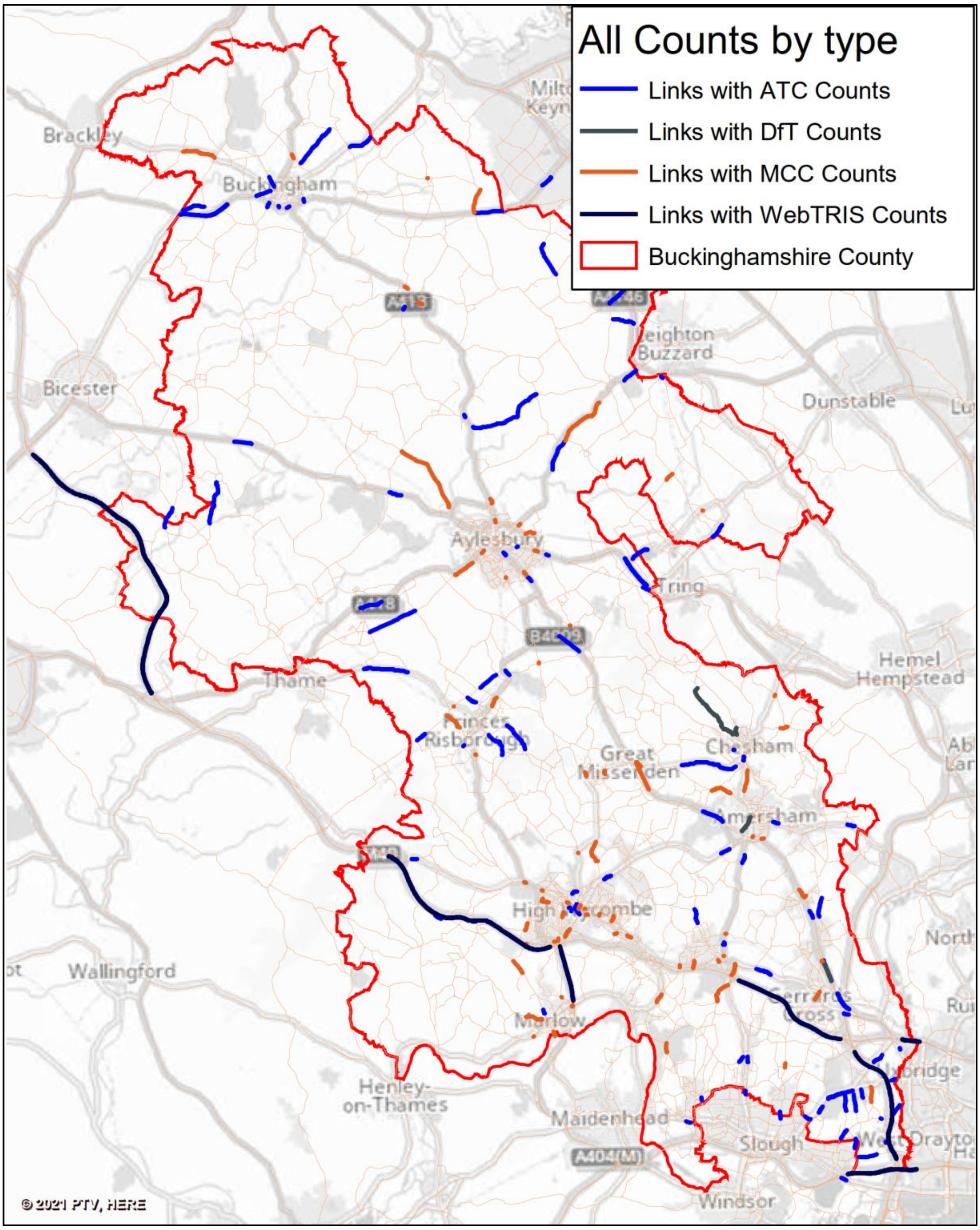


Figure 5-5: Location Plan of Final Volumetric Dataset

Note that in giving the number of counts, this refers to single-direction counts. The vast majority of individual count sites had two directions, i.e. two counts for each site. There was a small number of one-way sites which only had a single count.

It is important that the data used to calibrate the model is independent from data used to validate the model. A total of 298 (81% of the total) counts were used for the purposes of calibration and 70 (19% of the total) counts were retained for the purposes of validation.

Screenlines were created, across which the modelled and observed flows are compared in order to provide insight into the quality of the trip matrices. These screenlines are intended to capture the key movements through the study area. Figures illustrating the screenlines and the location of counts used in the model for calibration and validation, along with tables summarising the final statistics for count and screenline calibration and validation, are presented in sections 11.2 to 11.6 of this report.

To adjust counts collected prior to 2019 to be representative of 2019 traffic flows, factors were derived from the DfT count forecast. Using a consistent set of count data from 2015 to 2019, the change in average flow volumes was identified, and this proportionate change applied to pre-2019 counts. Separate factors were derived based on road type. Applying such factors to achieve a common base year is standard practice. The full set of factors is below:

Year	Uplift Factor 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 5-4: Traffic Count Adjustment Factors

In the above table, "Major Road" refers to A-roads and Motorways. "Minor Roads" are B-roads and lower.

Finally, to adjust count data to be representative of neutral month flows, a seasonality assessment was carried out. The seasonality factors calculated (shown in Table 5-5 below) were applied to the counts used as part of the model's calibration and validation.

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

Table 5-5: Seasonality Factors

5.3 Journey Time Surveys

Journey time data is used to compare travel times and delays in the traffic model to observed data as part of the model validation process.

In line with TAG Unit M3.1 section 4.3, journey time data along selected routes have been obtained using Teletrac data provided by BC.

Teletrac journey time data is collected from Global Positioning System (GPS) signals transmitted by in-car devices (e.g. satellite navigation devices). For the purposes of this work, data was extracted for the AM peak hour (08:00 to 09:00), the interpeak (10:00 to 16:00), and the PM peak hour (17:00 to 18:00) for all weekdays in 2019, other than Mondays, that complied with the TAG definition of neutral dates.

The routes for which journey time data have been extracted are presented in Figure 5-6, with a description of each route given in Table 5-6.

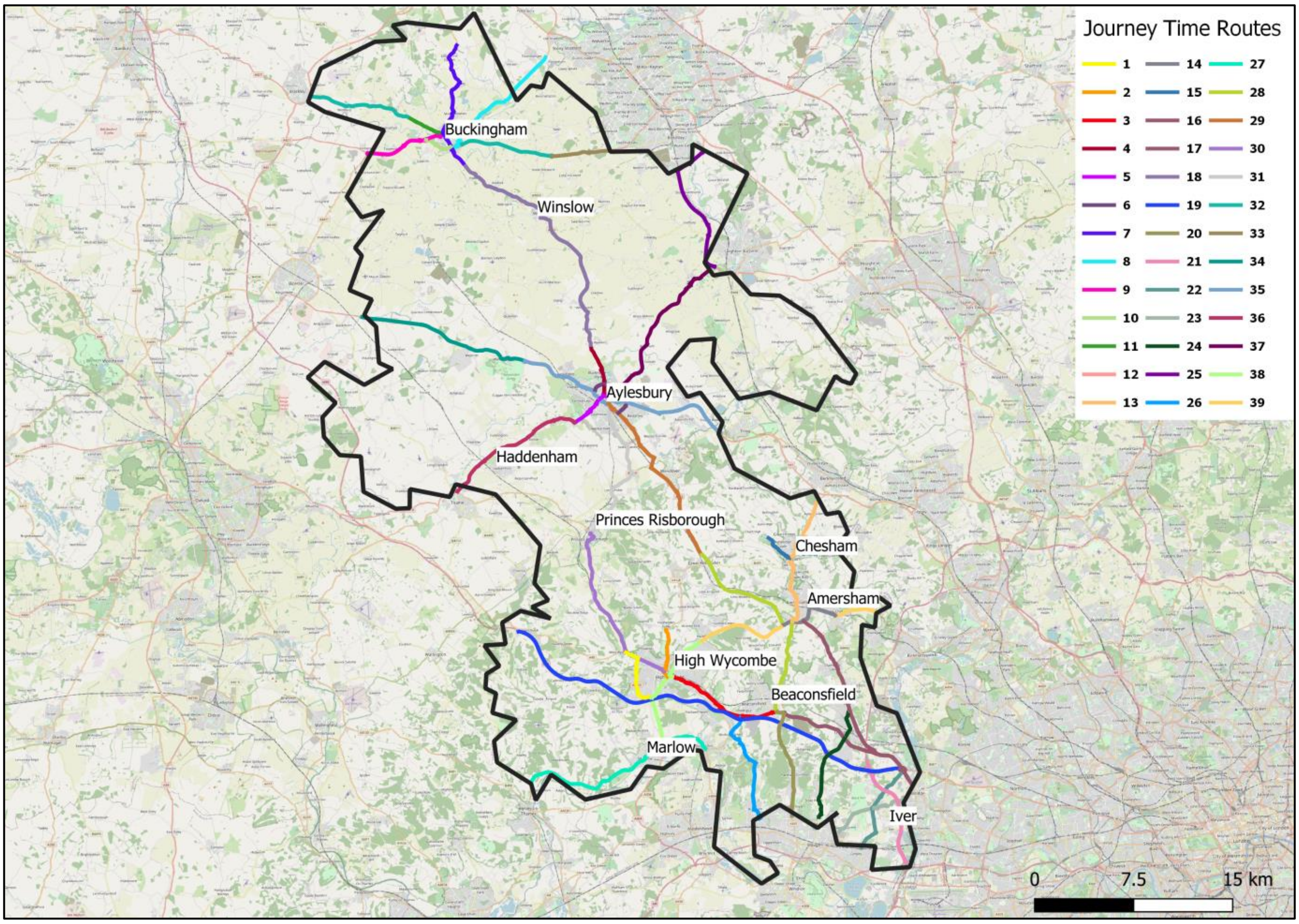


Figure 5-6: Journey Time Routes

Route	From	To
1-1	A4010/John Hall Way	A40/Pedestal Roundabout
1-2	A40/Pedestal Roundabout	A4010/John Hall Way
2-1	A40/Abbey Way	A4128/ Valley Road
2-2	A4128/ Valley Road	A40/Abbey Way
3-1	A40/Abbey Way at Easton Street	A40 at Aylesbury End
3-2	A40 at Aylesbury End	A40/Abbey Way at Easton Street

Route	From	To
4-1	A413/ at New Road	A413/ at New Street
4-2	A413/ at New Street	A413/ at New Road
5-1	A418/ at Portway	A418/at Elmhurst Rd roundabout
5-2	A418/at Elmhurst Rd roundabout	A418/ at Portway
6-1	A413/ at Wendover Road	A41/ Bicester Road roundabout
6-2	A41/ Bicester Road roundabout	A413/ at Wendover Road
7-1	A413/ at Bycell Road	A413/ neat Benthill
7-2	A413/ neat Benthill	A413/ at Bycell Road
8-1	A5/A508 roundabout	A413/at Lenborough Road
8-2	A413/at Lenborough Road	A5/A508 roundabout
9-1	A422/at Globe Terrace	A43/ Barleymow Roundabout
9-2	A43/ Barleymow Roundabout	A422/at Globe Terrace
10-1	A422/at Globe Terrace	A421/ Tingewick Road
10-2	A421/ Tingewick Road	A422/at Globe Terrace
11-1	A413/ near Benthill	A422/ near Radclive
11-2	A422/ near Radclive	A413/ near Benthill
12-1	A422/ near Radclive	A421/A413 roundabout
12-2	A421/A413 roundabout	A422/ near Radclive
13-1	A355/A413 roundabout	A416/ near Hockeridge Wood
13-2	A416/ near Hockeridge Wood	A355/A413 roundabout
14-1	A413/A404 roundabout	A404/ at Cokes Lane
14-2	A404/ at Cokes Lane	A413/A404 roundabout
15-1	MC2/at Berkeley	Botley Road/Tylers Hill Road
15-2	Botley Road/Tylers Hill Road	MC2/at Berkeley
16-1	A404/A413/A355 Stanley Roundabout	A413/A40
16-2	A413/A40	A404/A413/A355 Stanley Roundabout
17-1	Hillingdon Hill/Kingston Ln	A40 Pyebush Roundabout
17-2	A40 Pyebush Roundabout	Hillingdon Hill/Kingston Ln
18-1	A413/near Buckingham Park	A421/413 roundabout
18-2	A421/413 roundabout	A413/near Buckingham Park
19-1	M40/ Junction 5	M40/ Denham Roundabout
19-2	M40/ Denham Roundabout	M40/ Junction 5
20-1	A40/A355 roundabout	A355/ at M4 J6
20-2	A355/ at M4 J6	A40/A355 roundabout
21-1	M25/at J15	M25/at J17
21-2	M25/at J17	M25/at J15
22-1	A412/ at M40 Denham roundabout	B470/ at A4 London Road
22-2	B470/ at A4 London Road	A412/ at M40 Denham roundabout
23-1	A412/at Red Cow roundabout	A4007/at Trumper Way roundabout
23-2	A4007/at Trumper Way roundabout	A412/at Red Cow roundabout
24-1	B416/ at B416/A413 roundabout	A332/ at Ragstone Road

Route	From	To
24-2	A332/ at Ragstone Road	B416/ at B416/A413 roundabout
25-1	A5/ at A5/A416 junction	A4146/A418 roundabout
25-2	A4146/A418 roundabout	A5/ at A5/A416 junction
26-1	Huntercombe Spur/ M4 J7	B4440/ at B4440/A40 roundabout
26-2	B4440/ at B4440/A40 roundabout	Huntercombe Spur/ M4 J7
27-1	A4155/ at Fawley road	The Parade/Station Road roundabout
27-2	The Parade/Station Road roundabout	A4155/ at Fawley road
28-1	A40 Pyebush Roundabout	A413/at Aylesbury Road
28-2	A413/at Aylesbury Road	A40 Pyebush Roundabout
29-1	A413/at Aylesbury Road	A413/A41 Exchange Street roundabout
29-2	A413/A41 Exchange Street roundabout	A413/at Aylesbury Road
30-1	A4128/A40 Abbey Way/Oxford Road	A4010/Aylesbury Road
30-2	A4010/Aylesbury Road	A4128/A40 Abbey Way/Oxford Road
31-1	A4010/Aylesbury Road	A413/A41 Exchange Street roundabout
31-2	A413/A41 Exchange Street roundabout	A4010/Aylesbury Road
32-1	A43/at Buckingham Road	A421/B4033 roundabout
32-2	A421/B4033 roundabout	A43/at Buckingham Road
33-1	A421/B4033 roundabout	A421 Kents Hill Roundabout
33-2	A421 Kents Hill Roundabout	A421/B4033 roundabout
34-1	A41/A4421 roundabout	A41/at Waddesdon Hill
34-2	A41/at Waddesdon Hill	A41/A4421 roundabout
35-1	A41/at Blackgrove road	A41 /B488 junction
35-2	A41 /B488 junction	A41/at Blackgrove road
36-1	A418/A4129	A418/near Coppice
36-2	A418/near Coppice	A418/A4129
37-1	A418/near Coppice	A4146/A418 roundabout
37-2	A4146/A418 roundabout	A418/near Coppice
38-1	A404/A308 Bisham roundabout	A404/at Holmer Green Road
38-2	A404/at Holmer Green Road	A404/A308 Bisham roundabout
39-1	A404/at Holmer Green Road	A404/at Green Street
39-2	A404/at Green Street	A404/at Holmer Green Road

Table 5-6: Journey Time Routes Start and End Locations

For each route, the average journey time was calculated by summing all observed journey times for each link of the route and dividing by the number of observations for the link. It can be noted that, on average, there were approximately 500 observations for each link in the AM peak hour, 3,000 in the Interpeak period, and 450 in the PM peak hour.

All links were then summed to produce an average journey time for the route. This was undertaken for the AM peak hour, interpeak period and PM peak hour.

6. Network Development

6.1 Network Basis

The basis for the modelled network was the 2013 Countywide Model (and the sub-area models developed from it), which was initially created using the Integrated Transport Network (ITN), an Ordnance Survey dataset representing the Great Britain transport network as a series of links and nodes. ITN contains details of the characteristics of each road, including:

- Road type (motorway, trunk road, local route);
- Number of lanes and capacity;
- Restrictions such as one-way streets and HGV bans; and
- Other elements such as bus/cycle lanes.

The network was loaded into VISUM, which converted it into a series of links and nodes appropriate for modelling.

A total of 76 different highways classes or types were coded in the model, following guidance from COBA Volume 13 Section 1 part 5, classifying roads based on characteristics such as: road class, number of lanes, speeds, and modes allowed. A full list of all the defined link types can be found in Appendix B, however, the main classes considered in the analysis can be seen below:

- Motorways;
- Rural single carriageway;
- Rural double carriageway;
- Urban non-central;
- Urban central;
- Small town;
- Suburban single carriageway;
- Suburban dual carriageway;
- Residential road; and
- Roundabout.

The first three classes were assigned for all-purpose roads and motorways that are generally not subject to a local speed limit. Urban central and non-central were used for roads in large towns or conurbations typically subject to 30 mph speed limits. Small town was used as the link type in small towns or villages, while suburban was used for major routes though towns and cities which are generally subject to 40 mph speed limits.

6.2 Link Lengths and Nodes

The model uses the existing 2013 Countywide Model as a base for network development, which in turn was based on the ITN layer. The ITN was found to contain more nodes than was really necessary in order to represent the network in a model. These were largely intermediate nodes on a link, serving no apparent purpose; they did not for example, represent a junction, or a point at which the link characteristics changed. These intermediate nodes were removed, with the corresponding links on either side joined together into a single link. The link length, which was a property of the ITN layer, was summed for all ITN links that were merged into a modelled link. The length of the link was further checked within VISUM by measuring the scaled length of the link polygon.

6.3 Link Speeds and Speed Flow Curves

For the links imported into the model, the parameters governing speeds, capacities and the relationship between speed and traffic flow were derived from COBA Volume 13, Part 5. The link characteristics described in the manual were translated into parameters appropriate for use in the VISUM model. A number of different link types were drawn up based on COBA, to accommodate all different combinations of urban/suburban/rural, levels of development, road widths, number of lanes, and vehicle restrictions. For each link type, the relationship between vehicle flow and average speed, also known as a speed-flow curve, or in VISUM parlance, a "Volume-delay function" was defined. The Volume-delay functions used an 'adjusted BPR' function, the formulation of which was developed by the US Bureau of Public Roads, and is repeated 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.

From the formula, it is clear that there is a break point in the curve at $q = q_{max} \times c$ with a different relationship for links that are over the break point, to those which are under it. This break point was calibrated to reproduce break points from the equivalent speed-flow curves in the COBA Manual. The VDF allows for the flows to exceed the stated capacity of the links, however it should be noted that the propensity for this to occur is reduced as the model makes use of flow metering. This meets the guidance in TAG unit M3.1 appendix D8.

Appendix A provides further background on the SFC-VDF correlation and the following figures (Figure 6-1 to Figure 6-7) show curves for the BPR2 VDF for motorways, rural all-purpose carriageways, rural, suburban, urban and small town link types.

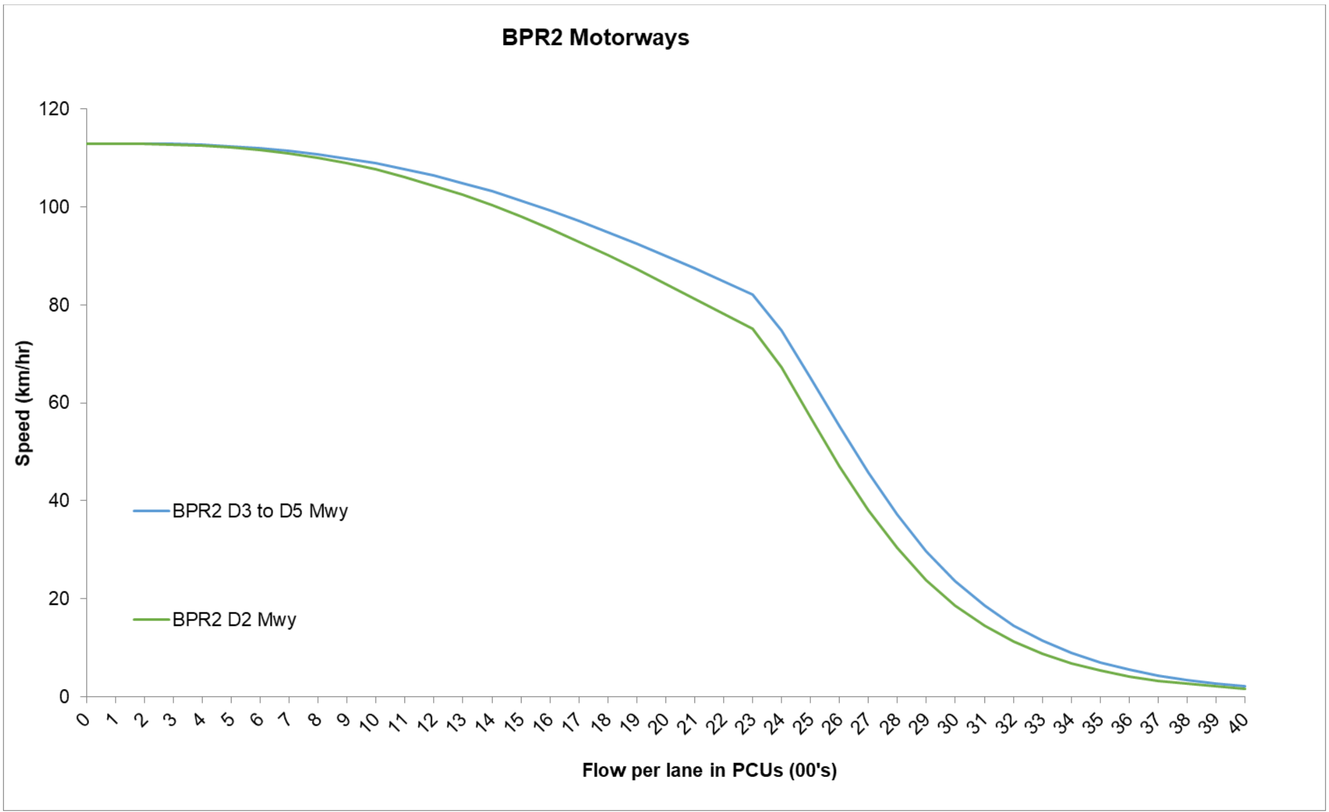


Figure 6-1: VDF Motorway Link Type

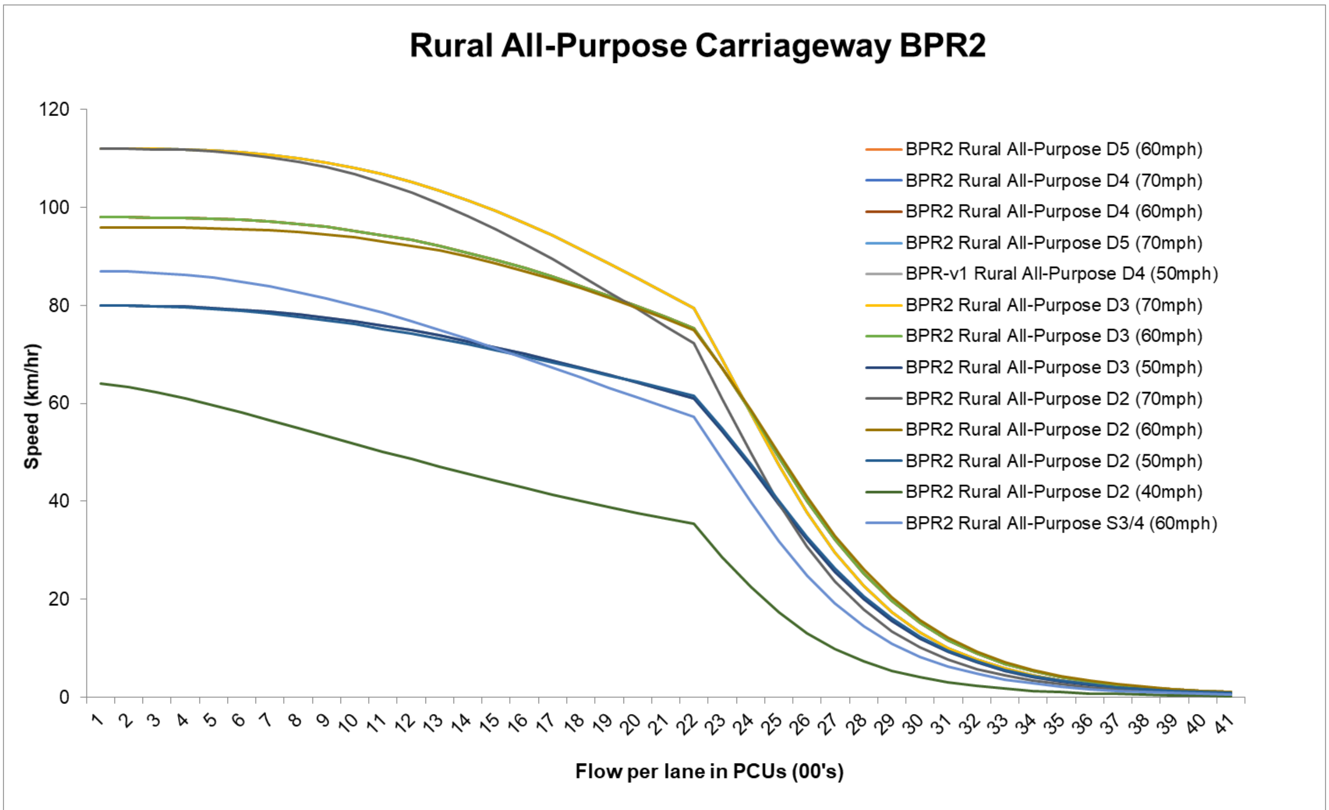


Figure 6-2: VDF Rural All-Purpose Carriageway Link Type

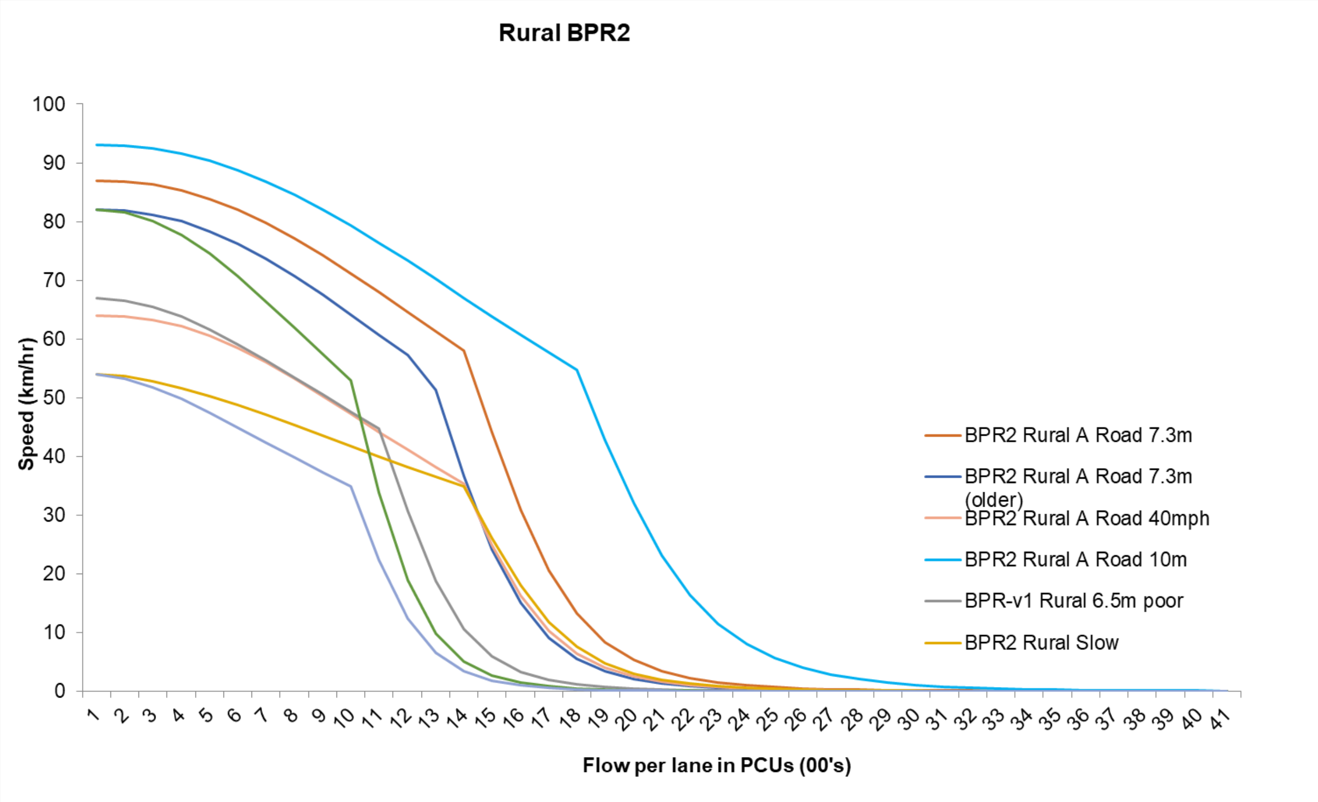


Figure 6-3: VDF Rural Link Type

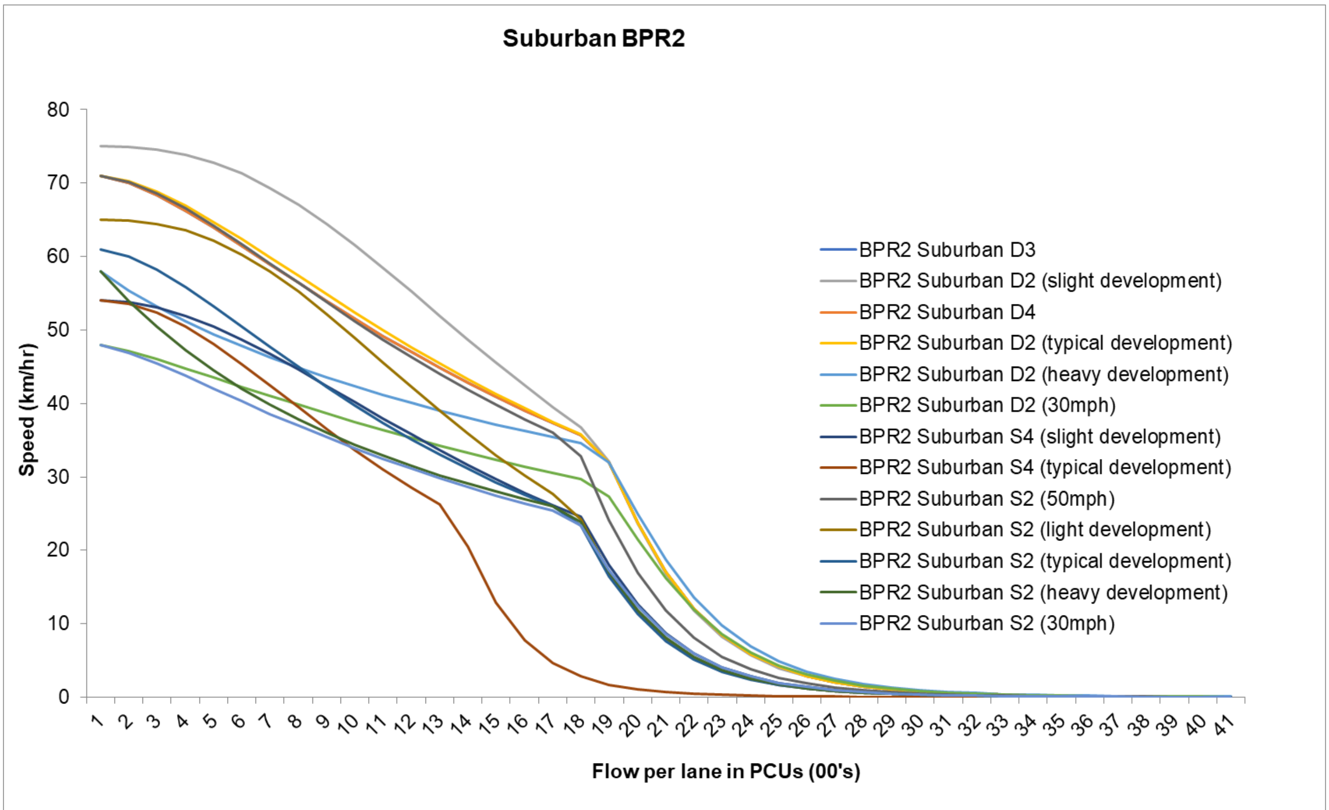


Figure 6-4: VDF Suburban Link Type

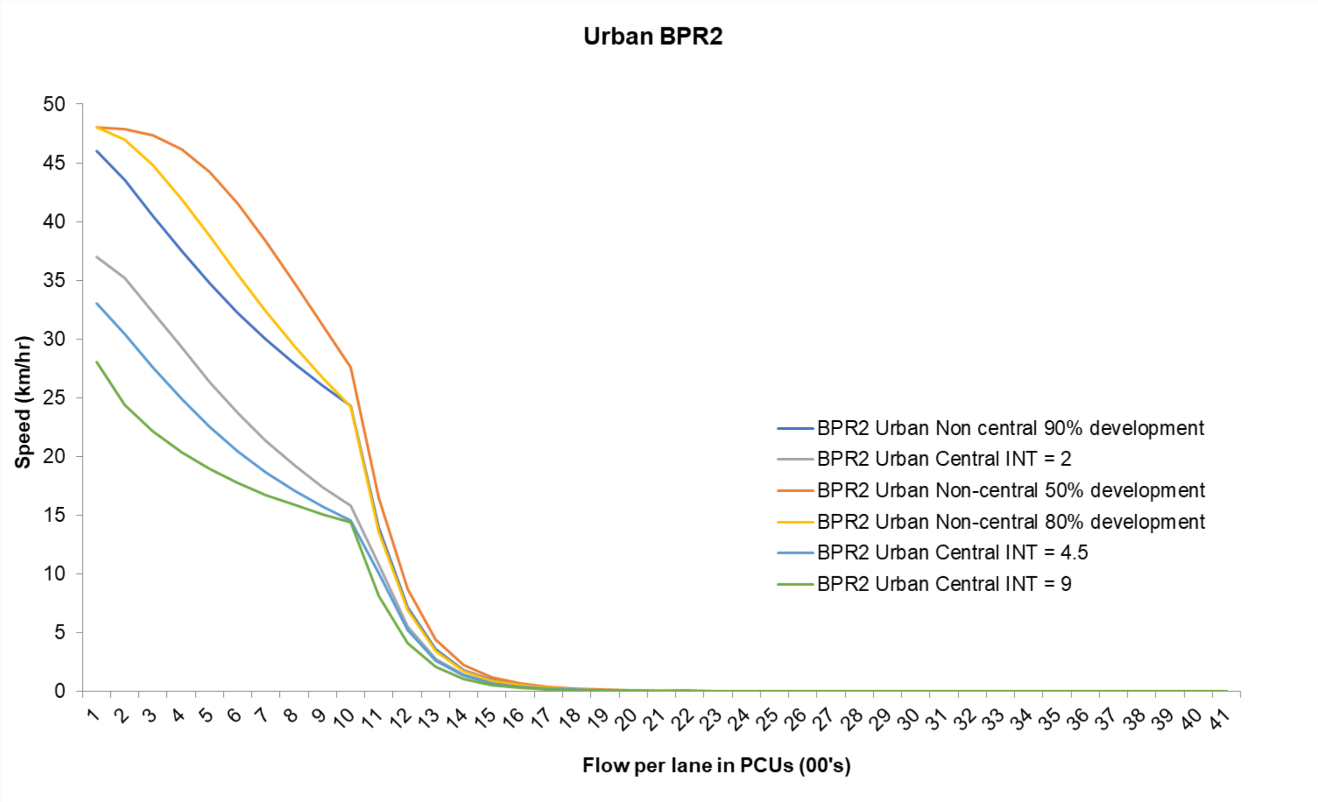


Figure 6-5: VDF Urban Link Type

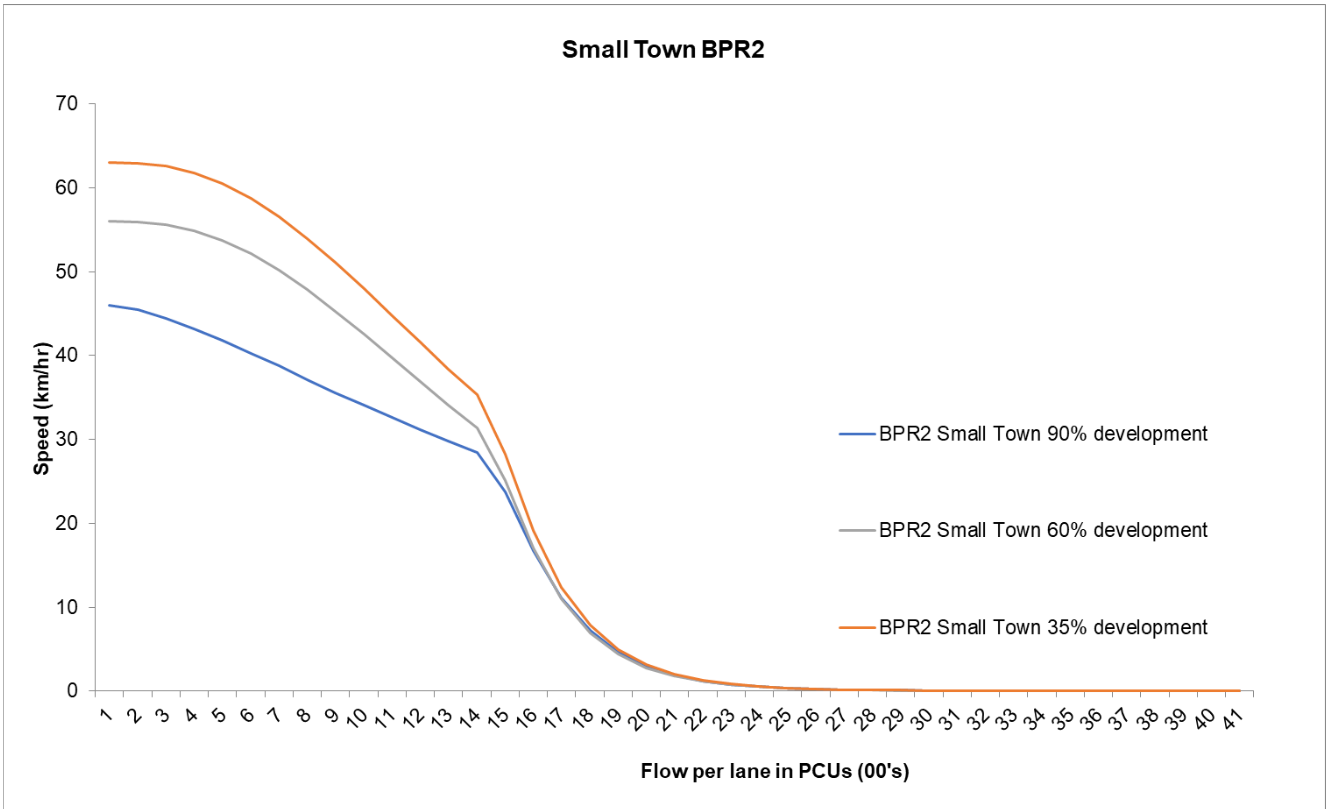


Figure 6-6: VDF Small Town Link Type

6.4 Junctions and Delays

All junctions within the study area were fully coded using VISUM's Intersection Capacity Analysis (ICA) functionality. This uses the junction type, number of lanes and modelled flows to calculate capacity and thereby turning delays. ICA uses formulae set by the 2010 edition of the Highway Capacity Manual, published by the US Transportation Research Board; these formulas are specific to the junction type. ICA relies on the input attributes identified above, and uses a number of default global values, to calculate the capacity and delay for each movement at a modelled junction. The default values cover aspects such as saturation flows per lane and turn type and gap acceptance values for vehicles on a minor arm.

The saturation flows typically used are 1,900 PCUs per hour per lane for signalised junctions. For priority junctions, the major flows effectively operate without any capacity restriction. Turn capacities on the minor arms are a function of the gap acceptance values and the conflicting traffic volumes; saturation flows are not considered. As an example, using the default gap acceptance values, Figure 6-7 illustrates the capacities for a left turn from a minor arm, under differing levels of conflicting flow:

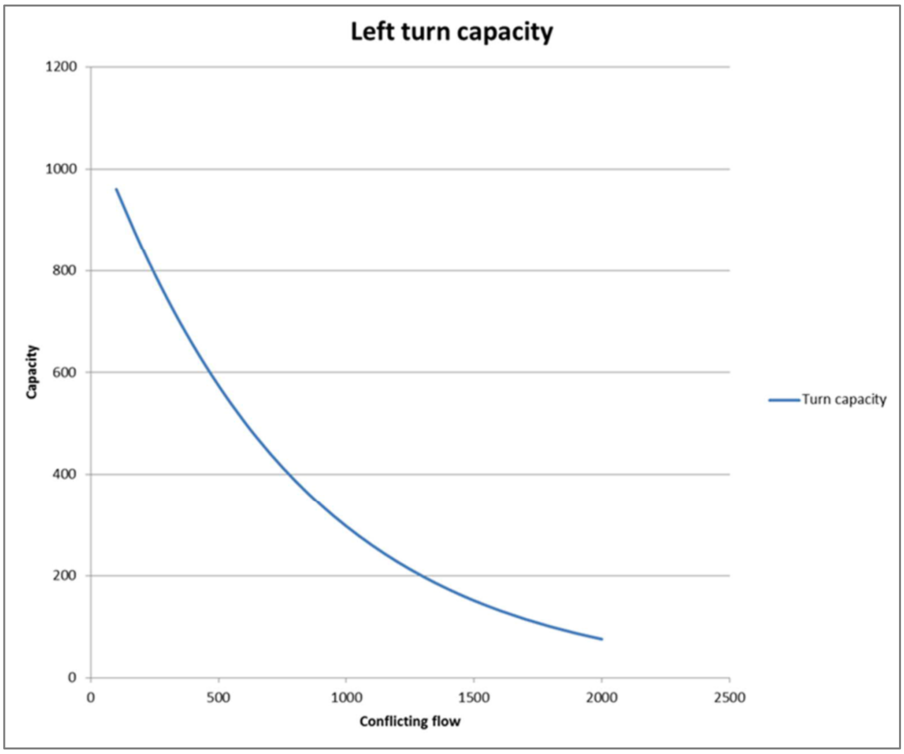


Figure 6-7: Left Turn Capacity

With very few exceptions it was found that the default values (for saturation flow and gap acceptance etc.) within ICA were sufficient to yield junction delays approximating observed delays very well. This can be seen from the journey time validation given in Section 11.8. However, the network and assignment calibration process identified particular junctions for which the default values were not appropriate; manual overrides were applied for those junctions by adjusting the critical Gap and follow-up times on each node individually depending on the number of accessing lanes.

The junctions were coded with the following attributes defined:

- Junction type;
- Major flow (i.e. which turning movements had priority);
- Banned turns;

- Number of lanes at stop lines;
- Turn type (i.e. straight on, left, right);
- Lane Allocations (which turns are made from which lanes); and
- Signal timings (for signalised junctions).

These attributes were coded using local knowledge, Google Earth and Google Streetview. They were checked for accuracy in the original 2013 Countywide Model and again for this BSTM to check that the link type is appropriate for use in this model.

For signalised junctions, timings were based on signal data extracted from Transport for Buckinghamshire's Urban Traffic Control (UTC) system as part of the original Countywide Model development study. This model had a base year of 2013, so any modification to junctions and their signal timings since 2013 have been reflected in the updated model.

An example of the coding of a signalised junction in the model is illustrated in Figure 6-8 on the next page, where the actual junction is shown alongside the signalised junction modelled coding of the A404/High Street junction in the centre of High Wycombe.

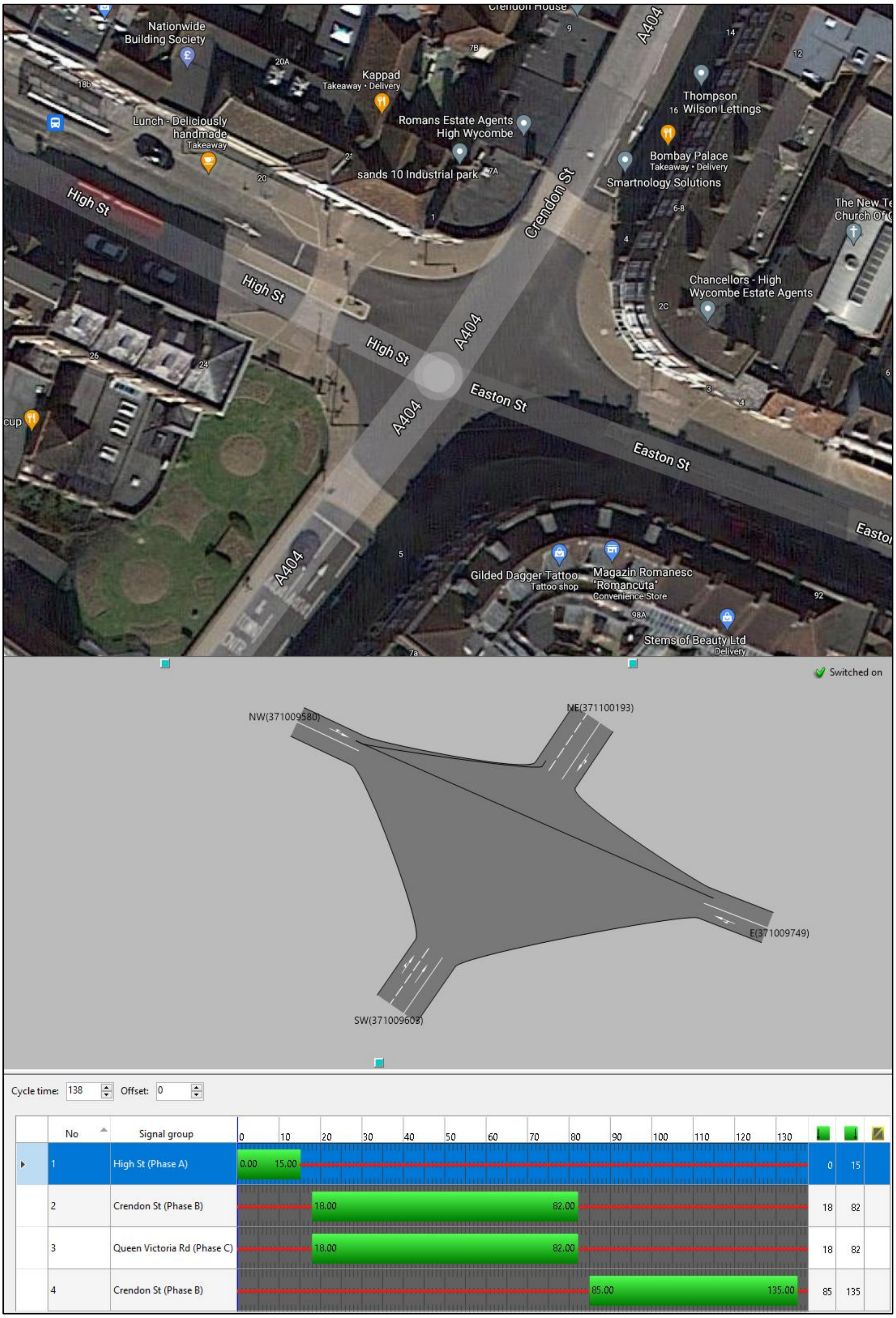


Figure 6-8: Actual Junction and the Equivalent Modelled Signalised Junction

6.4.1 Roundabouts

All roundabouts are modelled as a series of expanded nodes with the exception of some very small mini-roundabouts. The Kimber method has been utilised to configure roundabouts and the parameters adopted for different approach geometries are detailed in Table 6-1.

Arm		Approach Half Width (V) *(m)*	Entry Width (E) *(m)*	Flare Length (‘l) *(m)*	Entry Radius (R) *(m)*	Inscribed Roundabout Diameter (D) *(m)*	Entry Conflict Angle (PHI) *(Deg)*
Short Flare/ No Flare Length (<3 Cars or 10m)	**1 In approach, no flare**	3.65	4	5	15	User Defined	30
	2 In approach, no flare	7.30	8	5	15		30
	3 In approach, no flare	10.95	12	5	15		30
	1 In approach, 2 In entry	3.65	8	10	15		30
	2 In approach, 3 In entry	7.30	12	10	15		30
Long Flare Length (<=10 Cars or 60m)	**1 In approach, 2 In entry**	3.65	8	30	15	User Defined	30
	2 In approach, 3 In entry	7.30	12	30	15		30
Multi-Node Roundabout	**Circulatory Arm**	15	20	100	1000	200	0

Table 6-1: Roundabout Parameters to Adopt for TRL/Kimber Method

7. Network Calibration and Validation

7.1 Network Checking and Calibration

Based on the coded characteristics of each link, a number of checks of the network were made. The first of these was the standard network check offered by the VISUM modelling package, which checked aspects of the model such as network connectivity and illogical coding of junctions.

A network check list informed by advice in TAG Unit M3.1 was created, and the model was checked against each aspect of the list. The list is reproduced in Appendix D. Additional checking focused on the coded attributes of the links, including link speeds, number of lanes and capacity, as detailed below.

Free flow link speeds are a function of the link type (as specified in Appendix B). These speeds were checked by plotting them in VISUM and colouring links according to speed in bands. This plot is shown in Figure 7-1 below for the detailed study area:

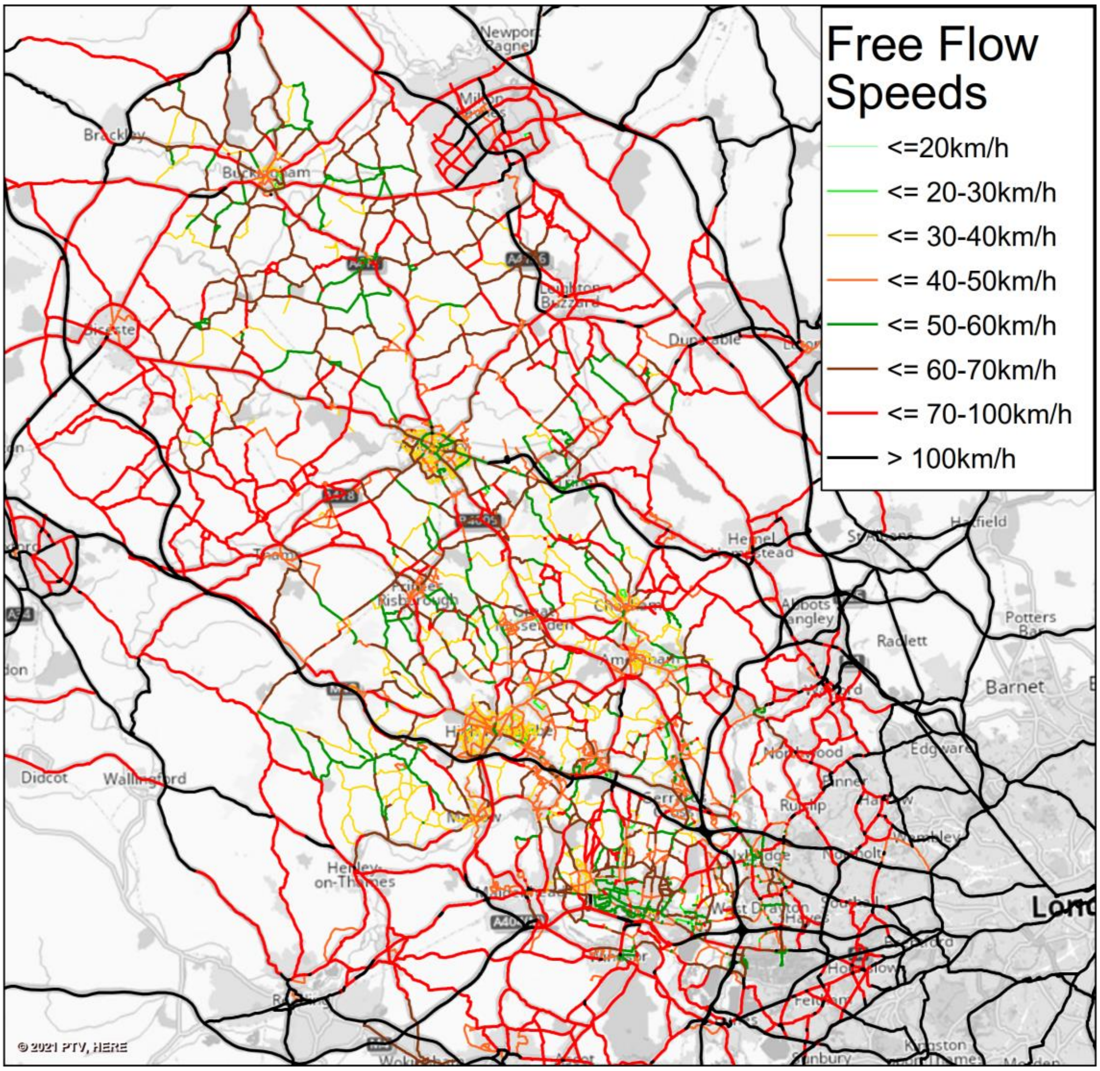


Figure 7-1: Free Flow Speeds in Buckinghamshire

Figure 7-1 shows that urban areas in the study area, such as High Wycombe and Aylesbury, have coded free flow speeds of around 20-30kph on minor residential streets, 40-50kph on more major residential streets, and 50-70kph on main through roads. In rural areas the free flow speed is between 70kph and 100kph; these roads are national speed limit roads.

The coded number of lanes was checked in a similar manner, with this plot shown in Figure 7-2 below:

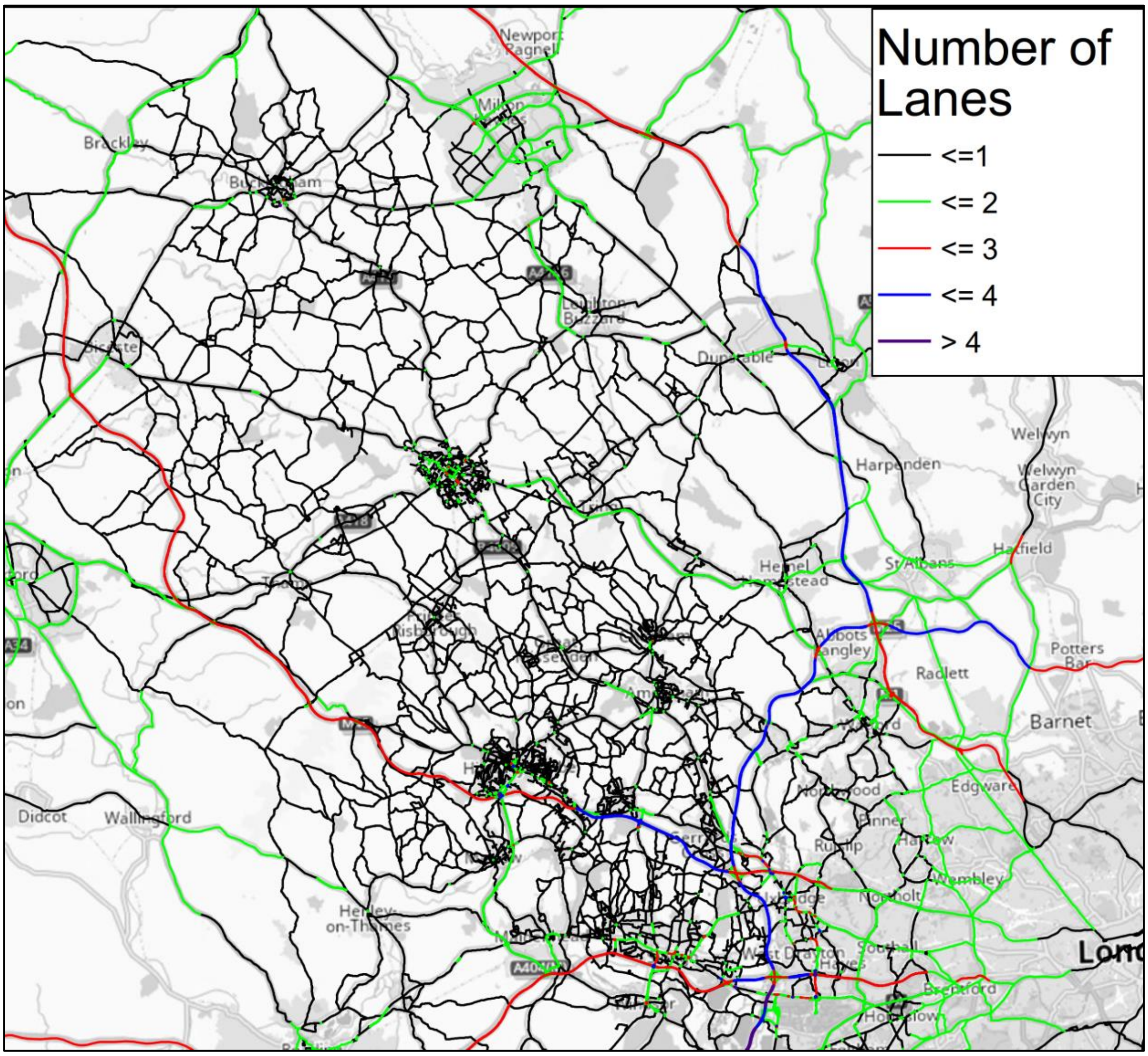


Figure 7-2: Number of Lanes on Each Link in the BSTM

Figure 7-2 shows that the majority of the links are coded as a single lane except for the main through routes and some links, which have been coded with two or three lanes, as expected from network checks and local knowledge.

Link capacity is again checked in a similar way, as shown below in Figure 7-3:

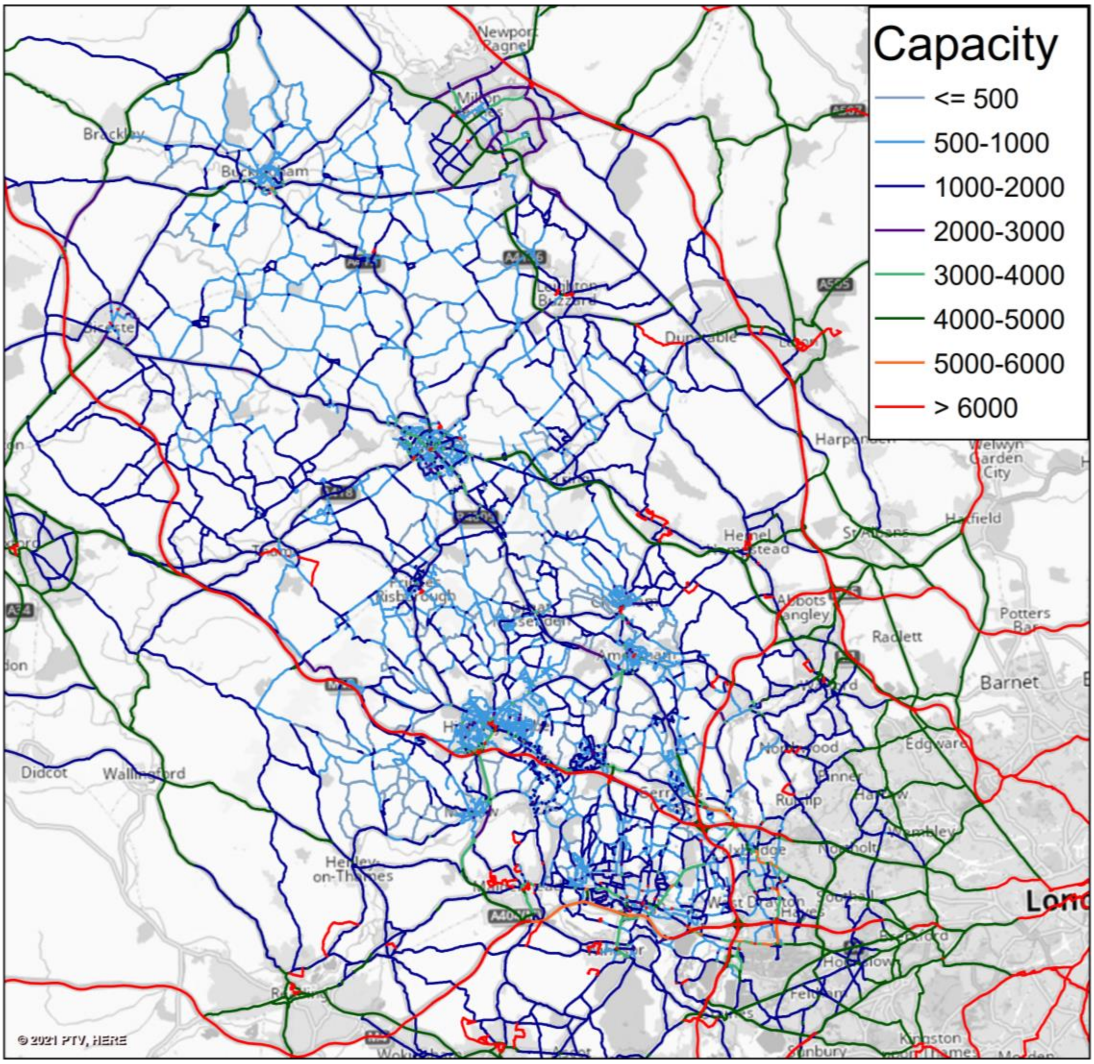


Figure 7-3: Link Capacity in the BSTM

Urban residential roads show the lowest capacities of around 500 vehicles per hour or less, whilst the M40, M4, M25 and A404 have the largest capacities. Main through roads tend to have capacity between 1,000 and 3,000 vehicles per hour. This is all considered to be a correct representation of the real link characteristics and capacities.

Finally, it should be noted that checks were made on the consistency of coding across all time periods, and these confirmed that only signal timings differed between the periods.

8. Route Choice Calibration

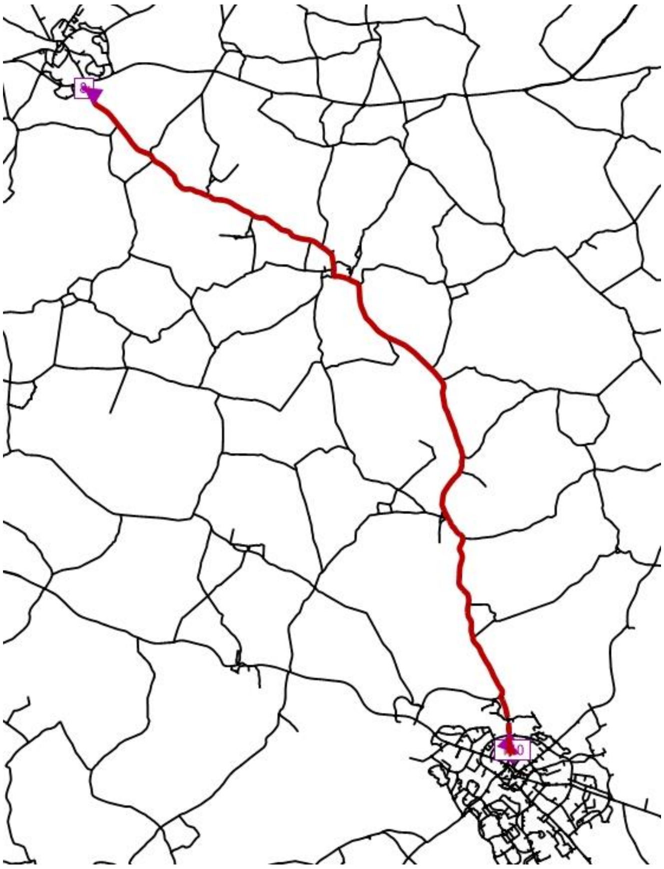
The model was further checked by examining shortest paths and minimum generalised cost routes through the network. These checks were done at an early stage of the model development and again towards the end of the model development process. Major urban areas covered by the network were identified and routes between them checked against Google Maps.

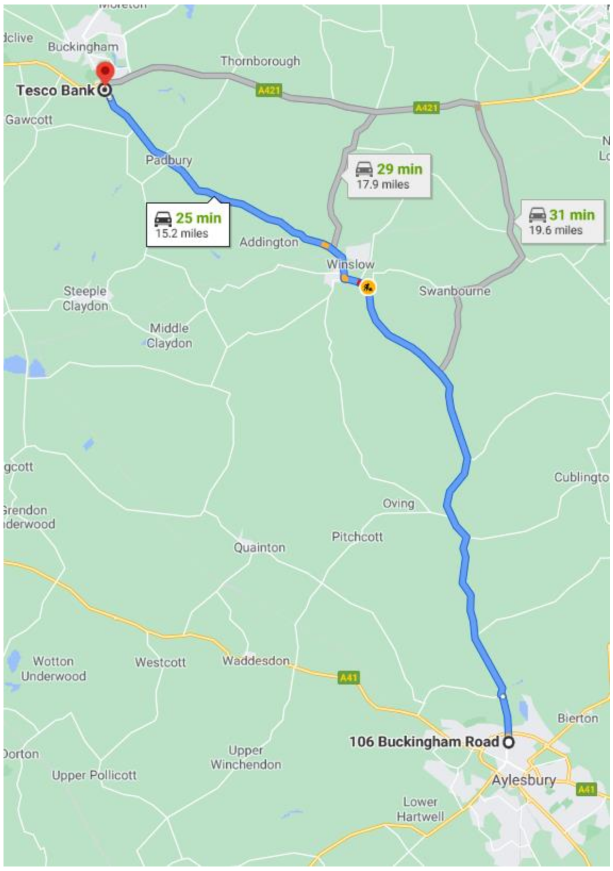
A combination of routes were checked, for a total of 27 routes, which is in line with guidance on the number of routes to be checked. According to TAG unit M3.1, the number of routes that should be checked is defined by:

(number of zones in model)$^{0.25}$ x number of user classes

The BSTM has 870 zones and five user classes and therefore 27 routes have been checked, which meets the guidance specified in TAG.

Where the modelled route choice was contrary to expectations (as defined by checking against suggested route choice in Google Maps), the modelled network was checked and adjusted. Some examples of the route checked in the model are illustrated below, with the modelled route shown in red and equivalent route from Google shown adjacent. A full set of route checks undertaken is presented in Appendix E.





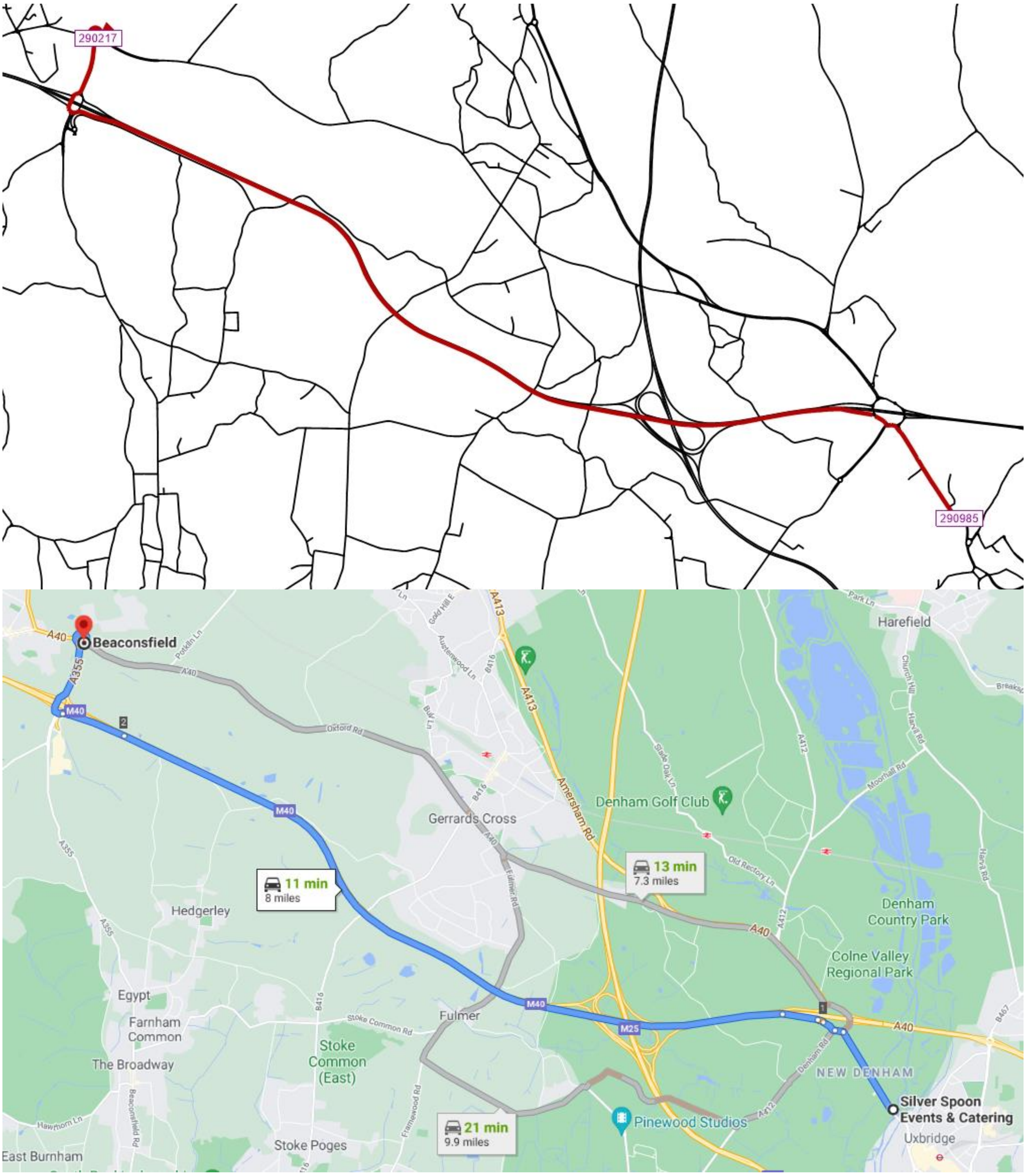


Figure 8-1: Route Choice Checks; Modelled Compared to Observed

9. Trip Matrix Development

9.1 Introduction

This chapter summarises the methodology and the process of the highway prior matrix development. This process was largely driven by the use of aggregated and anonymised mobile network data (MND) provided specifically for this study by Telefonica. Other data sources such as 2011 Census Journey to Work (JTW), National Travel Survey data (NTS), National Trip End Model (NTEM v7.2) and bespoke synthetic matrices were used to augment the MND and to correct for known biases.

The Heavy Goods Vehicle matrices (HGVs) and Light Goods Vehicle (LGV) movement were derived from the South East Regional Transport Model (SERTM), with a base year of 2015. These matrices are converted to the BSTM zone system and uplifted to 2019 using the DfT's Road Traffic Forecast (Scenario 1), the base year for the BSTM.

This chapter details the MND verification methods, synthetic matrix building, and data merging approach. The resultant OD matrices were subject to further refinement through the detailed calibration and validation of the trip matrix and assignment model described in chapters 10 and 11 of this report.

The structure of this chapter is based on the reporting requirements suggested in the new TAG guidance on base year matrix development (TAG Unit M2-2). However, in some places it amends the structure suggested in TAG Unit M2-2 Annex F to bring in additional detail necessary to understand the process and seamlessly link with the remainder of this report.

9.2 Purpose of Base Year Demand Matrices

9.2.1 Specification of Base Year Matrices

The base year matrix building has broadly followed the below approach:

- The guidance advises to begin with a wholly synthetic model, which makes minimal, but reasonable, assumptions to produce initial Production/Attraction (PA) matrices at the required level of detail.
- The initial synthetic model should start off with the all-day zonal productions and attractions implied by NTEM for each purpose (or, better, make use of the underlying car ownership and trip end functions applied to local data on population, households and employment).
- The matrix cells should then be filled by means of a standard gravity model that should be constrained to reproduce (at least) the average trip length for the journey purpose (taken either from local sources or national sources such as NTS). Next, factors giving modal choice and time of day (again, available as part of the NTEM database, although local data is preferred where possible) can be applied. In this way the complete prior matrix is built up by mode and time period, distinguishing the outbound and return portions of home-based purposes.
- The process of "introducing observed data" must then make allowance for the statistical accuracy of that data and preserve key features of the prior matrix (e.g. the total productions and the average trip length). Therefore, there is often a need for an iterative process which attempts to re-impose some features as "constraints".

These broad principles were followed in the development of the BSTM demand matrices.. The approach adopted in the development of the BSTM trip matrices was additionally informed by the experience gained by Jacobs, on North Wales Transport Model, Essex Countywide model and Kent Countywide Model which broadly follow the methodology in line with TAG Unit M2-2.. These were considered good examples of matrix development methods using various matrix verification and validation criteria. Other data sources (where applicable) were used to establish biases in the MND matrices and to determine the best approach for correcting these through the use of the synthetic matrices.

9.3 Overall Approach to Matrix Development

9.3.1 Methodology Outline

The construction of high-quality highway trip matrices is one of the critical components in model development. To enable this, the prior matrices have been constructed based upon a combination of both Mobile Phone Network Data (MND) and Synthetic matrices. This enables the Buckinghamshire matrices to be as complete as possible, combining the strengths associated with both approaches as shown by Figure 9-1 based on the fusion of the data.

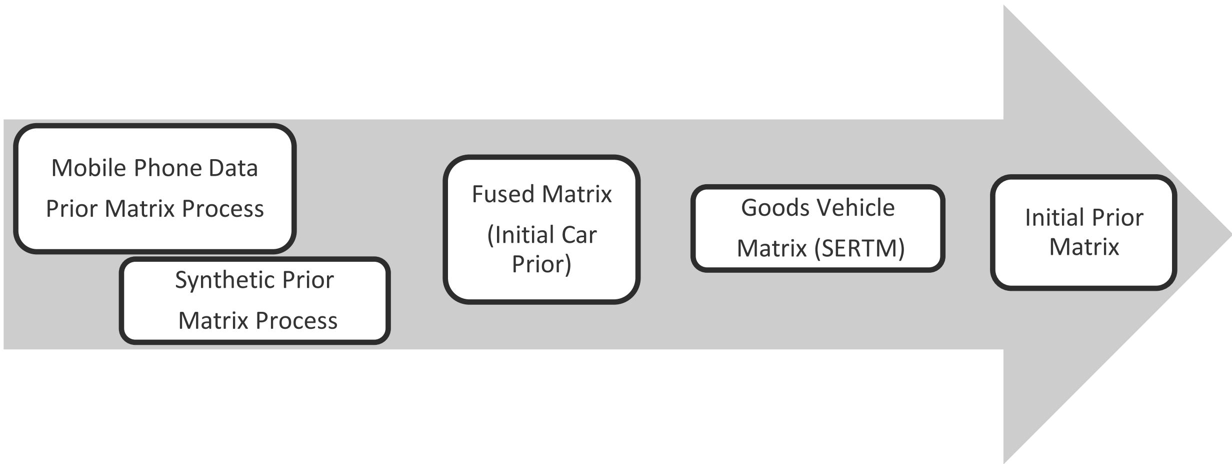


Figure 9-1: Overview of the Matrix Build Process

The following key steps were involved in order to process the prior matrices (see Figure 9-2 on the next page). Each step is outlined in more detail in this chapter:

- Build separate aggregate matrices at 24-hour level at Production-Attraction (PA) combining Road and HGV trips
- Remove HGV and LGV from the mobile phone data, using SERTM data trips;
- Develop synthetic PA matrices by purpose at 24-hour level at Production-Attraction (PA) level for car and bus trips;
- Fuse the synthetic and MND matrices together to form a combined prior matrix, including:
    - Short-Distance Corrections;
    - Disaggregating the matrices from mobile data sectors into Buckinghamshire model zones;
    - Splitting MND into Car and Bus;
    - HBO Purpose Segmentation; and
    - Trip End Production corrections.
- Apply staged adjustments to the matrices based on local evidence;
- Convert matrices from Production-Attraction (PA) level to Origin-Destination (OD) level for assignment;

- Convert matrices from people to vehicles; and
- Create peak period matrices (AM, IP, PM).

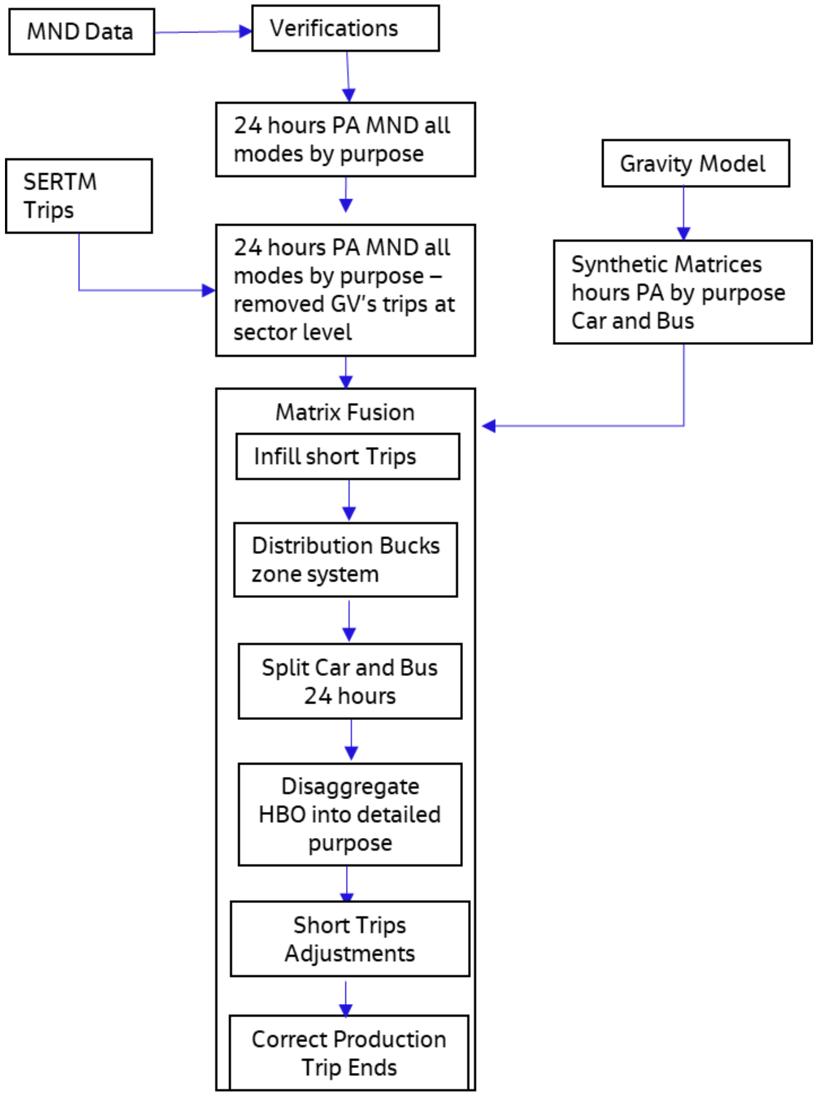


Figure 9-2: Matrix Build Process

The MND and synthetic matrices are derived as car driver and car passenger demands at the 24-hour level. In the assignment matrices for each time period the purpose matrices are combined into 3 car user classes as discussed in Section 4.7 alongside LGV and HGV.

9.3.2 Data Requirements

As defined in TAG, the data required for matrix development can be divided into three broad categories:

- **Matrix data –** either in OD or PA format and providing information about both ends of the trip or tour. These data typically come in different format, coverage, and level of aggregation and can include existing demand matrices, tracking data, sectoral data intercept surveys, and household interview surveys;
- **Zonal data –** typically representing land-use, demographic, and economic characteristics of the trip makers and associated with either of the trip ends; and

- **Volumetric data –** used to expand survey samples and to verify the accuracy of the matrices by comparing the traffic and passenger flows resulting from matrix assignment with vehicle and passenger counts.

Availability of data in each of these groups was carefully considered. The gaps and the necessary data collection, together with processing and verification steps, are described in the next section.

9.4 Data Assembly

9.4.1 Existing Data Sources

A number of data sources are used as input into the overall matrix development process:

- Mobile Network Data (MND) - includes the matrices provided by Telefonica at Middle Layer Super Output Area (MSOA) and Lower Layer Super Output Area (LSOA) level;
- South East Regional Transport Model (SERTM) - used as the source for goods vehicle matrices;
- National Trip End Model (NTEM) trip ends – used within synthetic matrix production;
- National Travel Survey (NTS) data - used for verifications; and
- Traffic counts - used as verification of the travel demands.

9.4.1.1 National Travel Survey

The NTS is a household survey that records personal travel for a sample of respondents. All detailed data between 2010 and 2019 was requested, being a robust and reliable source of the overall volume of travel and car trips. Analysis of the NTS data is used to check the mobile phone data and to support the synthetic matrices. The data provided information to:

- Calculate the trip rates:
- Create trip length profiles; and
- Provide analyses by trip purpose.

9.4.1.2 Census JTW

The standard 2011 Census Journey to Work data set was obtained from the Office for National Statistics (ONS). The data was used to compare the travel patterns derived from the mobile phone data set and to assess trip lengths for commuting trips.

9.4.1.3 Traffic Count Data

This is the same data as those used for assignment calibration and validation. This data provides additional insights into the performance of the demand matrices and provides a practical way of verifying their accuracy. The availability and collection of this type of data is covered in Chapter 5 of this report.

9.4.2 Mobile Network Data Specification

The MND was commissioned by Jacobs for the entirety of the Buckinghamshire area and beyond. The data provided by Telefonica was therefore specified to provide a fully observed initial matrix of trip patterns/movements to, from, within, and passing through Buckinghamshire. Within the MND cordon, all internal movements have been disaggregated by Telefonica to LSOA zone level using Census 2011 data.

There are 450 MSOA zones in the MND Internal Area and 49 zones in the MND External Area. These areas are shown in Figure 9-3 below. The dataset only includes trips which either begin, end, or travel through the MND Internal Area.

Figure 9-3: MND Zone System

The matrices were supplied in expanded form, representing trips made by the whole UK population on an average neutral weekday. The expansion was based on the ratio of MSOA population to the number of phones with a home location in that MSOA. All journeys were allocated a time, purpose, and mode, and split into their individual legs to create the OD matrix outputs segmented by model: Road (car and van drivers and passengers, motorcyclists, taxi passengers, LGV drivers, bus passengers, and coach passengers), HGV, and Rail Passengers.

The MND includes data for the entire day and by time period, which would enable production of 24-hour Production-Attraction and hourly Origin-Destination matrices. Also, the data is separated by four time periods according to their start time or the time they entered the MND Internal Area:

- AM Period: 07:00 to 10:00;
- Inter Peak Period: 10:00 to 16:00;
- PM Period: 16:00 to 19:00; and
- Off Peak: 19:00 to 07:00.

The MND includes data for average neutral weekdays (Monday to Thursday) for the period of Sunday 1st of September to Saturday 30th of November 2019, excluding bank holidays and non-typical days, which were defined as follows:

- Monday 2nd September 2019 (In-Service Training (INSET) day/schools close);
- Tuesday 3rd September 2019 (INSET day/schools close); and
- Monday 28th of October 2019 to Thursday 31st of October 2019 (Autumn half term).

The data was segmented into the following modes:

- Road (motorised trips) further segmented into:
  - Heavy Vehicle Trips (HGV Drivers, Coach Drivers); and

    - Non-Heavy Vehicle Trips (Car, Motorcycle, Coach, Bus, and LGV Trips).
- Public Transport (Rail Passengers).

The data was segmented into the following trip purposes:

- OB_HBW: outbound home-based commute;
- IB_HBW: inbound home-based commute;
- OB_HBO: outbound home-based other;
- IB_HBO: inbound home-based other;
- NHBW: non-home-based commute; and
- NHBO: non-home-based other.

Education trips made by these users are included in the home-based other trips.

The MND contained the following segmentation information for the matrices, shown in Table 9-1:

<table>
<tr><th>Code</th><th>Origin</th><th>Destination</th><th>Direction from Home</th><th>Purpose</th><th>Mode</th></tr>
<tr><td>OB_HBW</td><td>Home</td><td>Work</td><td>Outbound</td><td rowspan="2">Home</td><td rowspan="6">Non-Heavy Vehicle (Car, Motorcycle), Rail, Coach</td></tr>
<tr><td>IB_HBW</td><td>Work</td><td>Home</td><td>Inbound</td></tr>
<tr><td>OB_HBO</td><td>Home</td><td>Other</td><td>Outbound</td><td rowspan="2">Other</td></tr>
<tr><td>IB_HBO</td><td>Other</td><td>Home</td><td>Inbound</td></tr>
<tr><td>NHBW</td><td>Other
Work</td><td>Work
Other</td><td rowspan="2">Non-Home Based</td><td>Employers' Business</td></tr>
<tr><td>NHBO</td><td>Other</td><td>Other</td><td>Other</td></tr>
</table>

Table 9-1: MND Purpose and Segmentation

9.4.3 Data Processing and Expansion

The data processing and expansion steps were done by Telefonica. The steps undertaken to create initial OD matrices are summarised in Table 9-2.

Stages	Processing
Processing Event Data	• Collection of event data • Conversion of event data to dwells and journeys • Removal of invalid users
Processing Dwells	• Generation of Points of Interest (POIs) • The categorisation of POIs • Calculation of expansion factors
Processing Journey	• Categorising journeys by purpose • Identify journey mode • Select trips that penetrate cordon • Identify the time of the journey • Create OD matrix split by mode

Stages	Processing
Initial Validation Checks	• MND home-based trip origins against Census zone home population • MND work-based trip destinations against Census zone workplace population • Comparison of inbound trips and outbound trips per zone • MND trip length distribution for all trips against NTS trip length distribution • Trip rates based on expansion targets against the derived zonal trip ends • HGV trips against WebTRIS Annual Daily Flow

Table 9-2: Stages of MND Processing and Expansion

9.4.4 Data Verification

Prior to the use of the data, a series of initial verification checks were undertaken through a series of checks:

- Data symmetry checks;
- Trips patterns distribution;
- Comparison of MND trip length distribution with NTS data to understand any systematic biases in journey lengths;
- Comparison of journey purpose splits with NTS data to identify significant deviation from the expected patterns and suggest corrections of anomalies and biases; and
- Comparisons of MND trip ends with NTEM to understand the types of trips that may be over or under-represented in the MND.

9.4.4.1 Data Symmetry Checks

Table 9-3 shows the level of symmetry between inbound and outbound in each sector, with most sectors showing a symmetry factor of between 0.8 and 1.1 (based on inbound ÷ outbound). The sectors with large symmetry differences are external sectors (highlighted in Table 9-3), with only six external sectors showing over 5% difference (Scotland, East of England, West Sussex, Yorkshire and The Humber, North West, and East Sussex). Combined these sectors account for just 1% of overall demand. Given that they are external sectors, and account for such a small proportion of overall demand the relatively lower levels of symmetry for these are not considered to have any detrimental effect on the quality of the matrices.

Sector Number	Sector Name	Inbound (IB)	Outbound (OB)	Symmetry (IB/OB)	Symmetry (Large/Small)
101	Aylesbury North	77,007	76,555	1.01	100.6%
102	Aylesbury Central	50,739	50,888	1.00	100.3%
103	Aylesbury South	42,835	42,747	1.00	100.2%
104	Wycombe North-West	43,659	43,911	0.99	100.6%
105	Wycombe Central and East	89,230	89,909	0.99	100.8%
106	Wycombe South	44,209	44,274	1.00	100.1%
107	Chiltern North	64,498	64,664	1.00	100.3%
108	Chiltern South	25,758	25,675	1.00	100.3%
109	South Bucks West	26,791	26,818	1.00	100.1%
110	South Bucks East	42,610	42,670	1.00	100.1%
111	Milton Keynes	317,714	316,874	1.00	100.3%
112	Uxbridge	86,760	87,167	1.00	100.5%
113	Slough	146,060	146,330	1.00	100.2%

Sector Number	Sector Name	Inbound (IB)	Outbound (OB)	Symmetry (IB/OB)	Symmetry (Large/Small)
114	Bicester	36,547	36,241	1.01	100.8%
201	Central and North West London	251,854	242,450	1.04	103.9%
202	South and West London	86,121	85,879	1.00	100.3%
203	East London	25,271	24,383	1.04	103.6%
301	Bedfordshire	439,160	442,182	0.99	100.7%
302	Dacorum	140,130	139,879	1.00	100.2%
303	Three Rivers	76,008	76,471	0.99	100.6%
304	Hillingdon South	196,572	200,281	0.98	101.9%
305	Windsor and Maidenhead	148,241	148,126	1.00	100.1%
306	South Oxfordshire	98,471	98,404	1.00	100.1%
307	Cherwell	135,870	136,463	1.00	100.4%
308	Northamptonshire	293,110	294,112	1.00	100.3%
401	Hampshire	82,509	80,801	1.02	102.1%
402	Berkshire	459,665	460,607	1.00	100.2%
403	Oxfordshire	240,830	240,698	1.00	100.1%
404	Cambridgeshire	28,506	28,258	1.01	100.9%
405	East of England	7,272	6,666	1.09	109.1%
406	Essex	19,825	19,834	1.00	100.0%
407	Hertfordshire	259,552	259,477	1.00	100.0%
408	Kent	14,123	13,674	1.03	103.3%
409	Surrey	138,985	144,353	0.96	103.9%
410	West Sussex	12,709	11,778	1.08	107.9%
411	East Sussex	4,550	4,296	1.06	105.9%
901	South West	48,026	47,906	1.00	100.3%
902	West Midlands	69,825	69,847	1.00	100.0%
903	East Midlands	125,858	126,384	1.00	100.4%
904	North West	10,930	10,291	1.06	106.2%
905	Yorkshire and The Humber	9,386	8,821	1.06	106.4%
906	North East	1,798	1,763	1.02	102.0%
907	Wales	8,695	8,364	1.04	104.0%
908	Scotland	2,959	3,706	0.80	125.2%
Total		**4,531,228**	**4,530,877**	**1.00**	**100.0%**

Table 9-3: Matrix Totals by Sector (24-Hour Average Weekday)

9.4.4.2 Trips Patterns Distribution

Table 9-4 on the next page shows the overall distribution of trips in the MND unadjusted matrix. There are 4.6 million daily trips, of which 14% are internal Buckinghamshire area trips. The movements between Buckinghamshire area and external areas is 20% of all trips.

Areas	Bucks Internal	MND Internal	External	Total
Bucks Internal	646,519	276,457	183,129	**1,106,105**
MND Internal	275,126	1,126,134	723,185	**2,124,445**
External	184,763	731,165	456,898	**1,372,826**
Total	**1,106,408**	**2,133,756**	**1,363,212**	**4,603,376**

Table 9-4: Trip Pattern Distribution (24-Hour Average Weekday)

9.4.4.3 MND Trip Length Distribution

The trip length distribution (TLD) of trip productions was compared against the local NTS data as shown on Figure 9-4. This clearly shows the absence of short-distance trips, below ~6km, within the MND. This confirmed the need to develop synthetic matrices of demand and incorporate them into the prior matrices.

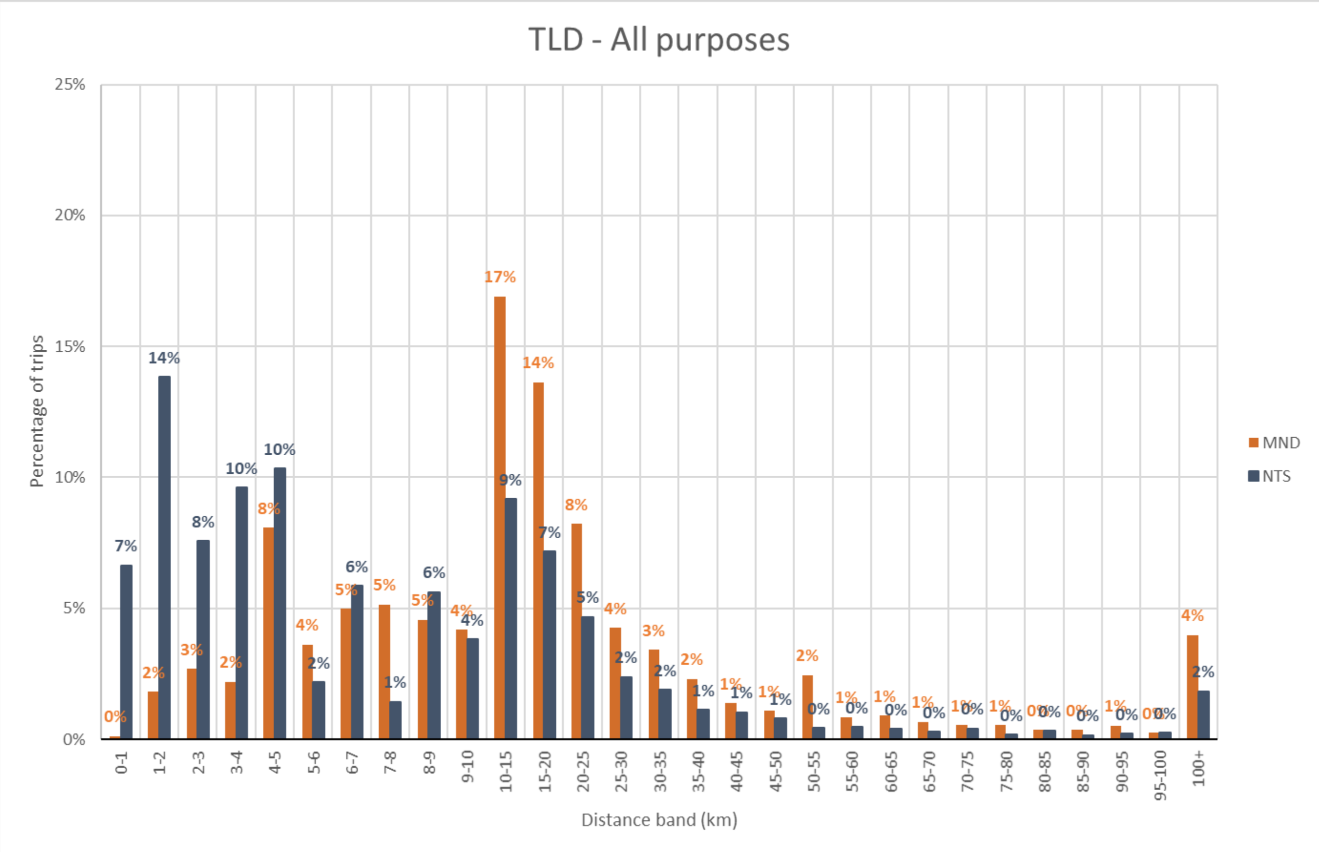


Figure 9-4: Trip Length Distribution – Mobile Phone Trips

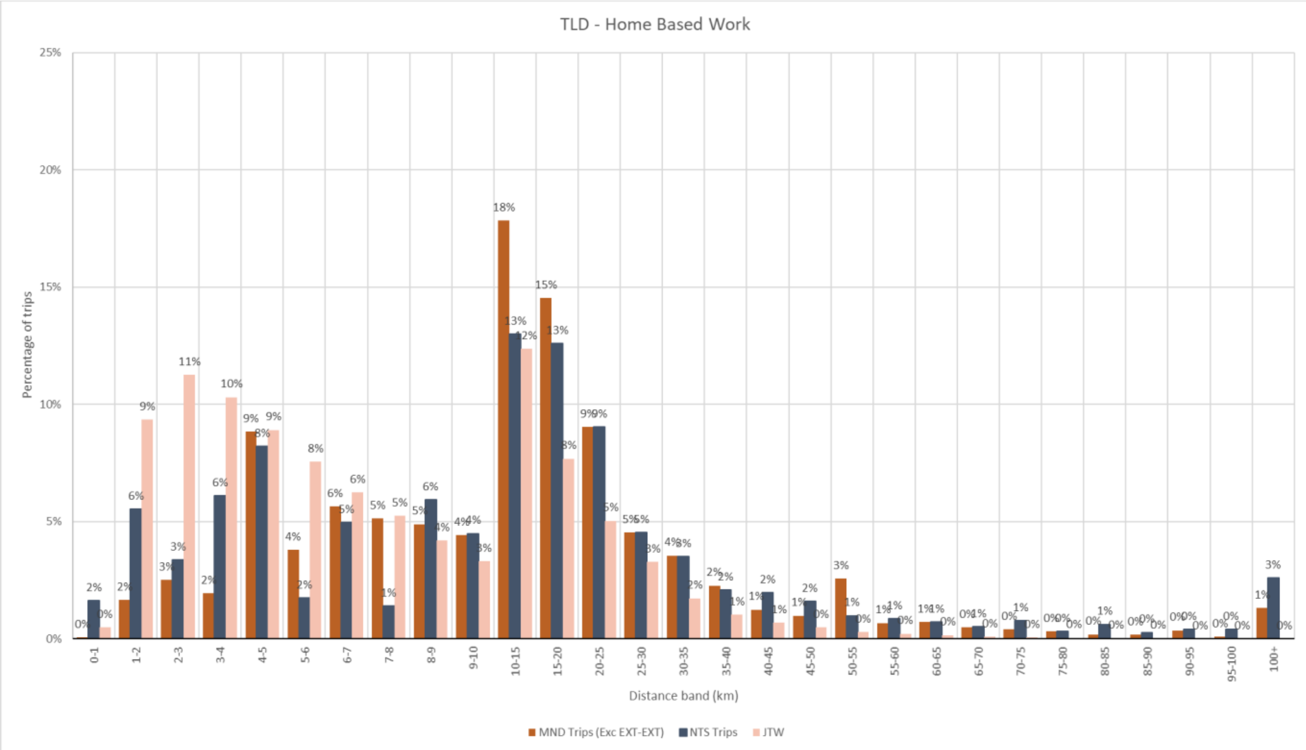


Figure 9-5: HBW Trip Length Distribution – Mobile Phone Trips

In the case of HBW, the comparisons in Figure 9-5 show a significant proportion of commuting trips in the lower distance bands (below 6km) when compared with both NTS and Census JTW. It counters the expectation that there should be a shortfall in the short-distance bands typically seen in MND and suggests a need for a correction of the distribution.

The MND matrix totals are shown in Table 9-5 below. They differ slightly from the overall matrix due to rounding after processing. The total matrix below incorporates HGV trips. It is noted that a separated matrix of MND HGV trips was provided but initial verification shows that the level of demand seemed low compared to the total road trips. As a result, more aggregate datasets were used and split during the development process.

Matrix	Road	HGV	24-Hours Trips Total
IB_HBO	1,147,655	0	1,147,655
IB_HBW	670,538	0	670,538
NHBO	537,815	53,011	590,826
NHBW	409,050	20,505	429,555
OB_HBO	1,097,450	0	1,097,450
OB_HBW	669,725	0	669,725
Total	**4,532,233**	**73,516**	**4,605,749**

Table 9-5: MND Matrix Totals by Purpose (24-Hour Average Weekday)

9.4.4.4 MND Trip Ends with NTEM

An initial set of trip productions and attractions were developed for each of the purposes based on the NTEM trip ends. These trip ends were compared against the MND trip ends at sector and zone level. They show that the MND trip ends are generally lower than the synthetic, although the relationship is consistent across the area. This reflects the lack of short trips in the MND. Figure 9-6 (on the next page) shows that the home-based sector level fit is 0.97. For non-home-based trip productions, the R^2 value is greater than 0.97.

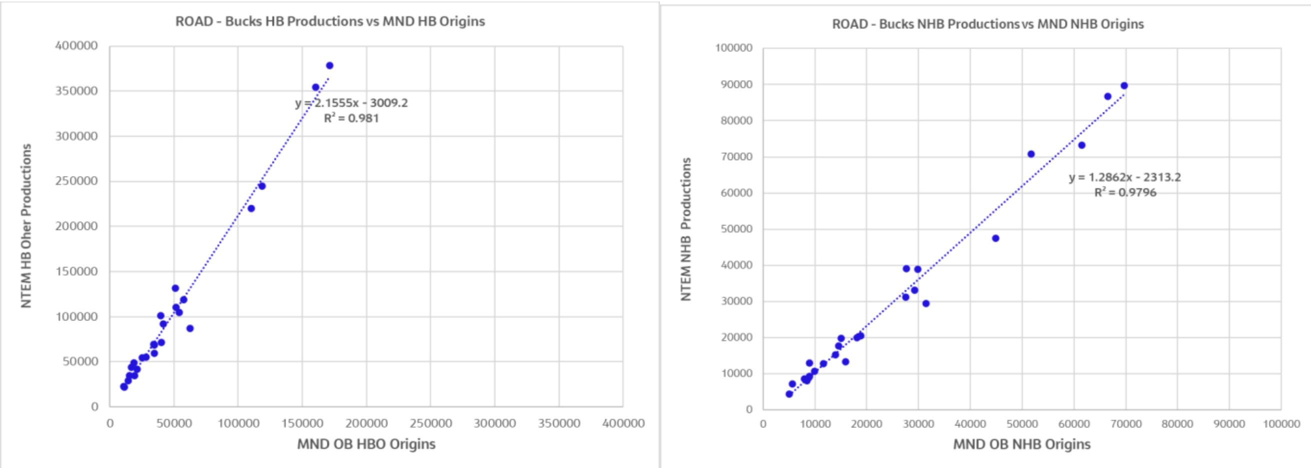


Figure 9-6: Sector Comparison of MND and Synthetic NTEM Trip Ends – Productions

A similar analysis was undertaken at zonal level (Figure 9-7). These show that the MND fit is not as good at more disaggregate levels and mainly reflects the missing short trips. It was therefore concluded that the MND needed to be expanded to NTEM trip levels but in a manner that retained the more reliable longer distance movements, concentrating the infilling for shorter distance missing trips.

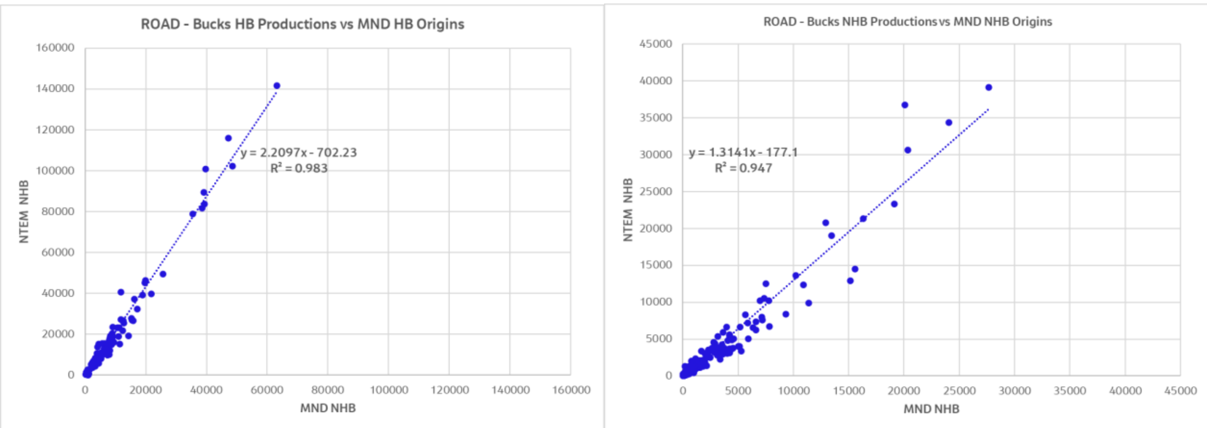


Figure 9-7: Zonal Comparison of MND and Synthetic NTEM Trip Ends – Productions

9.4.4.5 MND Trip Ends with NTS

The initial comparison of journey purpose split analysis highlighted a high proportion of NHB trips in the MND compared to NTS. This was consistent with earlier findings, which concluded that MND HB and NHB trips are disproportionately represented. This overstatement of NHB share was expected to be corrected during further processing of the MND, particularly following the separation of GV trips from the dataset. Furthermore, during the data fusion process, the overall trip numbers in the final matrices were to be controlled to TEMPro targets. Table 9-6 shows an initial comparison of journey purposes splits between MND and NTS data.

Source	HBW	HBO+	NHB
Raw MND	24.23%	41.73%	34.05%
NTS	27.22%	51.62%	21.16%

Table 9-6: Comparison of Initial Journey Purpose Split

9.4.5 Insights from the Data

Table 9-7 shows a summary of the verification checks suggested by TAG M2-2. This table shows concerns in relation to the magnitude of trips, particularly the short trips, while the symmetry and the trip patterns look reasonable. Therefore, the MND can provide inputs into the prior matrices with adjustments and fusion with short-distance trips.

Indicator	Attribute	Source	MND 24-Hour Matrices
Number of Trips	Trips rates and Trip ends	NTS, NTEM	Overall, MND trips are low when compared to these data sources as there is an absence of short-distance trips
Pattern of Trips	Distribution	Census JTW, NTEM, NTS	Greater lumpiness at zone level
	TLD	Census JTW, NTS	Shortage of short-distance trips
Demand Segmentation	Mode share	NTS	Good proportion between Road and Rail
	Purpose split	NTS	Large proportion of MND NHB trips
Matrix Symmetry	Inter-sector and symmetry	MND	Good symmetry

Table 9-7: Initial MND Verification Checks

9.5 Matrix Development Process

9.5.1 Synthetic Matrices

Synthetic car and bus demand matrices were used to infill the short-distance trips missing from the MND and to support the segmentation of the road matrices by vehicle type and trip purpose. The synthetic trip ends were also used to correct biases in MND at a detailed geographical level.

The synthetic matrix development followed a conventional approach of trip generation and trip distribution using a bespoke gravity model for personal car and public transport trips. In line with TAG, the matrices were built in the Production-Attraction (PA) form, for all-day travel, using the segmentation consistent with the BSTM demand model. The main principle of the gravity model was to obtain a trip matrix consistent with NTEM trip ends and the observed trip length distribution (TLD) from NTS.

9.5.1.1 Gravity Model Specification

The gravity models developed included bus travel as a distinct mode to support further segmentation of the MND road demand into car and bus trips.

Only internal movements within the study area were modelled in the gravity models. The external to external movements were omitted due to the lower level of zone and network detail in the external area. The MND was expected to provide higher quality data for these longer distance movements.

The gravity model formulation, the preparation of inputs, and the resulting synthetic matrices are discussed in the following sections.

The synthesised trips obtained from the gravity model have the general form:

$$Tij = Pi\ Aj\ ki\ lj\ f(cij)$$

where:

Tij represents trips between production zone i and attraction zone j;

Pi represents trip productions;

Ai represents trip attractions;

cij is the cost of the trip from production zone i to attraction zone j;

ki and lj are 'balancing factors' which are calculated in matrix preparation to allow the row and column totals of the matrix to match the production and attraction targets; and

$f(cij)$ is a deterrence function.

The deterrence function is a function of travel costs and introduces disincentive to travel with increasing cost of travel. They have one or more parameters to be calibrated and the number of these defines their degree of freedom with more parameters making it easier to obtain a closer fit with the observed trip length distribution. The deterrence functions used is the log normal distribution:

$$f(c_{ij}) = \frac{1}{c_{ij}\sigma\sqrt{2\pi}} exp\left(-\frac{(ln(c_{ij})-\mu)^2}{2\sigma^2}\right)$$

where μ and σ are calibration coefficients.

The parameters were determined by solving the log normal distribution formulae for the mean and the variance equations respectively:

$\mu = exp\ (M + S^2/2)$

$\sigma^2 = exp(S^2 + 2M) * (eS^2 - 1)$

where M and S were defined to be the mean number of trips weighted by the midpoint of the distance bands used in the TLDs and the square root of the variance of the TLDs, respectively.

9.5.1.2 Gravity Model Inputs

The variables required to satisfy the formulation of the gravity model are described above. These variables are represented by the following input data:

- Trip Ends (both Productions and Attractions derived from NTEM), including any factors which scale external trip ends to reflect the proportion of trips to the Fully Modelled Area;
- Generalised cost inputs from the assignment model; and
- Observed trip length distribution (TLD) derived from the NTS data.

9.5.1.2.1 Trip Ends

Production-Attraction (PA) trip end data from NTEM for the base year (2019) was extracted from TEMPro Version 7.2 for all modelled journey purposes listed in Table 9-8. TEMPro car and bus data was obtained for MSOAs for the average weekday. Trip ends for the larger zones in the model were formed by aggregating values over constituent MSOAs. For smaller zones, which required splitting MSOAs, 2011 Census data (resident and workplace population) was used, as detailed in Table 9-8.

Purpose	Production Split Factors	Attraction Split Factors
HB Commute		
HB Employers' Business HB Other HB Education NHB Employers' Business	Census – Resident Population	Census – Workplace Population
NHB Other		

Table 9-8: Data Used in Splitting MSOA Trip Ends to Smaller Zones

9.5.1.2.2 Gravity Model Cost Inputs

Cost input for use in the deterrence function of the gravity model is defined as generalised cost. Initial car and bus costs, using highway modelled distance skims obtained from early versions of the VISUM assignment, were used for the first cut of the gravity model and then refined in the subsequent steps once satisfactory interim matrices were achieved.

9.5.1.2.3 Trip Length Distribution

The NTS database was queried to produce observed TLDs with which to estimate the parameters of the deterrence function. For car, these were generated for productions inside Buckinghamshire to all attractions and for bus they were produced for Buckinghamshire to Buckinghamshire trips only.

9.5.1.3 Gravity Model Results

The coefficients of the deterrence function were revised to improve the fit to the observed NTS trip length patterns. The focus was on achieving a good match between the modelled and observed patterns for shorter distance bands while maintaining the overall TLDs as close as possible to the observed NTS values. It should be noted that the NTS data itself is subject to limitations and low data samples (especially for minor modes and purposes) and therefore was not considered fully reliable.

The home-based work demand was also compared to 2011 Census JTW data at a sector level, as shown in Figure 9-8. This comparison suggests a close correlation between the synthetic and observed sector-to-sector movements.

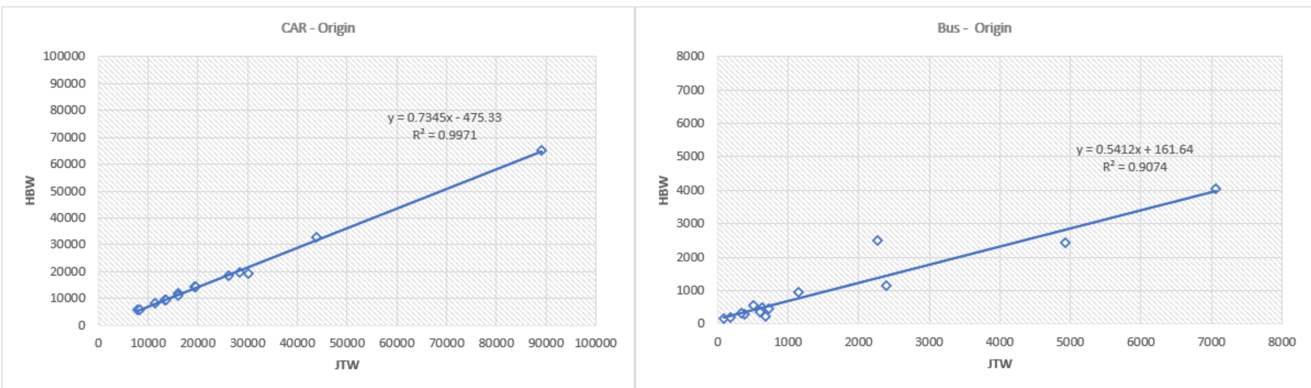


Figure 9-8: Comparison of Synthetic Car HBW Demand to JTW Car Demand

The resulting trip length distributions for car are presented in Figure 9-9 which compares car TLD for synthetic demand, JTW, and NTS data. The synthetic car matrices obtained from the gravity model show a plausible pattern for all journey purposes. Although some variation in trips can be seen, synthetic demand (based on TEMPro) suggests less HBW car travel than recorded in the Census.

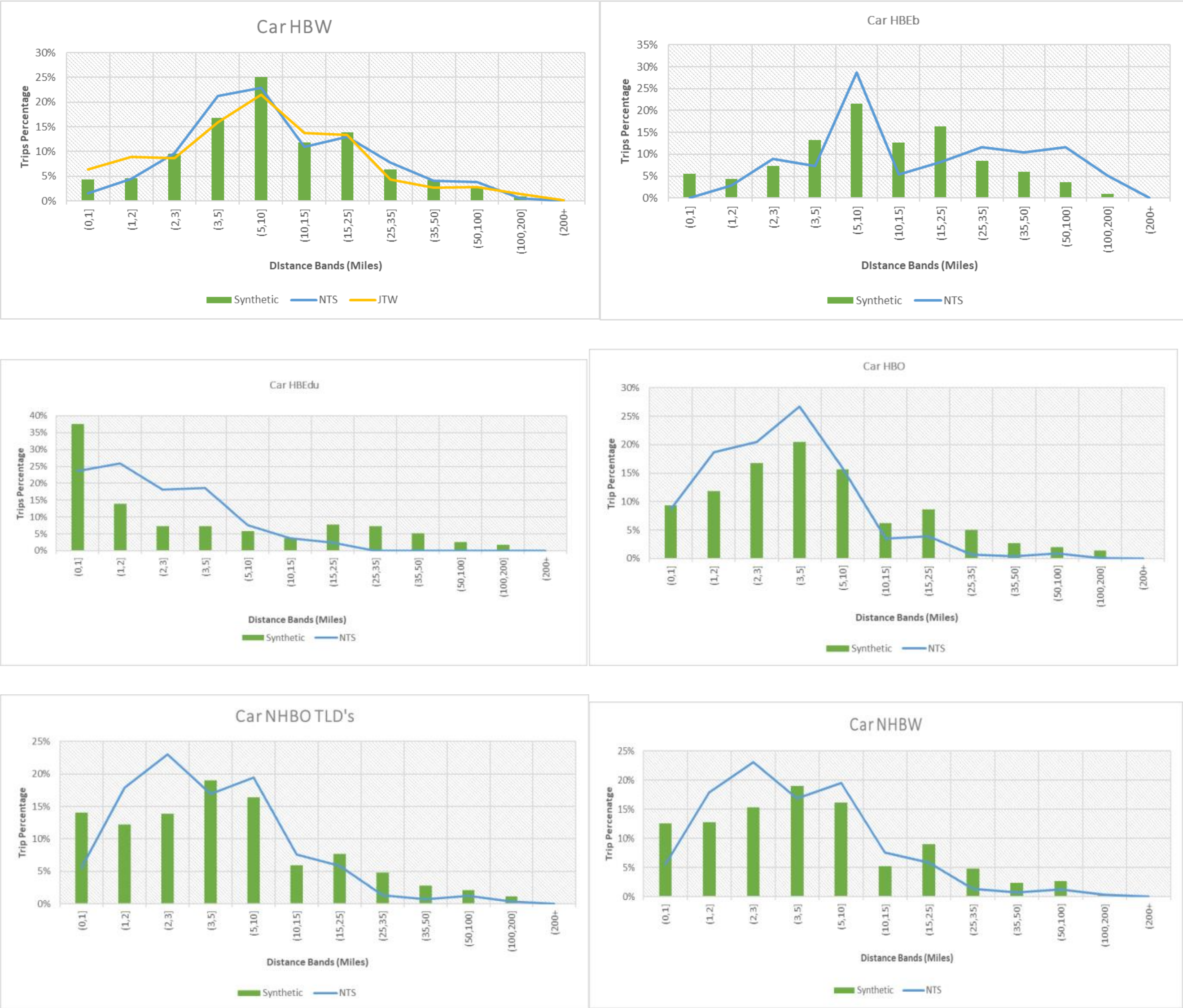


Figure 9-9: TLD Synthetic Car Compared Against JTW and NTS

9.5.1.4 Treatment of LGV Trips

The LGV trip matrices in the BSTM were imported from the South East Regional Traffic Model (SERTM). As the SERTM and BSTM zone systems and base years differ, a conversion was necessary. Firstly, the SERTM LGV matrices were disaggregated into the BSTM zone system. Then the figures were uplifted to reflect growth between 2015 and 2019 using factors derived from the DfT's Road Traffic Forecasts 2018 (RTF18) for all road types in the South East Region. After the basic adjustments of the format and base year, these matrices were used in two ways:

- To remove a proportion equivalent to LGV trips from the MND; and
- To form the basis of LGV matrices in the final set of demand matrices for the demand model.

In the first step, the rebased AM peak, inter-peak and PM peak LGV matrices were converted to 24-hour matrices for compatibility with the MND. As the LGV matrices are assumed to represent NHB trips, no conversion between the Origin-Destination (OD) and Production-Attraction (PA) format was needed based on the convention that

OD format is equivalent to PA format for non-home-based purposes. After the conversion, these matrices were used to remove the proportion of MND trips expected to represent LGV trips.

9.5.1.5 Treatment of HGV Trips

The HGV trip matrices in the BSTM were sourced from SERTM. Similarly, to LGVs, they were disaggregated and uplifted to 2019 using RTF18 data. In this case, there was no need to separate them from the remainder of MND as HGVs were readily identified with the dataset provided by Telefonica.

The SERTM-based matrices, which were subject to validation and refinement as part of SERTM development, were judged to be more reliable than the raw MND HGV matrices. Their use therefore avoided potential biases and challenges associated with the expansion of MND HGV data. Given the low reliability of the HGV data received from Telefonica, it was merged with the rest of the motorised traffic, from which HGVs were separated using SERTM HGV matrices. The MND HGV was replaced in its entirety with SERTM-based HGV data for use in the BSTM highway assignment.

9.5.2 Combining Data Sources

Having developed initial MND matrices, adjustments were undertaken based on available evidence before fusing them with the synthetic matrices. These included the following steps, previously presented in Figure 9-2.

9.5.2.1 Build 24-Hour Level Production-Attraction (PA) Combining Road and HGV Trips

Table 9-9 presents the initial total MND trips before the adjustments were undertaken.

Purpose	Internal - Internal	Internal - External	External - Internal	External - External	Total Trips
HBW	97,930	67,963	67,971	436,260	670,123
HBO	169,302	104,958	104,597	743,325	1,122,181
NHBO	54,811	64,697	65,862	403,963	589,333
NHBW	57,245	49,048	48,893	274,250	429,436
Total	**379,288**	**286,666**	**287,322**	**1,857,798**	**2,811,073**

Table 9-9: MND Matrix Totals by Purpose

9.5.2.2 Remove HGV and LGV From MND Road Trips

SERTM was used to create prior demand matrices for LGV and HGV, described in 9.5.1.4 and 9.5.1.5. These matrices were used to remove LGV and HGV trips from the MND. The removal was performed at an MSOA level for all movements with one or both trip ends in the internal area.

To achieve this, the car synthetic (all-purpose), bus synthetic, and SERTM-based LGV matrices were combined to form a single road-based trips dataset and used to calculate the proportion of LGVs in the combined dataset. To reduce the impact of large variations in the share of vehicle types by zone and provide more stable factors, the proportions were calculated at the sector level and then applied to the MND to split it into vehicle types. This approach avoids removing LGV trips as absolute numbers at a detailed zone level, which can be inappropriate if the absolute number of LGVs in the SERTM-based data exceeds the absolute number of MND trips due to the accuracy of the zone allocation in both SERTM and MND.

Table 9-10 (on the next page) presents the proportion of trips after removing LGVs and HGVs from the MND. In total, the percentage of trips kept from the original MND is 79% and, as expected, the greater percentage of trips removed are from NHBW which are the SERTM HGV trips. In total, 587,825 trips were removed from the initial MND combined road and HGV trips.

Purpose	Internal - Internal	Internal - External	External - Internal	External - External	Total Trips	Trips Removed
HBW	0.94	0.89	0.89	0.86	0.88	-80,891
HBO	0.98	0.94	0.94	0.90	0.92	-90,705
NHBO	0.84	0.82	0.84	0.80	0.81	-109,735
NHBW	0.47	0.28	0.26	0.25	0.29	-306,493
Total	**0.87**	**0.79**	**0.79**	**0.77**	**0.79**	**-587,825**

Table 9-10: Percentage of Trips Kept After Removing HGV and LGV

9.5.2.3 Replacing Short-Distance Trips in the Prior Matrix

When comparing MND to NTS, the trip length distribution highlighted an underrepresentation of short trips (described in section 9.4.4). This bias was corrected by infilling short-distance trips using the synthetic matrices. The infilling was undertaken at a sector level for each mobile phone trip purpose and mode separately. To retain as much of the MND as possible, whilst increasing the amount of short-distance travel, the available MND records were retained in infilling. It involved expanding the MND to match the production trip end totals from the gravity model and taking a proportion of the MND and synthetic trips based on how much infilling was required. As there were no reliable estimates for the external productions, those short-distance trips were replaced with the synthetic estimates.

Table 9-11 presents the proportion of trips after infilling short-distance trips with synthetic trips. In total, the percentage of trips is increased from the original MND by 12% and, as expected, the greater percentage of trips infilled are Internal to Internal (I-I). In total, 272,328 trips were infilled from the initial MND with synthetic trips.

Purpose	Internal - Internal	Internal - External	External - Internal	External - External	Total Trips	Trips Added
HBW	1.31	1.02	1.00	1.00	1.05	30,346
HBO	2.01	1.05	1.00	1.00	1.17	171,905
NHBO	2.05	1.03	1.00	1.00	1.10	50,024
NHBW	1.73	1.04	1.00	1.00	1.16	20,053
Total	**1.80**	**1.04**	**1.00**	**1.00**	**1.12**	**272,328**

Table 9-11: Short-Distance Trips Corrections

9.5.2.4 Disaggregate MND Matrices into Buckinghamshire Model Zones

The MND was aggregated to sector level to avoid 'lumpiness' at a zone level. As the objective is to create matrices compatible with the BSTM demand segments (24hr PA), a disaggregation of the sector MND matrices into the BSTM zone system was undertaken. This process followed the same percentage of trips allocated from the synthetic matrices (car and bus) into the zone level.

Table 9-12 shows that no trips were added or removed once MND trips were disaggregated from sector level to zone level, and also that each purpose maintained the total trips after allocating trips to each zone.

Purpose	Internal - Internal	Internal - External	External - Internal	External - External	Total Trips	Difference in Trips
HBW	1.00	1.00	1.00	1.00	1.00	0
HBO	1.00	1.00	1.00	1.00	1.00	0
NHBO	1.00	1.00	1.00	1.00	1.00	0
NHBW	1.00	1.00	1.00	1.00	1.00	0
Total	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0**

Table 9-12: Remaining Percentage of MND Trips After Sector Disaggregation

9.5.2.5 Split Car Mode from MND Road

To remove bus trips from the MND, an estimate of bus mode share for each OD movement was derived from the synthetic matrices. Checks were carried out to ensure that the distribution of shares was sensible (i.e. no outliers) and that the overall mode share by sector was in line with those suggested by TEMPro trip ends. The removal of bus trips was undertaken at a zone level separately for each trip purpose.

Table 9-13 presents the proportion of retained trips after removing bus trips from the MND road demand. In total, the percentage of remaining trips is 98%, and HBO purposes removed the greater percentage of bus trips from internal productions. For external productions it was assumed that all MND road trips are car trips. Table 9-13 also shows that a total of 41,240 bus trips were removed from the initial MND with bus synthetic trips.

Purpose	Internal - Internal	Internal - External	External - Internal	External - External	Total Trips	Trips Removed
HBW	0.95	0.98	1.00	1.00	0.99	-6,668
HBO	0.93	0.98	1.00	1.00	0.98	-26,696
NHBO	0.95	0.98	1.00	1.00	0.99	-6,034
NHBW	0.96	1.00	1.00	1.00	0.99	-1,842
Total	**0.94**	**0.98**	**1.00**	**1.00**	**0.98**	**-41,240**

Table 9-13: Remaining Percentage of Car Trips

9.5.2.6 Segmentation

The key objective of the detailed purpose segmentation is to create matrices compatible with the BSTM demand model segments (24hr PA) and with the assignment model user classes (time period OD). As described previously, the provisional MND was available for the following trip purposes: HBW, HBO+, NHBW and NHBO. As part of this step, the HBO+ demand was segmented further into Other (HBO), Education (HBEdu) and Employers' Business (HBEB) using the purpose shares based on the synthetic matrices for car. The splits were applied at a zone level to reflect differences in TLD by purpose whilst maintaining the purpose split at trip end level, reflecting planning data and land use. Whilst the resulting TLDs were different for each disaggregate trip purpose, the MND trip length distribution was retained at an aggregate level. For the external to external area, NTS purpose splits were used, as shown in Table 9-14:

Purpose	Car
HBO	74%
HBEB	5%
HBEdu	21%

Table 9-14: NTS Purpose Split for External to External Areas

Table 9-15 presents the percentage of remaining HBO trips after removal of bus trips from the MND road. In total, 27% of the HBO total trips are split into HBEB and HBEdu. Table 9-15 also shows that, overall, no trips were added or removed from the segmentation process.

Purpose	Internal - Internal	Internal - External	External - Internal	External - External	Total Trips	Difference in Trips
HBW	1.00	1.00	1.00	1.00	1.00	0
HBO	0.74	0.59	0.73	0.74	0.73	-322,133
NHBO	1.00	1.00	1.00	1.00	1.00	0
NHBW	1.00	1.00	1.00	1.00	1.00	0
HBEB	0.10	0.28	0.19	0.05	0.09	110,965
HBEdu	0.16	0.12	0.09	0.21	0.18	211,168
Total	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0**

Table 9-15: Remaining Percentage of HBO, HBEb and HBEdu After Purpose Split

9.5.2.7 NTS Short-Distance Adjustment

The trip length distribution verification checks were repeated throughout the process to ensure that the overall patterns of trips in the resulting matrices were consistent with NTS and to identify any further sources of bias to be addressed in subsequent iterations. These iterations led to further alteration of the short-distance adjustments with NTS data. The optimisation method was based on minimising the inconsistencies between the assigned prior matrix and the observed data through the modification of assumptions utilised in data merging and various conversions between daily PA and time period OD.

Table 9-16 presents the percentage of trips after optimising short-distance trips to match NTS trip length distributions. In total, the percentage of trips is increased from the previous step by 2%, and the greater percentage of trips infilled are NHBO and HBEb, and a reduction of HBEdu and NHBW. Table 9-16 also shows that a total of 60,223 trips were infilled compared to the MND total after the previous step.

Purpose	Internal - Internal	Internal - External	External - Internal	External - External	Total Trips	Difference in Trips
HBW	1.10	1.01	1.00	1.00	1.02	12,371
HBO	1.10	1.01	1.00	1.00	1.03	22,290
NHBO	1.33	1.03	1.00	1.00	1.06	31,109
NHBW	0.77	0.99	1.00	1.00	0.93	-10,321
HBEB	1.18	1.01	1.01	1.00	1.05	5,911
HBEdu	0.95	1.12	1.01	1.00	0.99	-1,137
Total	**1.10**	**1.02**	**1.00**	**1.00**	**1.02**	**60,223**

Table 9-16: Remaining Percentage of MND Trips After NTS Short-Distance Adjustment

9.5.2.8 Trip End Corrections

The spatial accuracy of MND is limited due to possible trip allocation and expansion errors. Therefore, some form of constraining to TEMPro trip ends was necessary to maintain consistency with land use and planning data. Recognising that TEMPro itself is subject to uncertainty and error, the constraints were applied to bring the trip end totals to within 10% of the target value. Table 9-17 presents the proportion of trips uplifted (or reduced) after optimising trip production correction. In total, the percentage of trips is increased from the previous step by 17%, and a total of 424,295 trips were added to the MND from the previous step.

Purpose	Internal - Internal	Internal - External	External - Internal	External - External	Total Trips	Difference in Trips
HBW	1.24	1.41	1.47	1.29	1.31	195,188
HBO	1.43	1.97	2.08	1.54	1.58	509,645
NHBO	0.92	1.01	1.15	0.95	0.97	-15,341
NHBW	1.50	1.38	1.50	1.47	1.47	61,710
HBEB	0.45	0.43	0.82	0.54	0.53	-55,221
HBEdu	1.74	2.40	2.66	1.89	1.92	193,473
Total	**1.10**	**1.20**	**1.41**	**1.15**	**1.17**	**889,453**

Table 9-17: Percentage of MND Trips after TEMPro Trip End Corrections

9.6 Matrix Verification and Refinements

9.6.1 Verification Checks and Matrix Adjustments

The verification tests undertaken at this stage (after fusion) focused on the same metrics as the initial verification of the MND and the monitoring of the performance of the gravity model and the synthetic matrices. The final verification checks focus on the performance of the matrices resulting from the fusion of the MND and synthetic data and provide an insight into what changes into matrix structure were introduced in that step. The findings of the final verification tests inform a final set of adjustments to the overall process and incorporate corrections identified as necessary during the earlier MND verification step.

9.6.1.1 Trip Length Distribution

Figure 9-10 shows the verification of trip length distributions for the final (fused) car data at 24-hour level as a result of the amendments, for each fused journey purposes. The comparisons show that the fused matrices replicate the observed TLDs well for most distance bands.

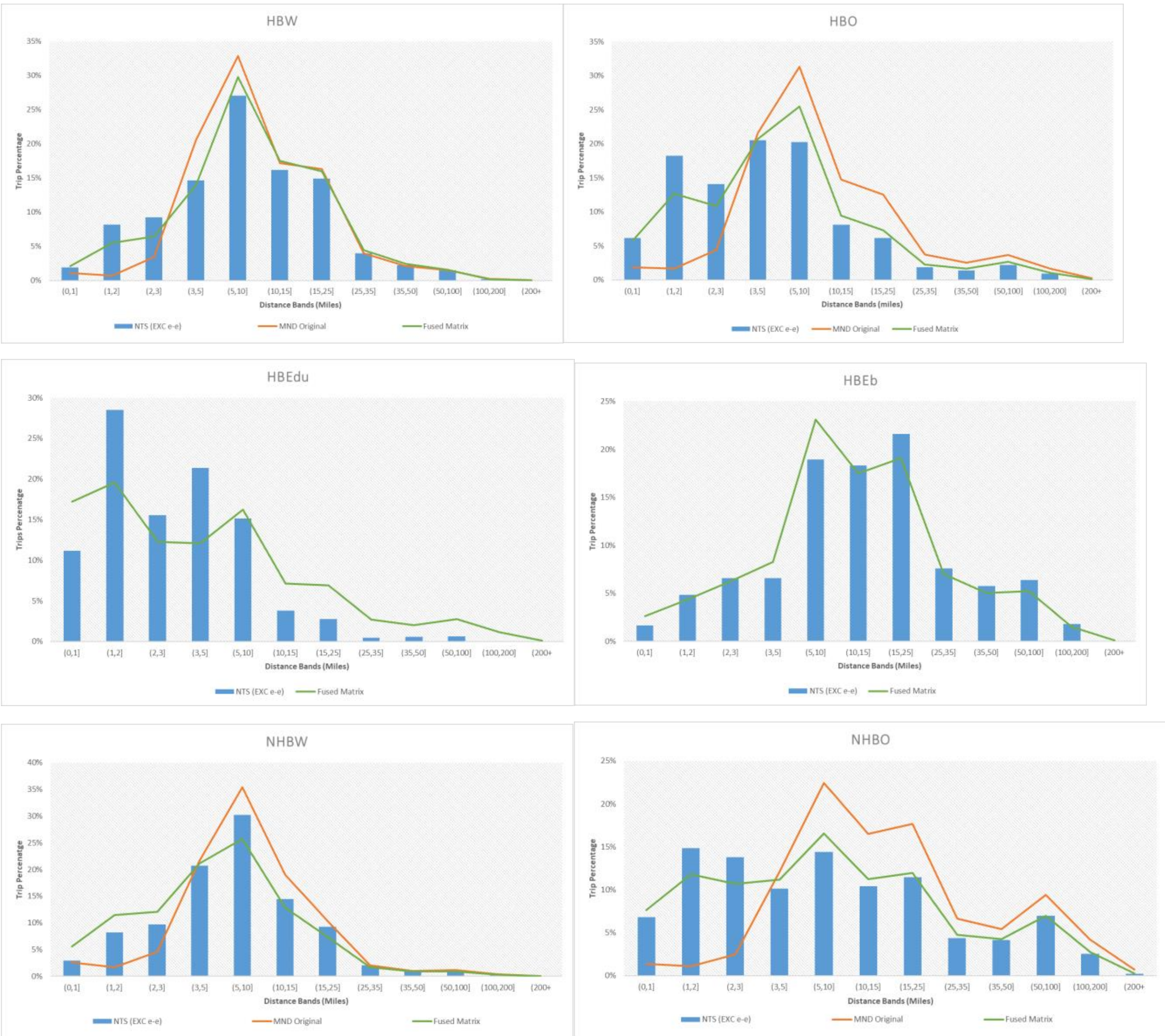


Figure 9-10: MND Original Matrix TLD, and Fused Matrix TLDs vs NTS (Excluding External to External Trips)

9.6.1.2 MND Trip Ends with NTEM

Figure 9-11 compares the internal car productions by zone with TEMPro data and shows a very good match between the final car productions by zone and TEMPro data for all journey purposes with high R^2 results.

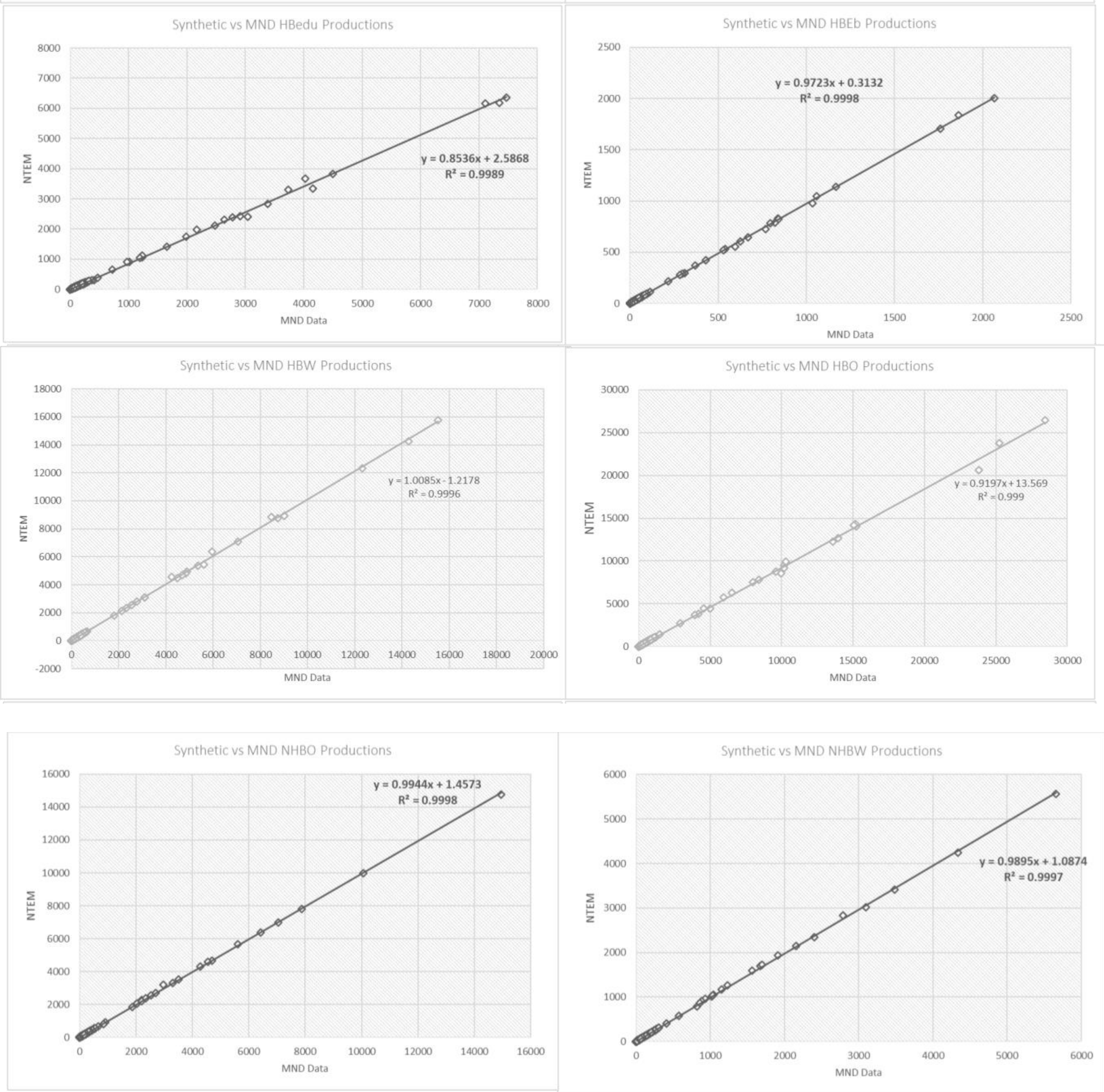


Figure 9-11: Comparison of Prior Car Demand Totals to TEMPro (Internal Productions by Zone)

Table 9-18 provides a summary of the verification checks for the prior matrices. This indicates that the 24-hour fused matrices were considered suitable for use.

Indicator	Attribute	Source	MND 24-Hour Matrices
Number of Trips	Trips rates and trip ends	NTS, NTEM	Combination of MND and synthetic matrices resolved issues of short-distance trips in the MND demands. Trip ends compared to NTEM and updated for growth
Pattern of Trips	Distribution	Census JTW, NTEM, NTS	Patterns identified from the MND look plausible against observed data
	TLD	Census JTW, NTS	TLD comparison is generally good against observed data sets
Demand Segmentation	Mode share	NTS	Assessment based on car only
	Purpose split	NTS	Purpose split makes use of NTEM allocations
	Time period split	Counts	Checks being carried out at hour period
Matrix Symmetry	Inter-sector and symmetry	MND	Good symmetry
Modelled Demand	Comparison against counts	Counts	Verification screenlines acceptable at period level

Table 9-18: Prior Matrix Verification Checks

9.6.2 Matrices for Assignment and Demand Models

The 24-hour matrices are converted to peak hour and OD format for assignment following a process shown in Figure 9-12. A set of factors were derived from NTS data for each peak period hour and purpose.

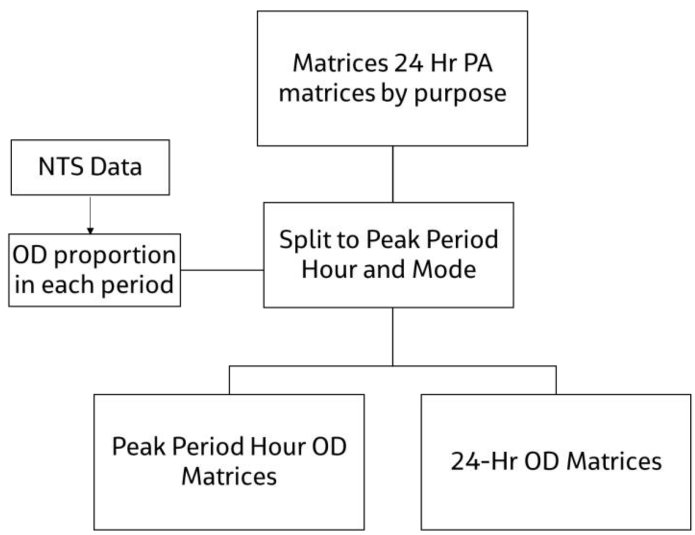


Figure 9-12: Peak Hour Matrix Development Process

Table 9-19 shows the factors derived from NTS to produce peak factors. These reflect the amount of travel from production to attraction and reversed in each period. For example, 70% of the 24-hour home-based work PA matrix is travel from home to work in the morning peak hour while 55.7% of the transposed PA matrix returns from working in the PM peak hour. The factors were applied across the entire modelled area.

Purpose	Direction	AM	IP	PM
HBW	IB	4.3%	13.8%	55.7%
	OB	69.6%	14.3%	4.7%
HBEB	IB	2.6%	26.3%	49.8%
	OB	53.8%	30.0%	6.6%
HBEdu	IB	14.4%	12.8%	68.7%
	OB	77.1%	10.4%	12.0%
HBO	IB	1.9%	33.7%	29.2%
	OB	12.0%	47.0%	19.0%
NHBW	OB	15.2%	61.4%	17.7%
NHBO	OB	17.7%	39.1%	32.6%

Table 9-19: Proportion of Daily Matrices in the Model Time Period

In addition, the person matrices were converted to vehicle matrices based on occupancy factors available from TAG presented in Table 9-20:

Purpose	Factors
Business	1.191
Commute	1.168
Other	1.666

Table 9-20: Vehicle Occupancy Factors

Table 9-21 shows the final fused matrix totals for assignment after applying the occupancy and Time of Day (ToD) factors:

Purpose	AM	IP	PM
Commute	165,253	45,676	154,374
Business	25,449	16,824	25,370
Other	202,047	144,254	218,466

Table 9-21: Car Matrix Totals (Average Weekday Peak Hour Assignment)

10. Trip Matrix Calibration and Validation

The following section outlines the adjustment process to improve the prior demand matrices and describes the resulting calibration of trip matrices through matrix estimation.

10.1 Prior Matrices Adjustments

The prior matrices, derived following the steps in Chapter 9, were assigned to the BSTM network and the assigned flows were compared against observed flows across screenlines. This comparison identified a need for further refinement of the trip matrices. The matrix development steps were reviewed, however since the required refinement was relatively small, it was decided not to revise the matrix development processes. Rather, small-scale adjustments were made to the trip matrices by aggregating into sectors and applying small factors to the sector-to-sector movements, to make small adjustments to better reflect the identified observed movements across screenlines. Checks were carried out to confirm that the adjustments did not significantly change patterns.

Table 10-1 shows the scale of change brought about by the adjustments to the matrix totals:

Vehicle Class	AM			IP			PM		
	Initial Prior	Final Prior	% Diff	Initial Prior	Final Prior	% Diff	Initial Prior	Final Prior	% Diff
UC1	165,253	167,062	1.08%	45,676	47,050	2.92%	154,374	155,718	0.86%
UC2	25,449	25,974	2.02%	16,824	17,564	4.22%	25,370	25,819	1.74%
UC3	202,047	205,070	1.47%	144,254	149,696	3.64%	218,466	223,923	2.44%
LGV	576,358	576,358	0.00%	555,261	555,261	0.00%	460,339	460,339	0.00%
HGV	275,258	275,258	0.00%	263,319	263,319	0.00%	173,252	173,252	0.00%
All Cars	392,750	398,106	**1.35%**	206,754	214,311	**3.53%**	398,210	405,460	**1.79%**
All Vehicles	1,244,367	1,249,723	**0.43%**	1,025,334	1,032,890	**0.73%**	1,031,801	1,039,051	**0.70%**

Table 10-1: Prior Matrix Adjustments

It is to be noted that (as mentioned in sections 9.5.1.4 and 9.5.1.5) GV matrices were obtained from SERTM. This covers a larger modelled area and therefore has a higher number of trips which, in BSTM terms, are external to external. Therefore the proportion of GVs is high in comparison with cars (for which there are relatively few external to external trips unless they travel through or close to the study area). Within the study area itself, the proportion of GV trips is appropriate.

The impacts of these prior matrix adjustments on model performance with respect to screenlines are outlined in the following table. The screenline locations are described in Section 11.2. The colour in the GEH column indicators whether the screenline improved (green) or not after the factoring process. Also included are overall results across all screenlines and the number of screenlines that pass acceptability criteria. Note that although the screenlines are named based on whether they are calibration (used in matrix estimation) or validation, in this case they are all effectively validation screenlines since this assessment was undertaken prior to any matrix estimation.

ID	Name	AM				IP				PM			
		Initial		Final		Initial		Final		Initial		Final	
		Diff	GEH	Diff	GEH	Diff	GEH	Diff	GEH	Diff	GEH	Diff	GEH
Cal_1	Cal_1-1	-33.37%	20.5	-27.52%	16.6	-43.57%	22.9	-41.80%	21.8	-28.86%	17.3	-26.06%	15.5
	Cal_1-2	-30.54%	18.2	-17.01%	9.8	-46.48%	25.2	-44.40%	23.9	-30.54%	18.7	-27.86%	16.9
Cal_2	Cal_2-1	-13.03%	12.2	-8.09%	7.5	-35.00%	28.5	-14.72%	11.3	-24.39%	23.7	-24.58%	23.9
	Cal_2-2	-27.57%	23.5	-23.86%	20.2	-38.66%	27.6	-24.36%	16.7	-25.50%	22.6	-20.98%	18.3
Cal_3	Cal_3-1	5.84%	5.1	1.41%	1.3	-3.88%	2.8	0.47%	0.3	4.19%	3.7	4.39%	3.9
	Cal_3-2	9.39%	7.9	5.63%	4.8	-15.92%	12.5	-0.65%	0.5	-10.53%	10.5	-2.41%	2.4
Cal_4	Cal_4-1	-36.32%	11.0	-36.05%	10.9	-22.39%	4.8	-17.41%	3.7	-25.90%	7.5	-19.94%	5.6
	Cal_4-2	-21.88%	5.9	-15.31%	4.0	-34.55%	8.0	-29.32%	6.7	-35.48%	11.4	-31.50%	10.0
Cal_5	Cal_5-1	-13.34%	5.5	-12.71%	5.2	0.00%	0.0	3.85%	1.1	-15.66%	6.3	-12.16%	4.9
	Cal_5-2	-20.53%	7.6	-19.95%	7.3	-12.84%	3.9	-6.18%	1.8	-10.78%	4.7	-12.37%	5.4
Cal_6	Cal_6-1	-29.78%	11.0	-24.44%	8.9	20.62%	4.0	26.38%	5.1	23.39%	5.7	29.66%	7.1
	Cal_6-2	22.26%	5.1	29.22%	6.5	-5.42%	1.2	0.22%	0.0	-34.53%	13.7	-31.78%	12.5
Cal_7	Cal_7-1	-39.74%	26.2	-34.84%	22.6	-40.95%	19.4	-28.24%	12.9	-36.73%	22.3	-35.11%	21.2
	Cal_7-2	-34.22%	20.1	-31.53%	18.4	-33.70%	15.0	-21.25%	9.1	-34.02%	21.0	-32.53%	20.0
Cal_8	Cal_8-1	-29.10%	14.6	-21.13%	10.3	-38.65%	15.4	-27.29%	10.5	-30.10%	14.7	-28.58%	13.9
	Cal_8-2	-38.16%	19.9	-30.49%	15.5	-43.08%	17.8	-32.61%	13.0	-30.88%	15.6	-29.73%	15.0
Cal_9	Cal_9-1	-20.53%	10.3	-19.42%	9.7	-24.61%	9.2	-19.18%	7.0	-9.27%	4.1	-4.56%	2.0
	Cal_9-2	-11.19%	5.0	-10.10%	4.5	-23.32%	8.5	-17.96%	6.5	-16.22%	7.7	-8.78%	4.1
Cal_10	Cal_10-1	-18.25%	9.5	-15.91%	8.2	-28.52%	12.1	-26.19%	11.1	-4.40%	2.1	-1.04%	0.5
	Cal_10-2	-22.42%	12.0	-21.39%	11.4	-37.07%	17.2	-34.96%	16.1	-24.89%	14.2	-21.28%	12.0
Cal_11	Cal_11-1	-4.55%	3.3	-3.19%	2.3	-15.51%	10.0	-0.08%	0.0	-14.04%	10.8	-2.43%	1.8
	Cal_11-2	14.69%	9.1	0.26%	0.2	-21.55%	14.3	-0.89%	0.6	-9.93%	7.6	2.54%	1.9
Cal_12	Cal_12-1	-26.93%	12.1	-21.65%	9.6	-24.06%	7.8	-16.86%	5.4	4.10%	1.6	6.77%	2.5
	Cal_12-2	-2.44%	1.0	-1.45%	0.6	-27.12%	9.0	-22.30%	7.3	-30.20%	14.3	-28.78%	13.6
Cal_13	Cal_13-1	-11.19%	5.6	-5.07%	2.5	-17.93%	7.0	4.90%	1.8	-15.42%	8.0	-17.17%	8.9
	Cal_13-2	-11.63%	5.7	-12.26%	6.0	-15.60%	5.9	10.80%	3.8	-13.30%	6.8	-15.90%	8.2
Cal_14	Cal_14-1	31.94%	9.1	31.73%	9.0	53.79%	10.0	56.55%	10.4	11.93%	3.4	15.80%	4.5
	Cal_14-2	9.92%	2.8	11.00%	3.1	40.94%	7.9	42.73%	8.2	31.18%	8.8	33.26%	9.3
Cal_15	Cal_15-1	23.89%	8.3	32.57%	11.1	-21.56%	6.8	-17.83%	5.6	-16.36%	6.8	0.76%	0.3
	Cal_15-2	9.67%	3.4	21.49%	7.4	-2.68%	0.8	2.68%	0.8	6.63%	2.5	13.13%	4.9

ID	Name	AM				IP				PM			
		Initial		Final		Initial		Final		Initial		Final	
		Diff	GEH	Diff	GEH	Diff	GEH	Diff	GEH	Diff	GEH	Diff	GEH
Cal_16	Cal_16-1	8.62%	2.6	17.13%	5.1	-46.51%	16.9	-44.35%	16.0	-20.81%	7.2	-19.15%	6.6
	Cal_16-2	9.80%	2.6	18.94%	5.0	-33.25%	10.5	-28.83%	9.0	6.84%	2.2	9.43%	3.0
Cal_17	Cal_17-1	-12.88%	4.8	-3.26%	1.2	-50.07%	22.4	-40.70%	17.6	-11.51%	4.9	-12.15%	5.2
	Cal_17-2	-18.76%	9.2	-11.12%	5.3	-63.73%	36.9	-57.64%	32.6	-50.43%	30.2	-43.33%	25.4
Cal_18	Cal_18-1	-20.06%	6.5	-19.75%	6.4	-22.87%	5.8	-21.28%	5.3	-28.08%	9.3	-26.39%	8.7
	Cal_18-2	-33.25%	12.4	-36.25%	13.7	-27.73%	7.3	-25.21%	6.6	-29.26%	10.4	-28.98%	10.3
Cal_19	Cal_19-1	-2.31%	1.5	0.14%	0.1	-20.66%	11.4	-18.41%	10.1	-13.86%	9.8	-8.82%	6.2
	Cal_19-2	-4.71%	3.0	-0.41%	0.3	-21.28%	11.7	-19.03%	10.4	1.91%	1.2	9.41%	5.8
Cal_20	Cal_20-1	-32.50%	17.9	-29.22%	15.9	-37.73%	15.9	-30.41%	12.6	-23.54%	11.2	-16.69%	7.8
	Cal_20-2	-29.83%	14.4	-24.09%	11.5	-44.03%	19.5	-38.94%	17.0	-28.89%	14.8	-25.78%	13.1
Cal_21	Cal_21-1	10.25%	5.0	10.72%	5.2	-16.36%	7.7	-10.04%	4.7	0.87%	0.5	1.94%	1.1
	Cal_21-2	-9.80%	6.0	-10.41%	6.4	-15.34%	7.8	-9.76%	4.9	-8.16%	5.0	-10.34%	6.3
Cal_22	Cal_22-1	-14.75%	8.0	-12.72%	6.9	-23.31%	11.2	-22.07%	10.5	-15.43%	8.0	-11.20%	5.7
	Cal_22-2	-38.39%	19.2	-32.04%	15.7	-25.76%	11.8	-24.18%	11.0	-1.56%	0.8	-0.04%	0.0
Cal_23	Cal_23-1	-6.54%	3.0	-5.42%	2.5	-18.38%	6.8	-17.82%	6.6	-23.35%	11.7	-23.76%	12.0
	Cal_23-2	-36.71%	21.7	-37.16%	22.0	-19.02%	7.1	-18.94%	7.0	-14.82%	7.2	-13.87%	6.7
Cal_24	Cal_24-1	1.73%	1.2	-10.99%	7.5	-29.64%	19.8	-4.46%	2.8	-20.39%	15.8	-9.95%	7.5
	Cal_24-2	-17.48%	12.8	-14.85%	10.8	-28.00%	18.4	-4.63%	2.9	-16.38%	12.1	-5.25%	3.8
Cal_25	Cal_25-1	-23.52%	10.3	-20.82%	9.1	-38.98%	14.5	-36.22%	13.4	-21.65%	10.1	-19.54%	9.1
	Cal_25-2	-0.79%	0.3	1.05%	0.4	-14.81%	4.7	-11.05%	3.5	-27.80%	13.1	-27.02%	12.7
Cal_26	Cal_26-1	-12.78%	5.7	2.77%	1.2	-53.73%	25.6	-2.10%	0.9	-43.95%	25.7	-42.27%	24.6
	Cal_26-2	-43.09%	24.6	-27.24%	14.8	-49.68%	22.7	-3.24%	1.3	-33.99%	18.2	-26.02%	13.6
Cal_27	Cal_27-1	-26.56%	10.1	-26.08%	9.9	-45.24%	14.3	-41.52%	13.0	-55.13%	26.8	-52.04%	25.0
	Cal_27-2	-33.21%	13.2	-30.69%	12.1	-36.15%	10.7	-29.36%	8.5	-13.83%	5.1	-14.23%	5.2
Cal_28	Cal_28-1	-37.10%	20.6	-34.08%	18.8	-24.85%	9.8	-20.10%	7.8	-18.52%	9.1	-15.74%	7.7
	Cal_28-2	-16.69%	8.3	-15.24%	7.6	-21.92%	8.4	-18.70%	7.1	-23.70%	11.9	-14.40%	7.1
Cal_29	Cal_29-1	22.19%	8.3	28.39%	10.5	-5.63%	1.9	-1.22%	0.4	-5.61%	2.5	-0.96%	0.4
	Cal_29-2	3.51%	1.4	5.95%	2.4	-7.21%	2.4	-4.08%	1.3	3.05%	1.3	7.52%	3.1

ID	Name	AM				IP				PM			
		Initial		Final		Initial		Final		Initial		Final	
		Diff	GEH	Diff	GEH	Diff	GEH	Diff	GEH	Diff	GEH	Diff	GEH
Cal_30	Cal_30-1	-52.23%	21.1	-51.90%	21.0	-57.07%	16.7	-50.73%	14.6	-31.79%	11.0	-32.19%	11.2
	Cal_30-2	-45.18%	17.4	-41.70%	15.9	-63.90%	20.7	-60.67%	19.4	-55.89%	23.2	-51.13%	20.9
Cal_31	Cal_31-1	11.51%	8.8	6.85%	5.3	-23.23%	17.2	-11.57%	8.3	8.01%	6.2	0.85%	0.7
	Cal_31-2	-2.68%	2.2	-4.45%	3.7	-27.55%	20.8	-12.89%	9.3	-0.92%	0.8	0.43%	0.4
Cal_32	Cal_32-1	-6.89%	3.2	-2.38%	1.1	-32.93%	12.8	-20.02%	7.5	0.07%	0.0	14.83%	5.5
	Cal_32-2	2.34%	0.8	-5.17%	1.8	-29.01%	11.1	-14.31%	5.3	-7.03%	3.3	-7.98%	3.7
Val_1	Val_1-1	-17.64%	9.3	-17.28%	9.1	-12.62%	4.7	-2.13%	0.8	-12.27%	6.1	-13.10%	6.5
	Val_1-2	-22.16%	11.3	-21.77%	11.1	-21.41%	8.4	-10.19%	3.9	-10.10%	5.0	-8.40%	4.1
Val_2	Val_2-1	-9.52%	4.4	-8.19%	3.8	-32.65%	14.7	-30.64%	13.7	-32.77%	18.8	-25.34%	14.2
	Val_2-2	-26.27%	12.9	-22.49%	10.9	-26.39%	11.3	-23.33%	9.9	-10.98%	5.3	-8.92%	4.3
Val_3	Val_3-1	-22.26%	10.3	-16.58%	7.5	-28.72%	9.6	-22.58%	7.4	-1.36%	0.5	2.08%	0.8
	Val_3-2	-8.50%	3.3	5.25%	2.0	-30.22%	10.4	-25.75%	8.7	-26.68%	12.8	-25.58%	12.3
Val_4	Val_4-1	-16.65%	7.2	-14.14%	6.1	-29.59%	10.7	-18.53%	6.5	-17.51%	7.3	-17.45%	7.3
	Val_4-2	-35.68%	17.2	-22.52%	10.5	-30.06%	10.8	-15.22%	5.2	-6.34%	2.5	-2.88%	1.1
Val_5	Val_5-1	-0.88%	0.5	-2.57%	1.6	-8.60%	3.9	1.20%	0.5	-14.49%	7.5	-17.43%	9.1
	Val_5-2	4.71%	2.0	-3.16%	1.4	-21.11%	9.3	-20.19%	8.9	-13.54%	8.0	-14.15%	8.4
Val_6	Val_6-1	-35.49%	18.1	-28.73%	14.4	-6.47%	2.0	-5.11%	1.5	15.32%	5.2	17.66%	6.0
	Val_6-2	11.37%	3.8	19.15%	6.3	-24.81%	8.7	-23.89%	8.4	-28.29%	14.0	-18.54%	8.9
Val_7	Val_7-1	-15.73%	8.9	-5.03%	2.8	-30.47%	15.4	-13.90%	6.7	-20.07%	12.4	-19.54%	12.0
	Val_7-2	-21.48%	13.6	-14.64%	9.1	-34.39%	18.3	-20.30%	10.3	-27.35%	17.9	-21.28%	13.7
Val_8	Val_8-1	-9.95%	4.4	-8.08%	3.5	-27.69%	10.7	-20.57%	7.8	-39.57%	22.0	-38.65%	21.5
	Val_8-2	-26.77%	12.3	-10.95%	4.8	-28.62%	10.8	-17.56%	6.4	-11.97%	5.2	-8.61%	3.7
Val_9	Val_9-1	-30.41%	15.0	-24.15%	11.7	-12.55%	4.2	-9.07%	3.0	2.91%	1.2	6.37%	2.7
	Val_9-2	-6.65%	3.0	-1.66%	0.7	-28.01%	10.4	-25.42%	9.4	-25.41%	12.6	-14.22%	6.8
All	**All**	**-13.02%**		**-10.75%**		**-26.56%**		**-15.99%**		**-16.11%**		**-12.54%**	
Fail		**66**	**62**	**62**	**59**	**74**	**73**	**65**	**59**	**67**	**65**	**61**	**61**
Pass		**16**	**20**	**20**	**23**	**8**	**9**	**17**	**23**	**15**	**17**	**21**	**21**
%Pass		**20%**	**24%**	**24%**	**28%**	**10%**	**11%**	**21%**	**28%**	**18%**	**21%**	**26%**	**26%**

Table 10-2: Screenline Comparison for Initial and Prior Matrices

The data in the above table highlights the following key points:

- The prior matrix adjustments generally improve the prior matrices based on the comparison with observed flows across screenlines. For example, for the final prior matrices 28% of screenlines have a GEH of less than 5 in the interpeak compared to 11% with the initial prior matrices; and

- Traffic flows are low overall across screenlines (e.g. 13% lower in the AM peak) and generally low across most individual screenlines in the initial prior matrices, which is improved for all three time periods in the final prior matrices, although still low relative to observed flows.

As a further test of the effect of matrix adjustments on trip length distribution, a series of plots have been produced comparing trip length distribution for the initial and final prior matrices, for all car user classes, which are shown in Appendix P. These plots illustrate that there is relatively little change in the trip length distribution and therefore that the effects of adjustments on trip patterns are minimal for cars. As an example, plots showing trip length distribution change for UC1 AM and UC1 PM are shown in Figure 10-1 and Figure 10-2 on the next page.

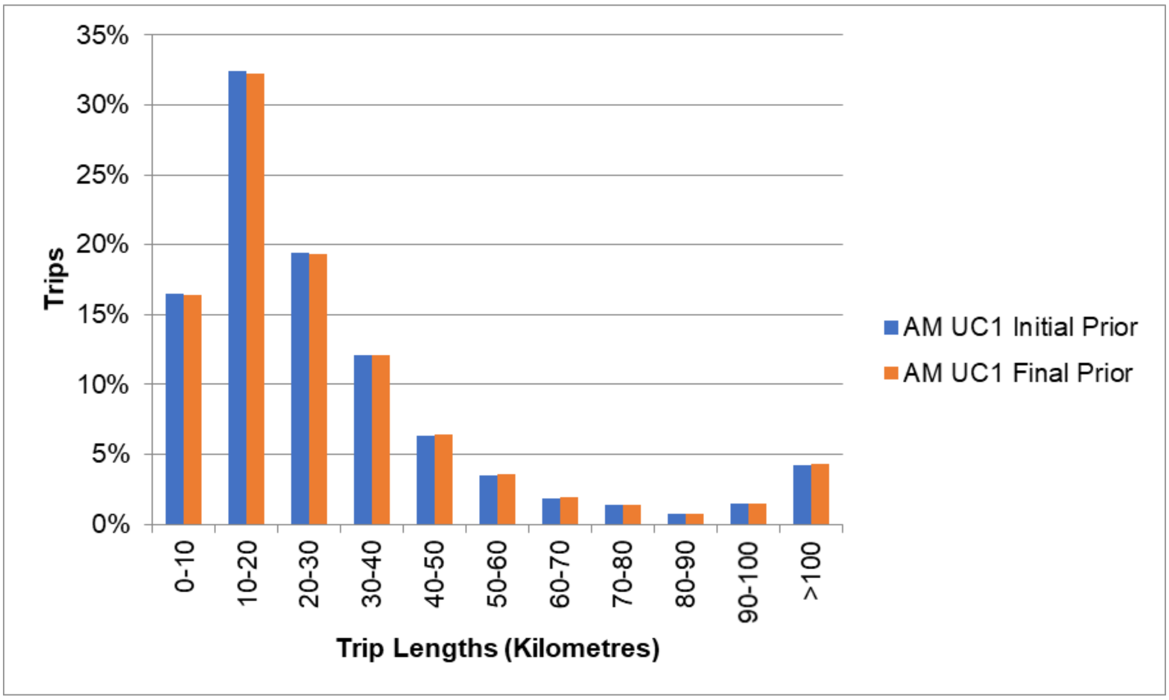


Figure 10-1: Matrix Trip Length Changes, UC1 AM

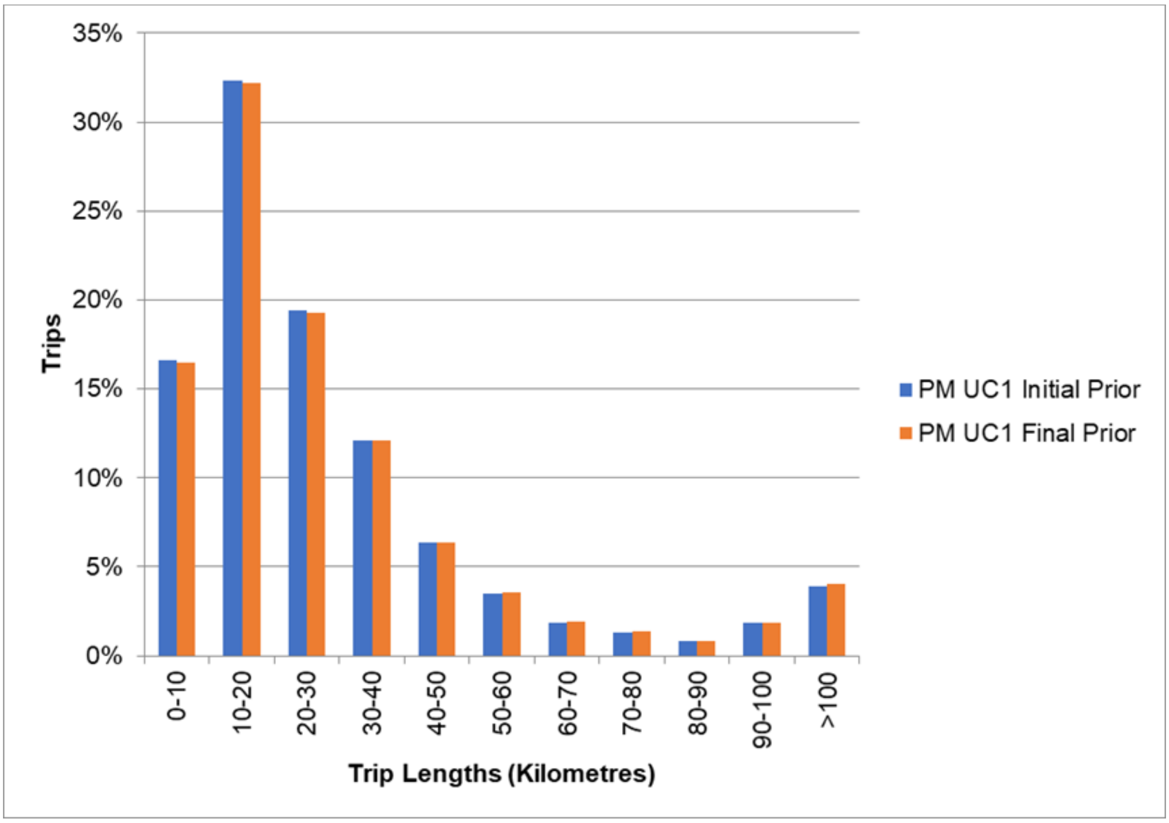


Figure 10-2: Matrix Trip Length Changes, UC1 PM

Adjustments were made for cars only. These adjusted car matrices were taken as 'final prior matrices' for matrix estimation. The matrix estimation process is described in the following section.

10.2 Matrix Estimation

After an initial assignment and refining of the modelled network, the trip matrices underwent a process of 'matrix estimation' whereby trip matrices were adjusted such that the resulting assigned flows better represented current conditions. The "TFlowFuzzy" module within VISUM was used for this process. The process of matrix estimation in general is well understood within the modelling community and will not be expanded upon here. The VISUM manual contains details of the specifics of the TFlowFuzzy process, but in principal it is much the same as any other matrix estimation process in any other transport modelling package.

The available count data is given for cars, LGVs, and HGVs and matrix estimation was undertaken for those vehicle classes separately. With specific reference to car trips, matrix estimation was run on the three user class matrices (commute, business, and other) jointly in a single process. This was done using the modelling procedure for matrix estimation which has the capability to split the car counts into three user class proportions based on the assigned user class volumes on links. It is important when running matrix estimation processes that the 'prior' (to estimation) trip matrices are not distorted such that the underlying trip patterns in the 'post' matrices are altered. To test to what extent this altering process has occurred the guidelines set out within Table 5 of TAG unit M3-1 have been applied to the prior and post-ME matrices, as detailed below in Table 10-3 below.

Measure	Significance Criteria
Matrix zonal cell values	Slope within 0.98 and 1.02 Intercept near zero R^2 in excess of 0.95

Measure	Significance Criteria
Matrix zone trip ends	Slope within 0.99 and 1.01 Intercept near zero R^2 in excess of 0.98
Trip length distributions	Means within 5% Standard deviation within 5%
Sector-to-sector level matrices	Differences within 5%

Table 10-3: Significance of Matrix Estimation Changes

The significance of matrix estimation for each measure detailed in the above table is described in section 10.2.2 to 10.2.5.

10.2.1 Matrix Totals

There is no current guidance set out in TAG unit M 3.1 on the acceptability of the amount of change brought about by matrix estimation to the matrix totals. A comparison of the matrix totals before and after the application of matrix estimation to show the impact of matrix estimation is shown in Table 10-4:

Vehicle Class	AM			IP			PM		
	Prior	Post ME	% Diff	Prior	Post ME	% Diff	Prior	Post ME	% Diff
UC1	167,062	170,587	2.07%	47,050	49,198	4.37%	155,718	159,882	2.60%
UC2	25,974	26,819	3.15%	17,564	18,584	5.49%	25,819	26,899	4.02%
UC3	205,070	208,711	1.74%	149,696	156,619	4.42%	223,923	229,003	2.22%
LGV	576,358	575,486	-0.15%	555,261	555,887	0.11%	460,339	459,008	-0.29%
HGV	275,258	272,451	-1.03%	263,319	260,980	-0.90%	173,252	171,408	-1.08%
All Cars	398,106	406,117	**1.97%**	214,311	224,402	**4.50%**	405,460	415,783	**2.48%**
All Vehicles	1,249,723	1,254,055	**0.35%**	1,032,890	1,041,269	**0.80%**	1,039,051	1,046,199	**0.68%**

Table 10-4: Comparison of Matrix Totals (Prior vs Post-ME)

Table 10-4 shows that, at a matrix total level across all vehicle classes, changes in the number of trips in the matrix are within (or close) to 5% for all vehicle types. This demonstrates that matrices post estimation are not significantly altered in terms of the total number of trips.

10.2.2 Matrix Zonal Cell Value Changes

The graphs in Figure 10-3 to Figure 10-8 show, for each time period and vehicle type in terms of cars and all vehicles, the cell values of the prior matrix plotted (on the horizontal axis) against the values in the same cell of the post matrix (on the vertical axis). Intrazonal trips are excluded from these graphs. A trend line with equation and R^2 value has also been plotted. Graphs for each separate highway user class are presented in Appendix F.

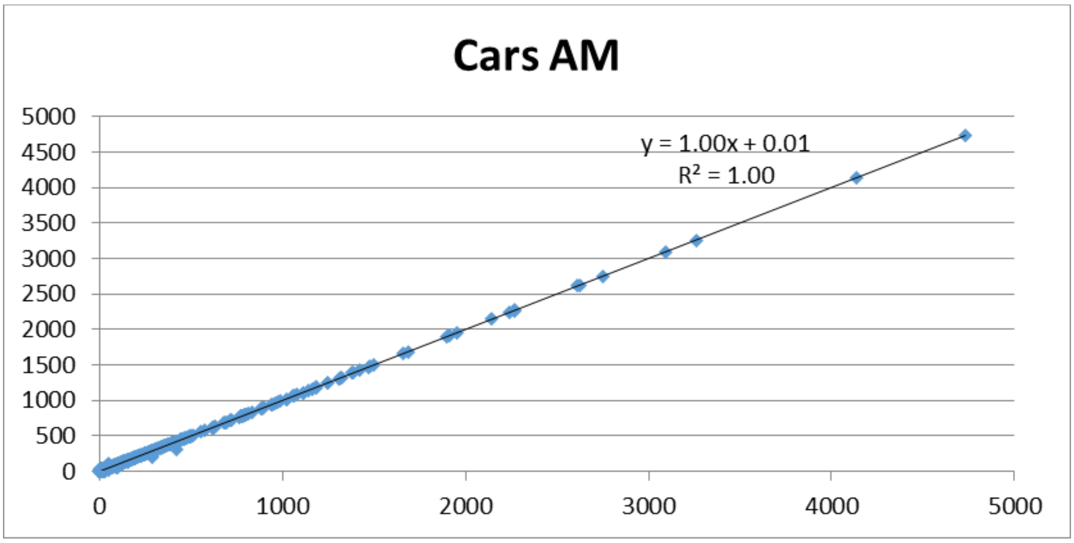


Figure 10-3: Cell Value of Prior Matrix Against Post-ME Matrix, Cars AM

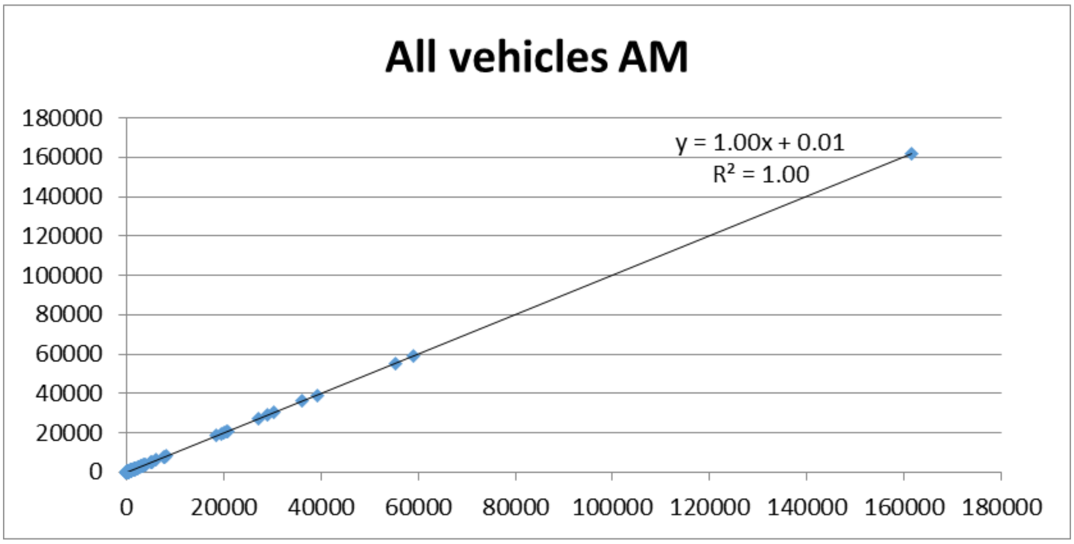


Figure 10-4: Cell Value of Prior Matrix Against Post-ME Matrix, All Vehicles AM

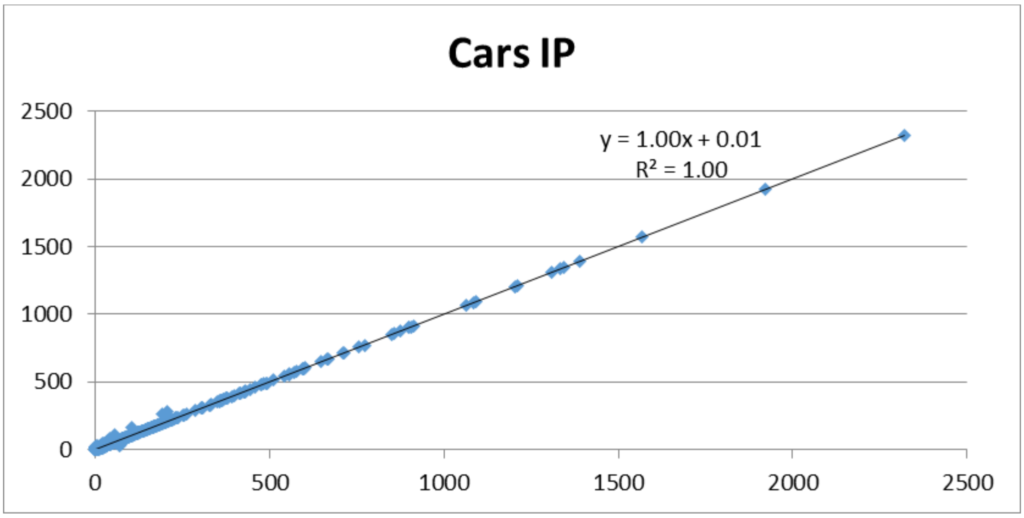


Figure 10-5: Cell Value of Prior Matrix Against Post-ME Matrix, Cars IP

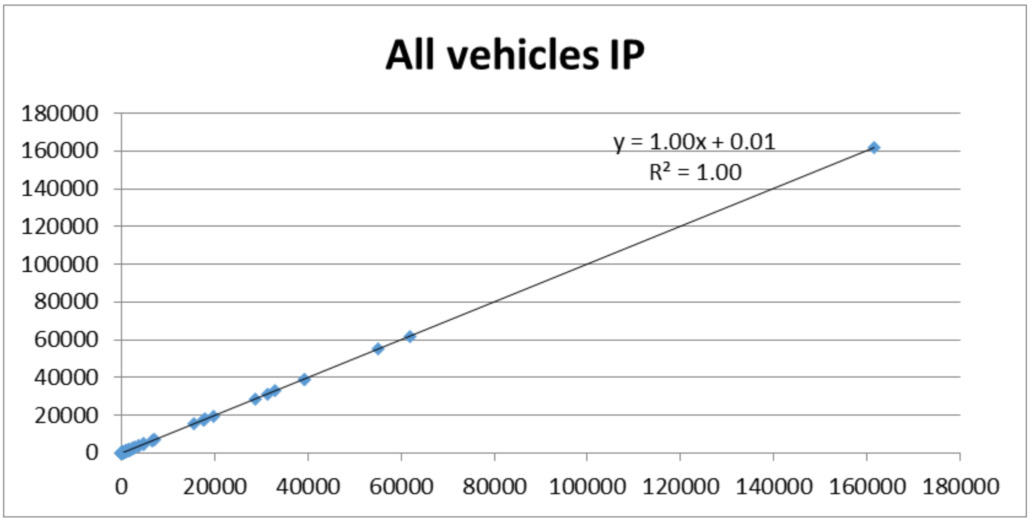


Figure 10-6: Cell Value of Prior Matrix Against Post-ME Matrix, All Vehicles IP

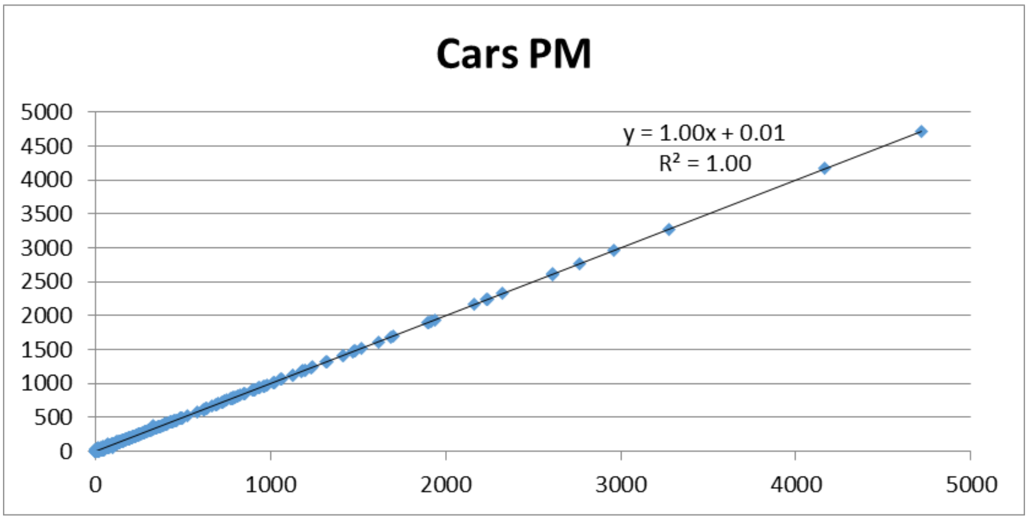


Figure 10-7: Cell Value of Prior Matrix Against PostME Matrix, Cars PM

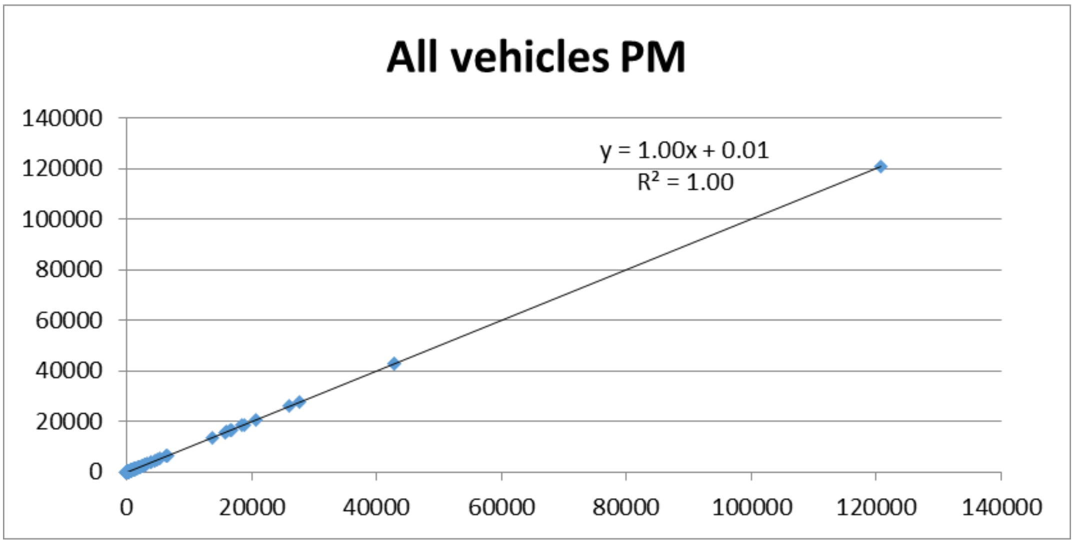


Figure 10-8: Cell Value of Prior Matrix Against Post-ME Matrix, All Vehicles PM

The guidance states that the trend line must have a gradient between 0.98 and 1.02, an intercept close to zero, and an R^2 value exceeding 0.95. Table 10-5 below summarises the data in the graphs and demonstrates that these conditions are met for cars and all vehicles in the AM, IP, and PM peak models. The table also includes data on LGVs and HGVs, and again, they meet the conditions.

Zonal Cell Value Summary	AM			IP			PM		
	R^2	Slope	Intercept	R^2	Slope	Intercept	R^2	Slope	Intercept
All vehicles	1.00	1.00	0.01	1.00	1.00	0.01	1.00	1.00	0.01
Cars	1.00	1.00	0.01	1.00	1.00	0.01	1.00	1.00	0.01
Car C	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.01
Car EB	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00
Car O	1.00	1.00	0.00	1.00	1.00	0.01	1.00	1.00	0.01
LGV	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00
HGV	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00

Table 10-5: Zonal Cell Value Summary

10.2.3 Matrix Trip End Changes

The check on how much matrix trip ends have been affected by matrix estimation is similar to the check on individual cell values in that the prior and post trip ends must be plotted on a graph and a trend line added. The graphs showing these for cars and all vehicles are below in Figure 10-9 to Figure 10-14. A full set of graphs by individual user class can be found in Appendix G. Intrazonal trips have been excluded from the trip end totals.

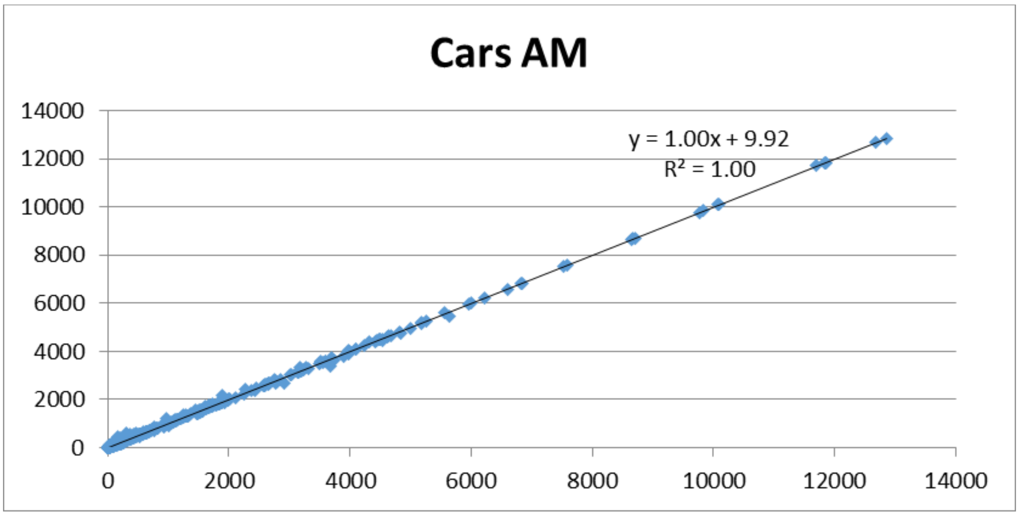


Figure 10-9: Matrix Trip End Changes, Cars Only AM

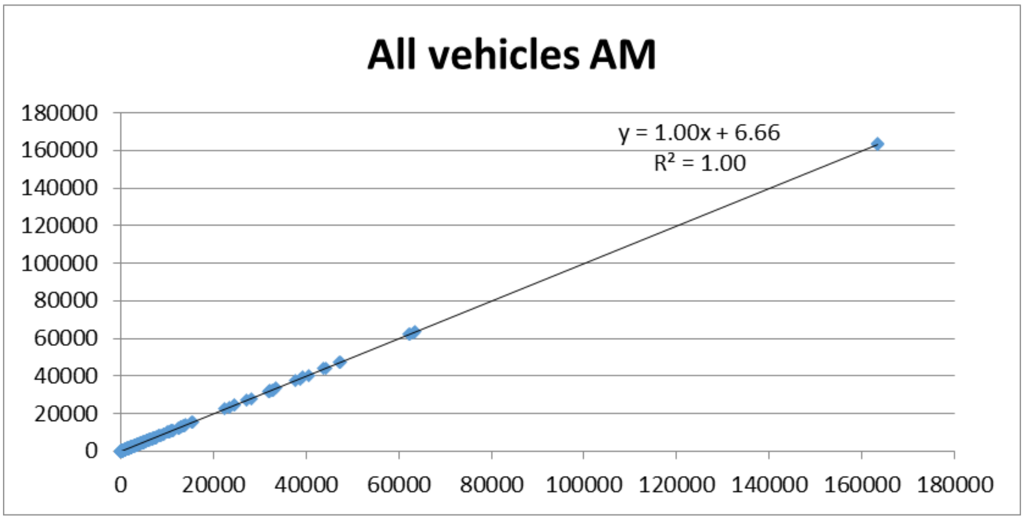


Figure 10-10: Matrix Trip End Changes, All Vehicles AM

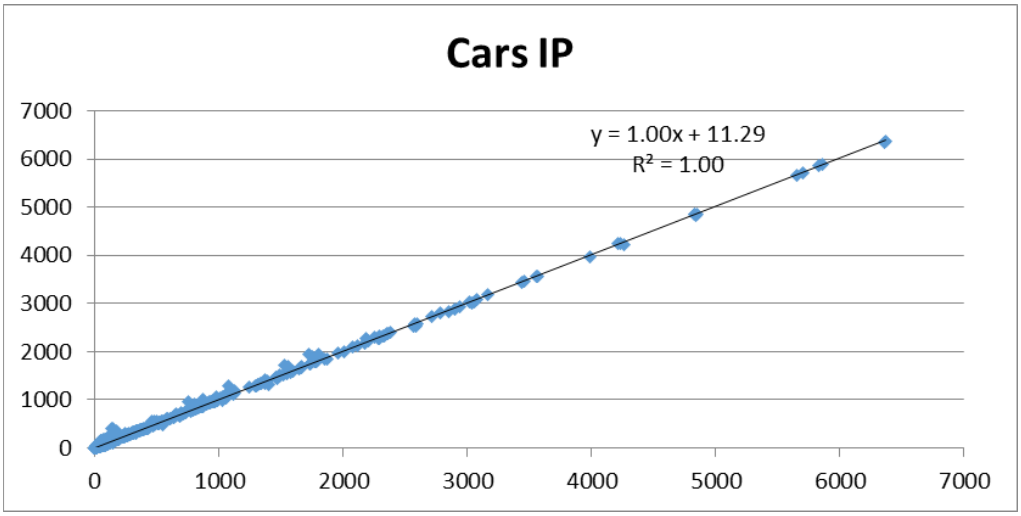


Figure 10-11: Matrix Trip End Changes, Cars Only IP

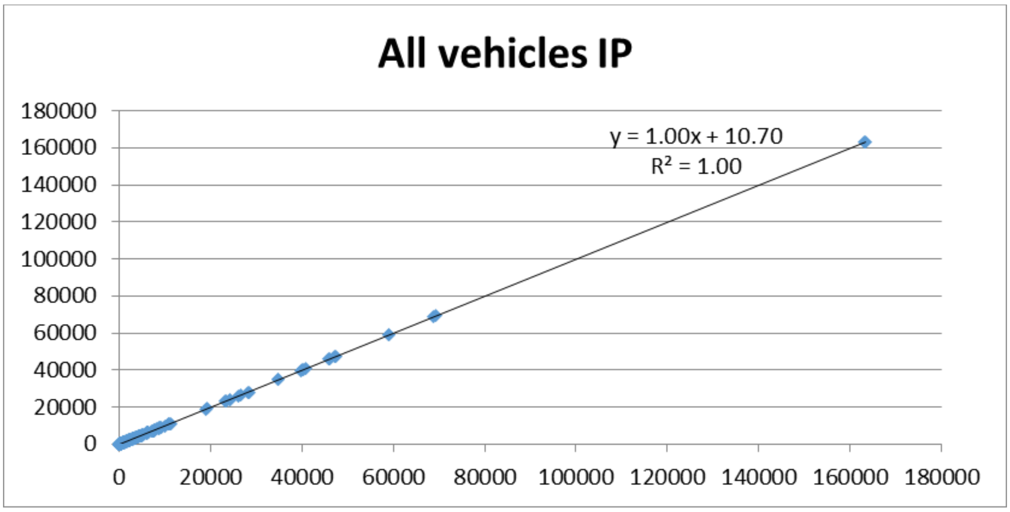


Figure 10-12: Matrix Trip End Changes, All Vehicles IP

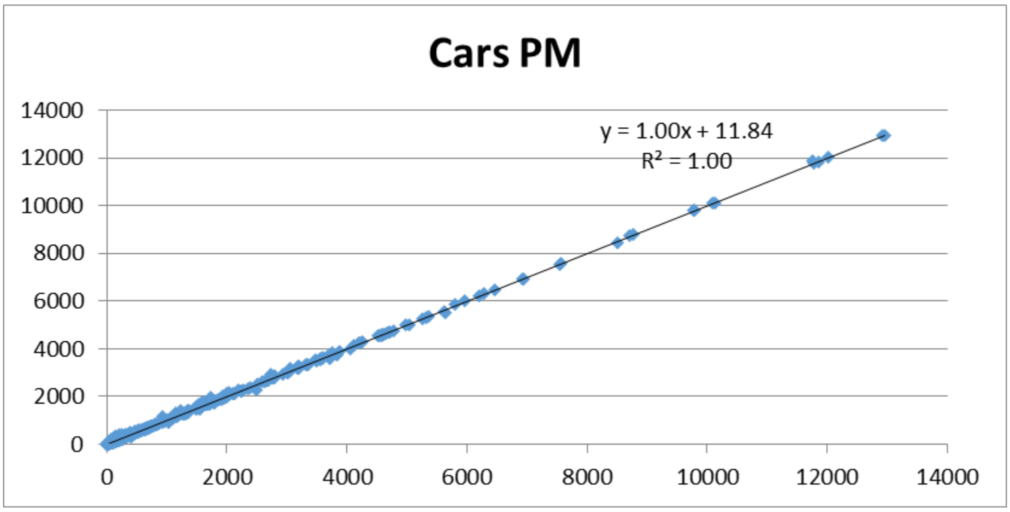


Figure 10-13: Matrix Trip End Changes, Cars Only PM

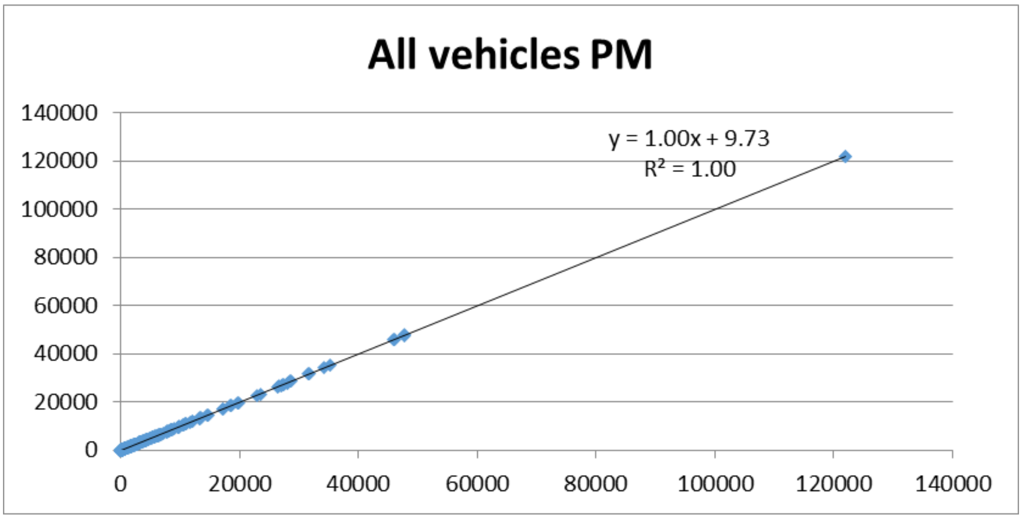


Figure 10-14: Matrix Trip End Changes, All Vehicles PM

The guidance on these trend lines is:

- Slope to be within 0.99 and 1.01;
- Intercept near zero; and
- R^2 in excess of 0.98.

As with the test on cell values, the R^2 and slope values for all highway user classes meet the TAG criteria stated above, which can be seen in Table 10-6 below. Although the intercept is further from the criteria than for matrix cell values, given the size of the trip end values in the regression graph, these intercepts are still relatively close to zero.

Trip End Summary	AM			IP			PM		
	R^2	Slope	Intercept	R^2	Slope	Intercept	R^2	Slope	Intercept
All vehicles	1.00	1.00	6.66	1.00	1.00	10.70	1.00	1.00	9.73
Car	1.00	1.00	9.92	1.00	1.00	11.29	1.00	1.00	11.84
Car C	1.00	1.00	4.32	1.00	1.00	2.39	1.00	1.00	4.72
Car EB	1.00	1.00	1.00	1.00	1.00	1.07	1.00	1.00	1.13
Car O	1.00	1.00	4.56	1.00	1.00	7.80	1.00	1.00	5.91
LGV	1.00	1.00	-0.74	1.00	1.00	0.88	1.00	1.00	-1.33
HGV	1.00	1.00	-2.81	1.00	1.00	-2.34	1.00	1.00	-1.85

Table 10-6: Trip End Summary

10.2.4 Trip Length Distributions

For trip length distributions, the guidelines in TAG suggest that both the mean and standard deviation of the post-ME trip lengths must not differ by more than 5% from those of the prior matrices. The mean and standard deviations for all of the matrices (not including intrazonal trips) are summarised in Table 10-7 (below) and Table 10-8 (on the next page).

Time and Trip Type	All Vehicles - Prior	All Vehicles – Post-ME	% Change
AM Average Trip Length	33.72	33.16	-1.66
AM Standard Deviation	77.32	76.63	-0.89
IP Average Trip Length	32.61	31.97	-1.98
IP Standard Deviation	80.22	79.29	-1.17
PM Average Trip Length	34.25	33.68	-1.66
PM Standard Deviation	76.10	75.33	-1.01

Table 10-7: Table of Trip Lengths and Standard Deviations (KM), All Vehicles

Time and Trip Type	Car - Prior	Car- Post-ME	% Change
AM Average Trip Length	37.83	37.33	-1.33
AM Standard Deviation	63.99	63.62	-0.58
IP Average Trip Length	43.30	41.83	-3.39
IP Standard Deviation	74.99	73.42	-2.08
PM Average Trip Length	39.44	38.74	-1.77
PM Standard Deviation	67.22	66.34	-1.32

Table 10-8: Table of Trip Lengths and Standard Deviations (KM), Car

The tables above show that the change in average and standard deviation trip lengths is minimal and well within guidelines for cars and all vehicles across all time periods.

As a further test of the effect of matrix estimation on trip length distribution, a series of plots have been produced comparing trip length distribution for the pre and post estimated matrices for all car user classes and for HGVs and LGVs. These can be found in Appendix O. These plots illustrate that there is relatively little change in the trip length distribution and therefore that the effects of matrix estimation on trip patterns are minimal for cars, LGVs and HGVs. As an example, plots showing trip length distribution change for UC1 AM and UC1 PM are shown in Figure 10-15 (below) and Figure 10-16 (on the next page):

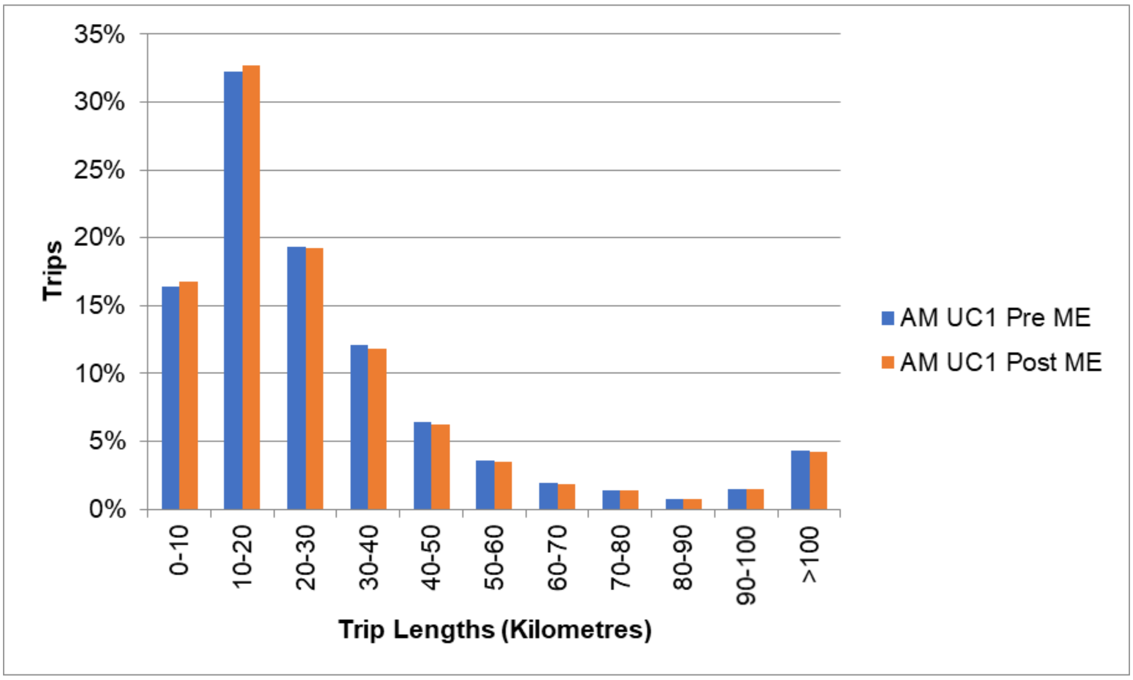


Figure 10-15: Matrix TLD Changes, UC1 AM

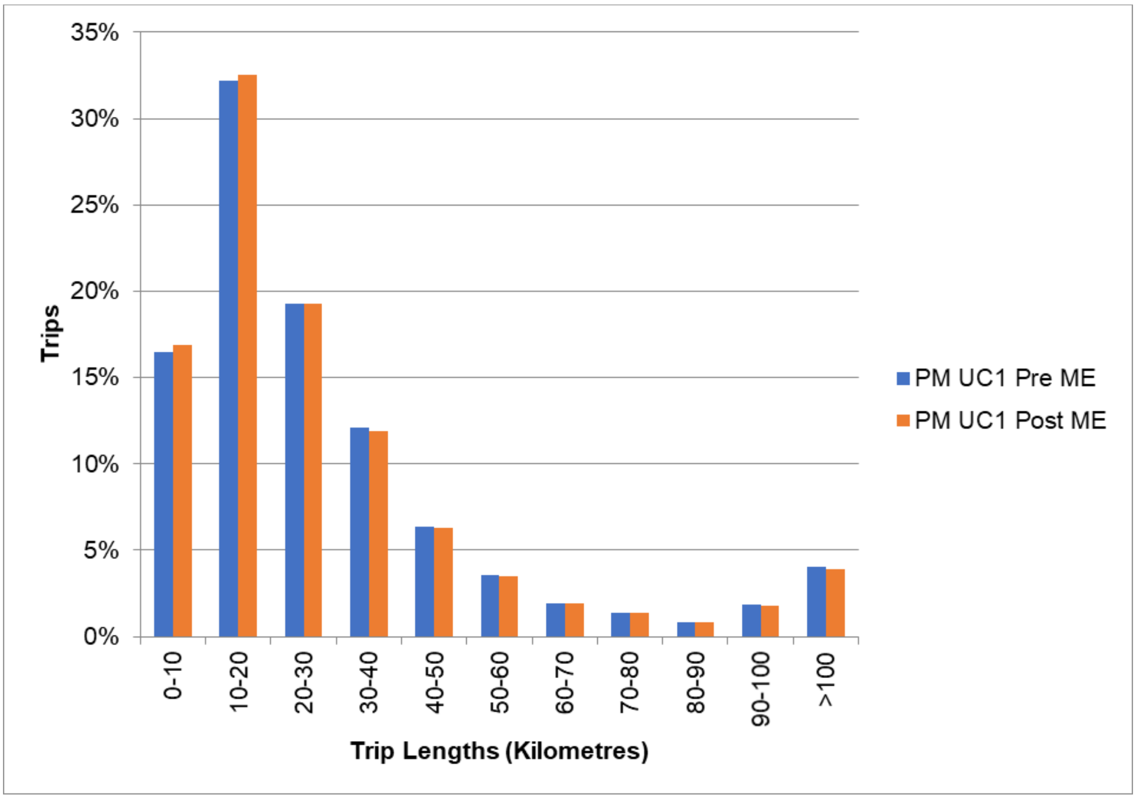


Figure 10-16: Matrix TLD Changes, UC1 PM

10.2.5 Sector-to-Sector Movements

Finally, TAG recommends a check on the matrix cells on a sector basis. The guidelines state that trips should not change by more than 5%. Using the sectors specified in 4.3.1 and in Figure 10-17 on the next page, the percentage and absolute change for each user class and each sector-to-sector movement as a result of matrix estimation are shown in Appendix H and Appendix I respectively. Tables showing the GEH for the change between Prior and Post ME matrices are also shown for all user classes in Appendix J.

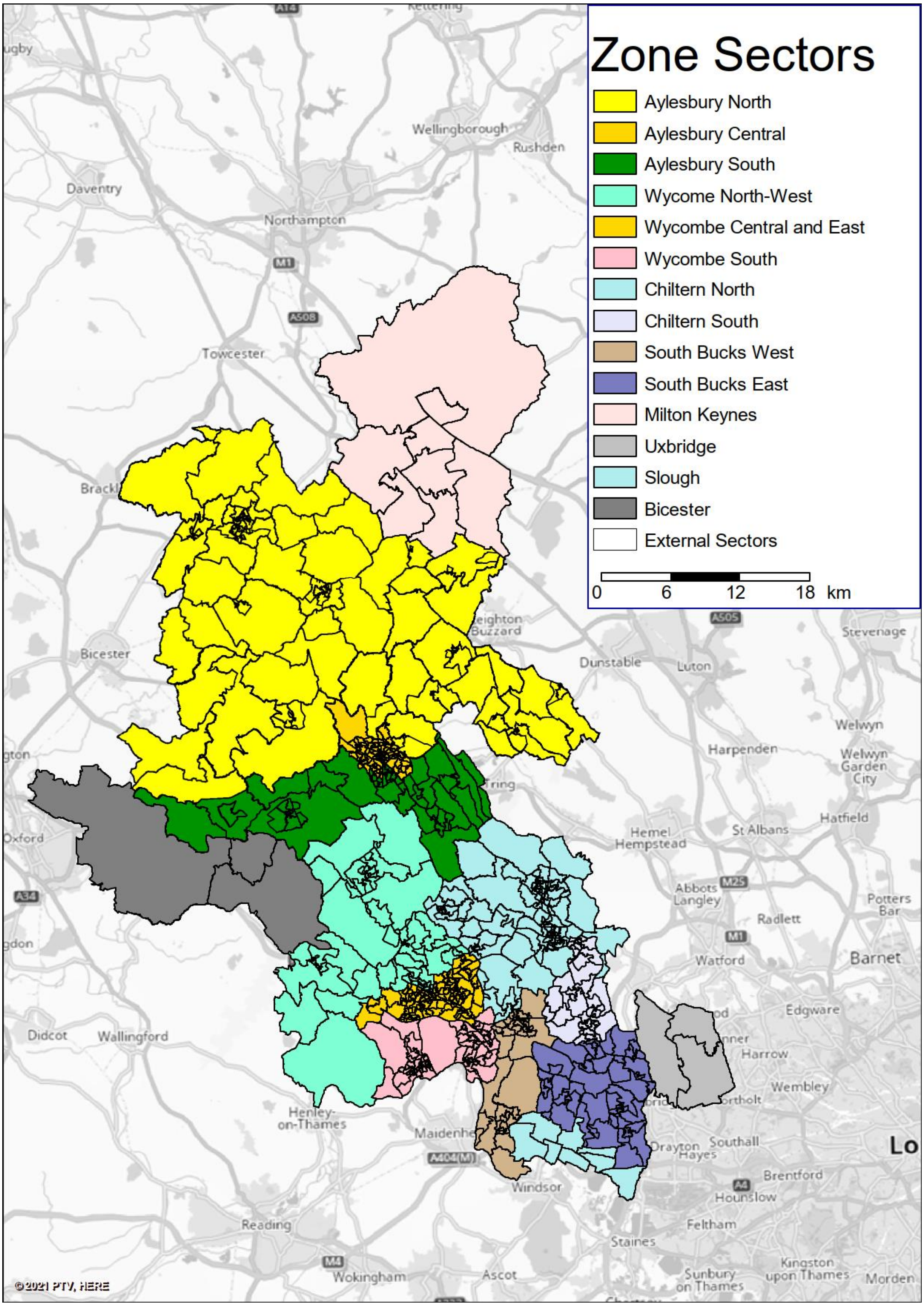


Figure 10-17: BSTM Model Zone Sectors

The tables in Appendix H show that some of the percentage changes of the sector-to-sector movements for cars and all vehicles exceed the 5% criteria. However, according to guidelines, the criteria is to be applied regardless of the number of trips in the sector. For sector-to-sector movements with relatively few trips it is more difficult to stay within the 5% criteria, although this could have been achieved if larger sectors were selected. Noting that in some cases there are relatively few trips, changes expressed as GEH values provide greater insight into the significance of some of these percentage changes. As can be seen from the tables in Appendix J, some sectors have changes in GEH values that are within 5, though some are more than 5, but changes overall provide assurance that matrix estimation is not significantly changing the underlying trip patterns. As an example, Table 10-9 below provides a summary of the range of GEH statistics in the sectored matrices for all car user classes for each time period:

User Class	GEH	AM	IP	PM
Commute	< 5	99.1%	99.7%	99.5%
	5 to 10	0.9%	0.3%	0.5%
	> 10	0.0%	0.0%	0.0%
Employers' Business	< 5	100.0%	100.0%	100.0%
	5 to 10	0.0%	0.0%	0.0%
	> 10	0.0%	0.0%	0.0%
Other	< 5	99.5%	99.2%	99.3%
	5 to 10	0.5%	0.7%	0.7%
	> 10	0.0%	0.1%	0.0%

Table 10-9: Matrix Estimation Changes – Sector-to-Sector Movements in GEH Range

11. Assignment Calibration and Validation

11.1 Convergence

A summary of the assignment method used is given in section 4.8. For ease of reference, the convergence criteria are repeated below in Table 11-1.

Measure of Convergence	Base Model Acceptable Values
Delta and %GAP	Less than 0.1% or at least stable with convergence fully documented and all other criteria met
Percentage of links with flow change (P) < 1%	Four consecutive iterations greater than 98%
Percentage of links with cost change (P2) < 1%	Four consecutive iterations greater than 98%

Table 11-1: Convergence Criteria

Convergence statistics for the final base model are shown in Table 11-2 below:

Time Period	Iteration Loop		Proximity Indicator: Gap (%)	Percentage of Links with Flow Change < 1%	Percentage of Links with Cost Change < 1%
AM	Final - 3	15	0.00010	99.12%	99.29%
	Final - 2	16	0.00009	99.27%	99.46%
	Final - 1	17	0.00009	99.28%	99.45%
	Final	18	0.00009	99.63%	99.52%
IP	Final - 3	9	0.00005	99.61%	99.88%
	Final - 2	10	0.00005	99.82%	99.93%
	Final - 1	11	0.00005	99.83%	99.95%
	Final	12	0.00005	99.85%	99.97%
PM	Final - 3	12	0.00014	99.11%	99.51%
	Final - 2	13	0.00013	99.21%	99.57%
	Final - 1	14	0.00013	98.87%	99.41%
	Final	15	0.00013	98.88%	99.54%

Table 11-2: Details of ICA Assignment

The results above show that the model has a level of convergence in line with the guidance from TAG.

11.2 Screenlines

All the counts (calibration and validation) are arranged along screenlines. TAG has a separate criterion for total screenline flows, which is that total modelled flows on all links crossing a screenline must be within 5% of the observed totals.

The calibration and validation screenlines used and the location of the counts used for these screenlines are illustrated in Figure 11-1:

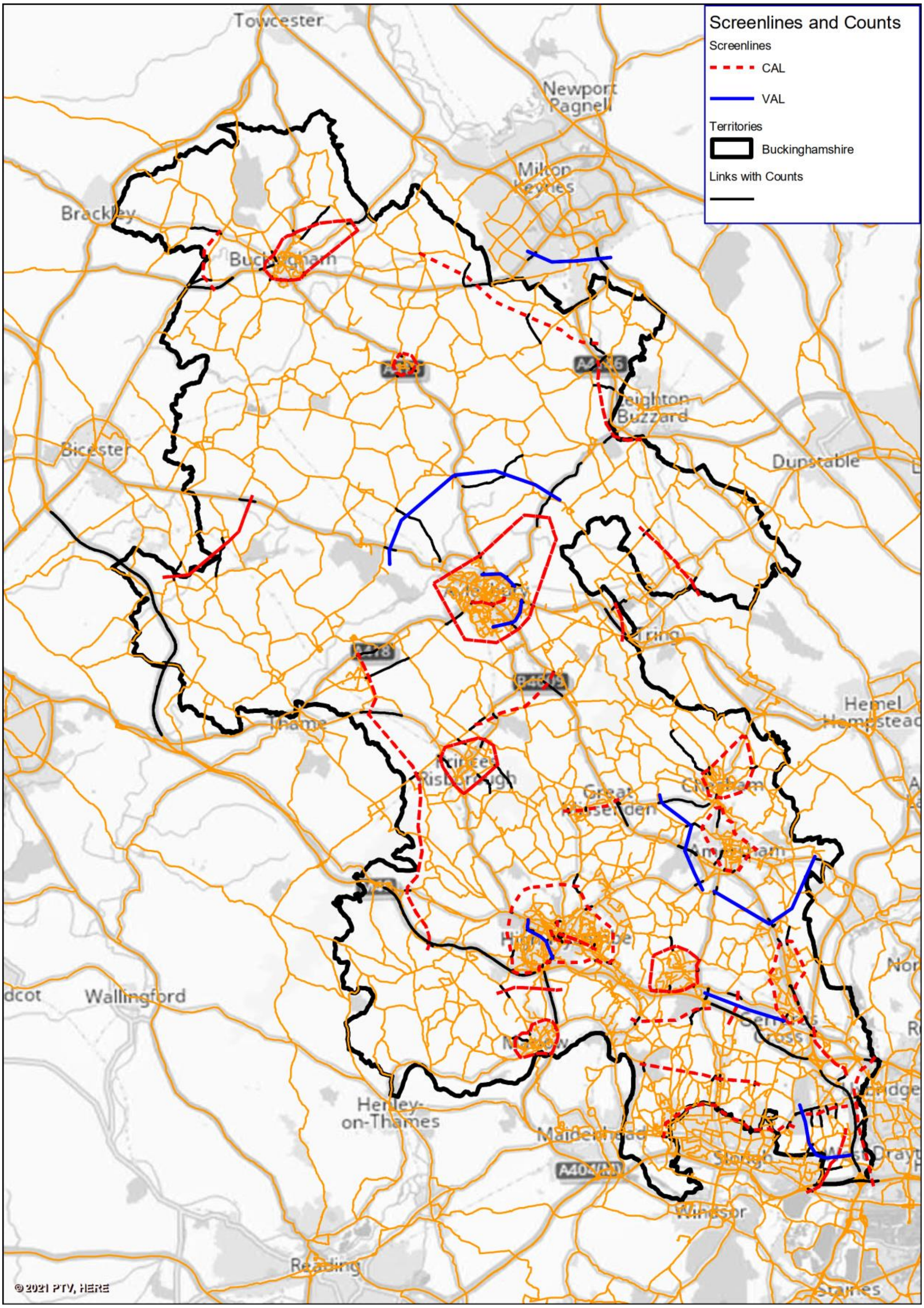


Figure 11-1: Calibration and Validation Screenlines

11.3 Count Calibration

The counts used for calibration are those on the calibration screenlines in Figure 11-1. The performance of the model in terms of comparisons with count data are measured in two ways. The first is GEH statistic and the second is made by reference to Table 3-2 in Section 3.

TAG advises that the practitioner should aim to reach a state where at least 85% of modelled links have a GEH of less than 5 or satisfy the criterion in Table 3-2. There were 298 calibration counts used in the base year model. The comparison of modelled flows against these calibration counts are summarised below in Table 11-3:

Measure	AM Peak			
	Cars	LGV	HGV	Total Vehicles
No. links with modelled flows meeting criteria	258/298	298/298	298/298	250/298
% links with modelled flows meeting criteria	87%	100%	100%	84%
Measure	**Interpeak**			
	Cars	**LGV**	**HGV**	**Total Vehicles**
No. links with modelled flows meeting criteria	288/298	298/298	298/298	282/298
% links with modelled flows meeting criteria	97%	100%	100%	95%
Measure	**PM Peak**			
	Cars	**LGV**	**HGV**	**Total Vehicles**
No. links with modelled flows meeting criteria	263/298	298/298	298/298	254/298
% links with modelled flows meeting criteria	88%	100%	100%	85%

Table 11-3: Calibration Link Flow Comparison with Observed Flows (Cars, LGV, HGV and Total Vehicles)

The table above shows that the 85% criterion for calibration counts is exceeded for almost all vehicle classes across all time periods. This is encouraging as it gives confidence that the model is representing base year traffic flows realistically. A full breakdown of the comparison at the individual count level is included in Appendix K.

11.4 Screenline Calibration

The TAG criterion for total screenline flows, as a check on the validity of the trip matrices, is that total modelled flows on all links crossing a screenline should be within 5% of the observed totals. The performance of the model along the calibration screenlines for all vehicles is summarised in Table 11-4 below:

Screenline	DIR	No. Links	AM			IP			PM		
			Obs.	Mod.	% Diff.	Obs.	Mod.	% Diff	Obs.	Mod.	% Diff.
Cal_1	Inbound	6	3,620	3,403	-6%	2,586	2,407	-7%	3,332	3,161	-5%
	Outbound	6	3,435	3,271	-5%	2,710	2,517	-7%	3,501	3,295	-6%
Cal_2	Inbound	12	9,371	8,925	-5%	6,733	6,649	-1%	9,224	8,717	-5%
	Outbound	10	7,164	6,748	-6%	4,978	4,866	-2%	7,483	7,125	-5%
Cal_3	Inbound	5	9,079	9,470	4%	6,229	6,544	5%	8,850	9,085	3%
	Outbound	5	8,418	8,925	6%	6,998	7,263	4%	10,222	10,384	2%
Cal_4	Inbound	3	866	933	8%	492	519	5%	796	867	9%
	Outbound	3	739	804	9%	539	562	4%	940	1,029	9%
Cal_5	Inbound	5	1,832	1,731	-6%	1,055	1,183	12%	1,677	1,756	5%
	Outbound	5	1,403	1,538	10%	1,050	1,158	10%	1,917	2,067	8%
Cal_6	Inbound	3	1,350	1,286	-5%	524	656	25%	736	874	19%
	Outbound	3	666	785	18%	585	629	8%	1,485	1,469	-1%
Cal_7	Inbound	6	3,841	3,566	-7%	2,150	2,090	-3%	3,234	3,080	-5%
	Outbound	6	3,223	3,022	-6%	1,971	1,927	-2%	3,327	3,235	-3%
Cal_8	Inbound	4	2,470	2,247	-9%	1,547	1,432	-7%	2,233	2,116	-5%
	Outbound	4	2,527	2,279	-10%	1,608	1,446	-10%	2,374	2,152	-9%
Cal_9	Inbound	8	2,678	2,494	-7%	1,493	1,433	-4%	2,084	2,057	-1%
	Outbound	8	2,247	2,128	-5%	1,457	1,391	-5%	2,332	2,283	-2%
Cal_10	Inbound	6	2,834	2,638	-7%	1,922	1,871	-3%	2,457	2,485	1%
	Outbound	6	2,893	2,715	-6%	2,173	2,056	-5%	3,176	3,069	-3%
Cal_11	Inbound	7	6,292	6,745	7%	4,643	4,992	8%	6,224	6,525	5%
	Outbound	7	4,998	5,168	3%	4,862	5,063	4%	6,315	6,526	3%
Cal_12	Inbound	4	2,042	1,941	-5%	1,143	1,193	4%	1,624	1,698	5%
	Outbound	4	1,734	1,763	2%	1,191	1,215	2%	2,164	1,983	-8%
Cal_13	Inbound	3	2,837	2,844	0%	1,753	1,906	9%	2,684	2,698	1%
	Outbound	3	2,638	2,780	5%	1,707	1,911	12%	2,764	2,817	2%
Cal_14	Inbound	3	1,072	1,223	14%	544	648	19%	982	1,097	12%
	Outbound	3	951	1,065	12%	557	629	13%	1,003	1,095	9%
Cal_15	Inbound	4	1,556	1,792	15%	1,083	1,046	-3%	1,729	1,750	1%
	Outbound	4	1,504	1,678	12%	1,006	1,096	9%	1,644	1,746	6%
Cal_16	Inbound	3	1,103	1,244	13%	1,186	1,075	-9%	1,174	1,143	-3%
	Outbound	3	876	996	14%	1,015	973	-4%	1,179	1,341	14%
Cal_17	Inbound	3	1,496	1,361	-9%	1,776	1,520	-14%	1,873	1,809	-3%
	Outbound	3	2,505	2,495	0%	2,702	2,228	-18%	2,927	2,441	-17%
Cal_18	Inbound	3	1,157	1,095	-5%	707	702	-1%	1,069	1,071	0%
	Outbound	3	1,356	1,281	-6%	751	737	-2%	1,234	1,158	-6%
Cal_19	Inbound	5	4,855	4,962	2%	3,394	3,480	3%	5,185	5,330	3%
	Outbound	5	4,600	4,537	-1%	3,372	3,434	2%	4,463	4,807	8%
Cal_20	Inbound	7	2,864	2,727	-5%	1,688	1,675	-1%	2,167	2,254	4%
	Outbound	7	2,183	2,133	-2%	1,793	1,793	0%	2,457	2,523	3%

Screenline	DIR	No. Links	AM			IP			PM		
			Obs.	Mod.	% Diff.	Obs.	Mod.	% Diff	Obs.	Mod.	% Diff.
Cal_21	Inbound	6	2,890	3,082	7%	2,462	2,443	-1%	3,264	3,293	1%
	Outbound	6	4,083	3,958	-3%	2,851	2,782	-2%	3,915	3,895	-1%
Cal_22	Inbound	3	3,169	3,041	-4%	2,463	2,533	3%	2,711	2,828	4%
	Outbound	3	2,320	2,114	-9%	2,209	2,367	7%	3,045	3,288	8%
Cal_23	Inbound	9	2,363	2,298	-3%	1,513	1,570	4%	2,454	2,506	2%
	Outbound	9	3,268	3,251	-1%	1,516	1,544	2%	2,419	2,477	2%
Cal_24	Inbound	2	5,279	5,449	3%	4,632	4,875	5%	6,024	6,179	3%
	Outbound	2	5,968	6,111	2%	4,546	4,867	7%	5,740	5,931	3%
Cal_25	Inbound	4	1,941	1,901	-2%	1,360	1,314	-3%	2,168	2,060	-5%
	Outbound	4	1,759	1,747	-1%	1,137	1,082	-5%	2,098	1,906	-9%
Cal_26	Inbound	2	2,053	2,132	4%	1,901	1,960	3%	2,864	2,597	-9%
	Outbound	2	2,953	2,651	-10%	1,821	1,911	5%	2,556	2,388	-7%
Cal_27	Inbound	2	1,438	1,312	-9%	988	896	-9%	1,843	1,519	-18%
	Outbound	2	1,520	1,417	-7%	914	888	-3%	1,392	1,369	-2%
Cal_28	Inbound	5	2,923	2,625	-10%	1,639	1,612	-2%	2,426	2,303	-5%
	Outbound	5	2,626	2,482	-5%	1,587	1,595	1%	2,441	2,408	-1%
Cal_29	Inbound	3	1,792	1,938	8%	1,305	1,374	5%	2,179	2,335	7%
	Outbound	3	1,943	2,058	6%	1,291	1,354	5%	1,948	2,093	7%
Cal_30	Inbound	4	1,448	1,260	-13%	798	848	6%	1,194	1,074	-10%
	Outbound	4	1,364	1,291	-5%	871	869	0%	1,402	1,255	-10%
Cal_31	Inbound	4	7,665	7,703	0%	6,137	5,768	-6%	7,310	7,201	-1%
	Outbound	4	7,755	7,569	-2%	6,040	5,654	-6%	7,887	7,781	-1%
Cal_32	Inbound	5	2,326	2,454	6%	1,480	1,451	-2%	1,615	1,684	4%
	Outbound	5	1,372	1,391	1%	1,486	1,396	-6%	2,295	2,256	-2%
Total			**191,493**	**189,973**	**-1%**	**138,620**	**138,868**	**0%**	**195,431**	**194,744**	**0%**
Total Screenlines			**64**								
<5% Difference			**25/64 (39%)**			**35/64 (55%)**			**37/64 (58%)**		
<7.5% Difference			**45/64 (70%)**			**49/64 (77%)**			**47/64 (73%)**		
<10% Difference			**54/64 (84%)**			**55/64 (86%)**			**57/64 (89%)**		

Table 11-4: Calibration Screenline Comparison Table

As demonstrated in the table above, of the 64 calibration screenlines in total, 25 screenlines in the AM peak, 35 in the IP and 37 in the PM peak have total modelled flows within 5% of the observed totals. 45 out of 64 screenlines in the AM peak, 49 in the IP, and 47 in the PM peak have total modelled flows within 7.5% of the observed totals. Finally, 54 in the AM peak, 55 in the IP, and 57 in the PM peak have total modelled flows within 10% of the observed totals. The total modelled flow across the screenlines is within -1%, 0% and 0% of the observed totals for the AM, IP and PM peaks respectively.

Given the wide scope of the model, this level of calibration is deemed acceptable, however improvements will be required once the model is applied for a specific purpose. Further detail on the screenline calibration is given in Appendix M, including a breakdown of individual vehicle classes. Also, as mentioned in Section 3 following TAG unit M3.1 paragraph 3.3.8, additional screenline summaries with high flow roads (e.g. motorways) excluded have also been provided in Appendix M.

11.5 Count Validation

Count validation relies on making similar comparisons to the ones made for the count calibration, but against independent counts, i.e. those not used in the model building process up to this point in either the matrix building or the matrix estimation process.

There are 70 counts used in validation, and the model's performance against these counts is summarised in Table 11-5 below.

Measure	AM Peak			
	Cars	LGV	HGV	Total Vehicles
No. links with modelled flows meeting criteria	58/70	67/70	66/70	54/70
% links with modelled flows meeting criteria	83%	96%	94%	77%
Measure	Interpeak			
	Cars	LGV	HGV	Total Vehicles
No. links with modelled flows meeting criteria	54/70	67/70	66/70	48/70
% links with modelled flows meeting criteria	77%	96%	94%	69%
Measure	PM Peak			
	Cars	LGV	HGV	Total Vehicles
No. links with modelled flows meeting criteria	51/70	66/70	68/70	49/70
% links with modelled flows meeting criteria	73%	94%	97%	70%

Table 11-5: Validation Link Flow Comparison with Observed Flows (Cars, LGV, HGV and Total Vehicles)

The table above shows that the 85% criterion for validation counts is not met, but the proportion of the validated count data is ranging from 69% to 97%. **This gives confidence that the model is representing the base year traffic flows realistically**. A full breakdown of the comparison at the individual count level is included in Appendix L.

11.6 Screenline Validation

The validation counts are arranged across screenlines, as illustrated in Figure 11-1 above. The table below shows the performance of validation counts across screenlines for all vehicles.

Screenline	DIR	No. Links	AM			IP			PM		
			Obs.	Mod.	% Diff.	Obs.	Mod.	% Diff	Obs.	Mod.	% Diff.
Val_1	Inbound	4	2,921	2,801	-4%	1,741	1,869	7%	2,552	2,535	-1%
	Outbound	4	2,785	2,541	-9%	1,722	1,765	2%	2,628	2,636	0%
Val_2	Inbound	3	2,384	2,392	0%	2,107	2,003	-5%	3,106	2,755	-11%
	Outbound	3	2,553	2,242	-12%	2,001	2,049	2%	2,464	2,496	1%
Val_3	Inbound	4	2,197	2,306	5%	1,178	1,078	-8%	1,538	1,468	-5%
	Outbound	4	1,666	1,606	-4%	1,230	1,187	-3%	2,216	2,072	-6%
Val_4	Inbound	2	1,978	2,012	2%	1,386	1,700	23%	1,766	1,894	7%
	Outbound	2	2,246	2,256	0%	1,367	1,814	33%	1,691	2,146	27%
Val_5	Inbound	2	3,983	4,348	9%	2,252	2,709	20%	2,690	2,544	-5%
	Outbound	2	2,250	2,442	9%	2,033	2,003	-1%	3,480	3,295	-5%
Val_6	Inbound	3	2,443	1,850	-24%	1,124	1,118	-1%	1,390	1,621	17%
	Outbound	3	1,436	1,412	-2%	1,382	1,152	-17%	2,327	1,970	-15%
Val_7	Inbound	5	3,348	3,115	-7%	2,573	2,527	-2%	3,759	3,527	-6%
	Outbound	5	3,962	3,818	-4%	2,798	2,737	-2%	3,992	3,820	-4%
Val_8	Inbound	3	2,109	2,072	-2%	1,586	1,625	2%	2,713	2,183	-20%
	Outbound	3	2,113	2,229	5%	1,507	1,714	14%	1,982	2,119	7%
Val_9	Inbound	5	2,416	2,286	-5%	1,309	1,473	13%	2,016	2,421	20%
	Outbound	5	2,252	2,142	-5%	1,493	1,488	0%	2,357	2,389	1%
Total			**45,042**	**43,870**	**-3%**	**30789**	**32011**	**4%**	**44667**	**43891**	**-2%**
Total Screenlines			**18**								
<5% Difference			**10/18 (56%)**			**10/18 (56%)**			**6/18 (33%)**		
<7.5% Difference			**13/18 (72%)**			**11/18 (61%)**			**12/18 (67%)**		
<10% Difference			**16/18 (89%)**			**12/18 (67%)**			**12/18 (67%)**		

Table 11-6: Validation Screenline Comparison Table

As demonstrated in the table above, of the 18 validation screenlines in total, 10 screenlines in the AM peak, 10 in the IP and 6 in the PM peak have total modelled flows within 5% of the observed totals. 13 screenlines in the AM peak, 11 in the IP, and 12 in the PM peak have total modelled flows within 7.5% of the observed totals. Finally, 16 screenlines in the AM peak, 12 in the IP, and 12 in the PM peak have total modelled flows within 10% of the observed totals. The total modelled flow across the screenlines is within -3%, 4% and -2% of the observed totals for the AM, IP and PM peaks respectively.

Given the wide scope of the model, this level of screenline validation is deemed acceptable, however improvements will be required once the model is applied for a specific purpose. Further detail on the screenline validation is given in Appendix L including a breakdown of individual vehicle classes. Also, as mentioned in Section 3, following TAG unit M3.1 paragraph 3.3.8, additional screenline summaries with high flow roads (e.g. motorways) excluded have also been provided in Appendix L.

11.7 Overall Statistics and Model Performance Across Specific Areas

The overall calibration and validation statistics are summarised in Table 11-7 and Table 11-8 below. Detailed breakdowns of all calibration and validation statistics are provided in appendices K, L and M.

Cal/Val Stats	Criteria at Link Level					
	AM		IP		PM	
	Car	Total	Car	Total	Car	Total
Cal Counts	87%	84%	97%	95%	88%	85%
Val Counts	83%	77%	77%	69%	73%	70%
All Counts	85%	81%	92%	89%	84%	81%

Table 11-7: Calibration and Validation Overall Statistics at Link Level

	Screenlines														
	AM					IP					PM				
Criteria	< 5%	< 7.5%	< 10%	Final Criteria	GEH < 4	< 5%	< 7.5%	< 10%	Final Criteria	GEH < 4	< 5%	< 7.5%	< 10%	Final Criteria	GEH < 4
Car	44%	74%	84%	65%	80%	50%	73%	85%	72%	83%	50%	71%	79%	63%	73%
Total	43%	71%	85%	61%	72%	55%	73%	82%	72%	80%	52%	72%	84%	72%	77%

Table 11-8: Calibration and Validation Overall Statistics at Screenline Level

Area	AM		IP		PM		Count Type		Number of Counts
	Performance (Car)	Performance (Total)	Performance (Car)	Performance (Total)	Performance (Car)	Performance (Total)	MCC %	ATC %	
Amersham	93%	93%	89%	89%	82%	71%	57%	43%	28
Aylesbury	81%	83%	100%	93%	80%	78%	48%	52%	54
Beaconsfield	93%	93%	86%	89%	75%	82%	64%	36%	28
Bicester	100%	100%	100%	100%	100%	100%	0%	100%	8
Buckingham	100%	96%	100%	100%	100%	96%	17%	83%	24
Chesham	92%	100%	100%	100%	100%	100%	67%	33%	12
Gerrards Cross	70%	80%	100%	90%	80%	80%	50%	50%	10
Great Missenden	100%	100%	100%	100%	88%	88%	100%	0%	8
High Wycombe	79%	76%	79%	81%	76%	79%	76%	24%	58
Iver	83%	81%	88%	79%	83%	88%	5%	95%	42
Leighton Buzzard	63%	63%	88%	88%	88%	75%	0%	100%	8
Marlow	92%	100%	100%	100%	83%	83%	83%	17%	12
Milton Keynes	93%	79%	93%	93%	93%	93%	29%	71%	14
Pr. Risborough	97%	93%	100%	100%	93%	93%	27%	73%	30
Slough	60%	60%	100%	100%	90%	85%	20%	80%	20
Tring	83%	83%	83%	83%	100%	100%	67%	33%	6
Winslow	100%	100%	100%	100%	100%	100%	67%	33%	6
TOTAL	**85%**	**81%**	**92%**	**89%**	**84%**	**81%**	**45%**	**55%**	**368**

Table 11-9: Model Performance Across Specific Areas of Buckinghamshire

As summarised in Table 11-9, the model performance across specific areas of Buckinghamshire exceeds the criteria of 85% in most cases, however in some areas the criteria is not met. Considering the limitations with regard to the relatively low reliability of MCCs (which make up 45% of the total counts used in the model) compared to ATCs, **the results are deemed appropriate** and, if and when more data becomes available, further enhancements can be made to the model.

11.8 Journey Time Validation

Journey times within the model were checked by comparison of the modelled journey times against the observed times along the routes identified in Section 3 and Figure 11-2 below. TAG advises that the total modelled journey time from start to finish should be within 15% of the observed time, and that this should ideally be the case for 85% of all journey time routes. However, that simple comparison ignores the fact that modelled and observed journey times could deviate significantly from each other along specific sections of a route, and the overall time could still be within the specified acceptance criteria. To ensure rigour in the modelled delays and journey times, the model has been developed in order to ensure that the modelled times match the observed times not just for the total time along the routes, but also at all points of the routes. To that end, distance versus time graphs for the modelled and observed times are provided in Appendix N.

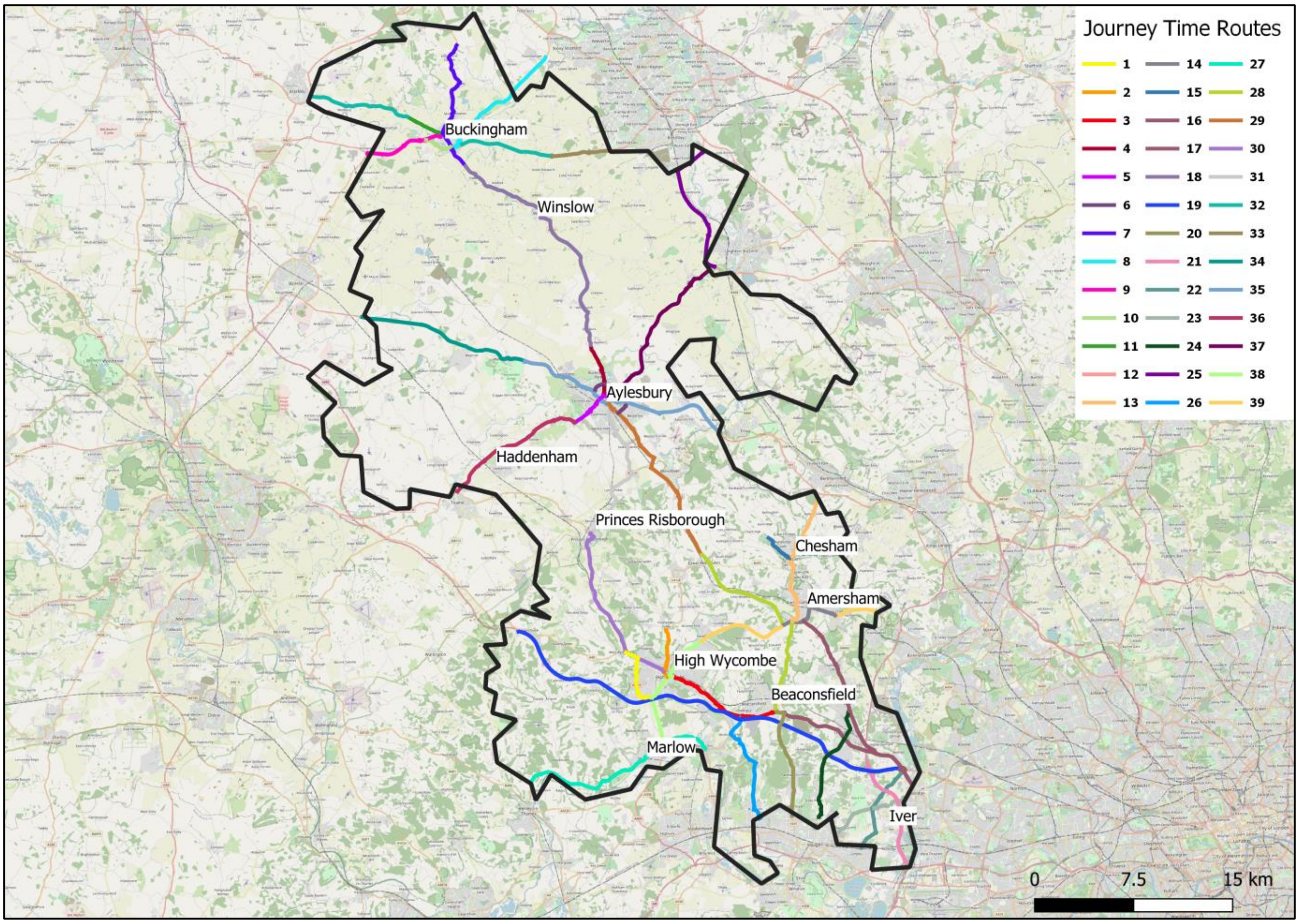


Figure 11-2: Journey Time Validation Routes

A summary of the journey time validation across each time period is given in Table 11-10 and Table 11-11 below:

Time Period	Number of Routes	Number of Routes Within 15%	Total % of Routes Meeting Criteria
AM	78	58	74%
IP	78	67	86%
PM	78	60	77%

Table 11-10: Journey Time Validation Summary

Route No.		Description	Length	AM Observed Time	AM Modelled Time	Difference	IP Observed Time	IP Modelled Time	Difference	PM Observed Time	PM Modelled Time	Difference
			(km)	[HH:MM:SS]	[HH:MM:SS]	%	[HH:MM:SS]	[HH:MM:SS]	%	[HH:MM:SS]	[HH:MM:SS]	%
1	11	A4010/John Hall Way --> A40/Pedestal Roundabout	4.873	00:09:21	00:11:15	20.38%	00:08:33	00:09:48	14.65%	00:11:08	00:12:11	9.37%
	12	A40/Pedestal Roundabout --> A4010/John Hall Way	4.867	00:15:55	00:12:14	-23.17%	00:08:53	00:09:44	9.66%	00:12:47	00:10:48	-15.47%
2	21	A40/Abbey Way --> A4128/ Valley Road	3.845	00:06:24	00:07:03	10.29%	00:06:16	00:06:59	11.33%	00:07:17	00:08:05	10.94%
	22	A4128/ Valley Road --> A40/Abbey Way	3.790	00:12:16	00:09:57	-18.90%	00:06:15	00:06:56	10.81%	00:06:51	00:06:54	0.73%
3	31	A40/Abbey Way at Easton Street --> A40 at Aylesbury End	8.932	00:24:54	00:23:12	-6.82%	00:14:59	00:17:37	17.53%	00:19:37	00:19:01	-3.04%
	32	A40 at Aylesbury End --> A40/Abbey Way at Easton Street	8.623	00:16:06	00:17:45	10.29%	00:13:07	00:16:33	26.14%	00:17:59	00:18:40	3.79%
4	41	A413/ at New Road --> A413/ at New Street	3.748	00:12:13	00:12:26	1.83%	00:05:13	00:05:04	-2.81%	00:06:16	00:06:18	0.43%
	42	A413/ at New Street --> A413/ at New Road	3.783	00:05:41	00:06:00	5.55%	00:05:01	00:04:42	-6.42%	00:07:08	00:06:21	-10.89%
5	51	A418/ at Portway --> A418/at Elmhurst Rd roundabout	4.947	00:13:37	00:12:09	-10.82%	00:09:57	00:08:24	-15.57%	00:15:14	00:10:49	-28.97%
	52	A418/at Elmhurst Rd roundabout --> A418/ at Portway	5.041	00:15:22	00:11:51	-22.86%	00:09:31	00:08:33	-10.23%	00:12:59	00:10:41	-17.67%
6	61	A413/ at Wendover Road --> A41/ Bicester Road roundabout	4.663	00:15:30	00:11:54	-23.27%	00:09:56	00:08:04	-18.79%	00:13:11	00:10:31	-20.21%
	62	A41/ Bicester Road roundabout --> A413/ at Wendover Road	4.651	00:17:09	00:12:07	-29.33%	00:09:37	00:07:56	-17.45%	00:12:57	00:10:14	-21.01%
7	71	A413/ at Bycell Road --> A413/ neat Benthill	8.554	00:13:01	00:12:24	-4.78%	00:11:41	00:11:39	-0.25%	00:12:17	00:12:37	2.67%
	72	A413/ neat Benthill --> A413/ at Bycell Road	8.580	00:13:52	00:13:11	-4.97%	00:12:00	00:11:46	-2.00%	00:14:12	00:13:21	-5.97%
8	81	A5/A508 roundabout --> A413/at Lenborough Road	7.580	00:09:18	00:08:37	-7.33%	00:07:55	00:08:12	3.56%	00:08:44	00:08:35	-1.78%
	82	A413/at Lenborough Road --> A5/A508 roundabout	7.671	00:10:29	00:09:56	-5.19%	00:08:21	00:08:48	5.49%	00:08:46	00:09:14	5.41%
9	91	A422/at Globe Terrace --> A43/ Barleymow Roundabout	8.565	00:11:21	00:10:09	-10.60%	00:10:30	00:09:34	-8.91%	00:11:16	00:10:18	-8.55%
	92	A43/ Barleymow Roundabout --> A422/at Globe Terrace	8.491	00:11:13	00:10:49	-3.55%	00:10:48	00:09:26	-12.53%	00:13:38	00:10:25	-23.53%
10	101	A422/at Globe Terrace --> A421/ Tingewick Road	6.743	00:09:30	00:09:15	-2.65%	00:08:26	00:08:52	5.12%	00:09:06	00:09:13	1.36%
	102	A421/ Tingewick Road --> A422/at Globe Terrace	6.792	00:08:50	00:09:34	8.20%	00:08:10	00:09:02	10.66%	00:11:03	00:09:26	-14.59%
11	111	A413/ near Benthill --> A422/ near Radclive	4.205	0:08:45	0:07:42	-11.99%	0:06:32	0:06:24	-2.01%	0:08:57	0:07:41	-14.20%
	112	A422/ near Radclive --> A413/ near Benthill	4.209	0:08:09	0:07:37	-6.53%	0:06:21	0:06:32	2.76%	0:08:36	0:07:33	-12.27%
12	121	A422/ near Radclive --> A421/A413 roundabout	4.427	0:08:10	0:07:33	-7.54%	0:06:19	0:06:23	1.05%	0:08:36	0:07:26	-13.50%
	122	A421/A413 roundabout --> A422/ near Radclive	4.446	0:08:32	0:07:42	-9.77%	0:06:42	0:06:19	-5.68%	0:08:56	0:07:37	-14.72%

Route No.		Description	Length	AM Observed Time	AM Modelled Time	Difference	IP Observed Time	IP Modelled Time	Difference	PM Observed Time	PM Modelled Time	Difference
			(km)	[HH:MM:SS]	[HH:MM:SS]	%	[HH:MM:SS]	[HH:MM:SS]	%	[HH:MM:SS]	[HH:MM:SS]	%
13	131	A355/A413 roundabout --> A416/ near Hockeridge Wood	10.756	0:21:18	0:22:10	4.03%	0:17:31	0:18:42	6.72%	0:25:03	0:20:19	-18.92%
	132	A416/ near Hockeridge Wood --> A355/A413 roundabout	10.718	0:26:57	0:22:20	-17.13%	0:17:01	0:18:45	10.14%	0:18:28	0:20:18	9.94%
14	141	A413/A404 roundabout --> A404/ at Cokes Lane	4.846	0:11:26	0:10:10	-11.10%	0:06:56	0:08:29	22.45%	0:07:22	0:08:54	20.80%
	142	A404/ at Cokes Lane --> A413/A404 roundabout	4.852	0:11:04	0:09:54	-10.59%	0:07:24	0:08:41	17.29%	0:08:41	0:09:51	13.35%
15	151	MC2/at Berkeley --> Botley Road/Tylers Hill Road	4.286	0:09:58	0:08:51	-11.22%	0:07:08	0:07:21	3.05%	0:07:43	0:07:42	-0.20%
	152	Botley Road/Tylers Hill Road --> MC2/at Berkeley	4.334	0:09:58	0:09:33	-4.16%	0:07:49	0:08:01	2.59%	0:07:29	0:08:15	10.13%
16	161	A404/A413/A355 Stanley Roundabout --> A413/A40	11.826	0:16:35	0:14:11	-14.54%	0:10:59	0:11:38	5.83%	0:11:18	0:12:22	9.52%
	162	A413/A40 --> A404/A413/A355 Stanley Roundabout	11.830	0:12:19	0:12:50	4.10%	0:11:18	0:12:03	6.67%	0:14:02	0:13:27	-4.12%
17	171	Hillingdon Hill/Kingston Ln --> A40 Pyebush Roundabout	11.834	0:15:58	0:16:27	3.04%	0:13:25	0:15:15	13.72%	0:15:29	0:16:30	6.61%
	172	A40 Pyebush Roundabout --> Hillingdon Hill/Kingston Ln	11.849	0:20:10	0:16:26	-18.52%	0:13:16	0:15:18	15.28%	0:15:45	0:15:46	0.08%
18	181	A413/near Buckingham Park --> A421/413 roundabout	23.207	0:23:41	0:22:49	-3.64%	0:22:28	0:21:29	-4.41%	0:22:56	0:23:22	1.86%
	182	A421/413 roundabout --> A413/near Buckingham Park	23.196	0:25:33	0:26:30	3.72%	0:22:34	0:21:22	-5.33%	0:22:41	0:22:59	1.33%
19	191	M40/ Junction 5 --> M40/ Denham Roundabout	31.777	0:23:19	0:21:57	-5.89%	0:17:30	0:19:03	8.89%	0:19:29	0:19:40	0.94%
	192	M40/ Denham Roundabout --> M40/ Junction 5	31.811	0:19:06	0:19:10	0.31%	0:17:53	0:19:11	7.27%	0:18:48	0:19:56	6.03%
20	201	A40/A355 roundabout --> A355/ at M4 J6	8.5702	0:14:33	0:13:48	-5.13%	0:11:06	0:12:24	11.67%	0:12:11	0:13:47	13.22%
	202	A355/ at M4 J6 --> A40/A355 roundabout	8.362	0:13:05	0:14:33	11.19%	0:11:03	0:11:50	6.99%	0:13:47	0:14:17	3.65%
21	211	M25/at J15 --> M25/at J17	8.513	0:07:16	0:07:03	-2.93%	0:06:39	0:05:27	-18.03%	0:10:06	0:09:05	-9.99%
	212	M25/at J17 --> M25/at J15	8.377	0:10:34	0:09:51	-6.82%	0:06:17	0:05:28	-12.94%	0:07:51	0:08:20	6.22%
22	221	A412/ at M40 Denham roundabout --> B470/ at A4 London Road	6.907	0:13:25	0:10:59	-18.09%	0:08:06	0:08:27	4.25%	0:10:29	0:10:31	0.31%
	222	B470/ at A4 London Road --> A412/ at M40 Denham roundabout	6.931	0:10:07	0:10:23	2.57%	0:08:23	0:07:52	-6.16%	0:13:16	0:10:10	-23.37%
23	231	A412/at Red Cow roundabout --> A4007/at Trumper Way roundabout	5.733	0:07:33	0:06:48	-9.88%	0:06:08	0:06:05	-0.95%	0:07:12	0:06:31	-9.52%
	232	A4007/at Trumper Way roundabout --> A412/at Red Cow roundabout	5.703	0:08:36	0:07:16	-15.43%	0:06:38	0:06:18	-4.96%	0:10:14	0:07:35	-25.89%

Route No.		Description	Length	AM Observed Time	AM Modelled Time	Difference	IP Observed Time	IP Modelled Time	Difference	PM Observed Time	PM Modelled Time	Difference
			(km)	[HH:MM:SS]	[HH:MM:SS]	%	[HH:MM:SS]	[HH:MM:SS]	%	[HH:MM:SS]	[HH:MM:SS]	%
24	241	B416/ at B416/A413 roundabout --> A332/ at Ragstone Road	8.978	0:18:20	0:14:45	-19.53%	0:14:02	0:13:49	-1.57%	0:15:28	0:14:40	-5.21%
	242	A332/ at Ragstone Road --> B416/ at B416/A413 roundabout	8.967	0:17:31	0:16:09	-7.77%	0:13:46	0:13:55	1.09%	0:15:22	0:15:11	-1.18%
25	251	A5/ at A5/A416 junction --> A4146/A418 roundabout	10.885	0:09:27	0:08:32	-9.60%	0:07:45	0:08:15	6.37%	0:09:17	0:08:54	-4.18%
	252	A4146/A418 roundabout --> A5/ at A5/A416 junction	10.927	0:10:23	0:09:30	-8.50%	0:07:54	0:08:32	8.02%	0:08:03	0:08:14	2.22%
26	261	Huntercombe Spur/ M4 J7 --> B4440/ at B4440/A40 roundabout	8.946	0:11:58	0:10:53	-9.03%	0:11:11	0:09:42	-13.18%	0:12:23	0:10:47	-12.86%
	262	B4440/ at B4440/A40 roundabout --> Huntercombe Spur/ M4 J7	9.074	0:13:55	0:12:23	-10.97%	0:11:02	0:10:13	-7.38%	0:11:24	0:12:18	7.89%
27	271	A4155/ at Fawley road --> The Parade/Station Road roundabout	15.827	0:24:54	0:22:16	-10.60%	0:20:50	0:20:45	-0.42%	0:24:11	0:22:32	-6.83%
	272	The Parade/Station Road roundabout --> A4155/ at Fawley road	15.831	0:26:02	0:22:49	-12.35%	0:20:50	0:20:14	-2.85%	0:22:45	0:21:53	-3.78%
28	281	A40 Pyebush Roundabout --> A413/at Aylesbury Road	17.459	0:17:37	0:17:14	-2.21%	0:16:48	0:16:23	-2.52%	0:23:00	0:18:01	-21.69%
	282	A413/at Aylesbury Road --> A40 Pyebush Roundabout	17.473	0:25:44	0:20:26	-20.60%	0:16:51	0:16:23	-2.76%	0:17:22	0:16:55	-2.63%
29	291	A413/at Aylesbury Road --> A413/A41 Exchange Street roundabout	14.025	0:18:45	0:18:15	-2.62%	0:15:26	0:14:25	-6.54%	0:19:59	0:16:51	-15.67%
	292	A413/A41 Exchange Street roundabout --> A413/at Aylesbury Road	13.946	0:20:26	0:16:01	-21.59%	0:15:17	0:14:08	-7.50%	0:16:49	0:15:28	-8.07%
30	301	A4128/A40 Abbey Way/Oxford Road --> A4010/Aylesbury Road	13.533	0:20:29	0:19:19	-5.66%	0:18:08	0:17:33	-3.20%	0:22:21	0:20:11	-9.67%
	302	A4010/Aylesbury Road --> A4128/A40 Abbey Way/Oxford Road	13.505	0:25:05	0:20:45	-17.27%	0:18:14	0:17:52	-2.04%	0:21:13	0:19:25	-8.51%
31	311	A4010/Aylesbury Road --> A413/A41 Exchange Street roundabout	12.338	0:23:58	0:20:59	-12.42%	0:16:54	0:15:50	-6.35%	0:24:44	0:18:44	-24.27%
	312	A413/A41 Exchange Street roundabout --> A4010/Aylesbury Road	12.513	0:25:17	0:20:52	-17.45%	0:16:54	0:16:29	-2.45%	0:18:28	0:18:37	0.81%
32	321	A43/at Buckingham Road --> A421/B4033 roundabout	20.379	0:23:18	0:23:51	2.36%	0:20:19	0:20:23	0.35%	0:22:28	0:22:31	0.24%
	322	A421/B4033 roundabout --> A43/at Buckingham Road	20.364	0:22:28	0:22:17	-0.82%	0:20:21	0:20:26	0.43%	0:22:02	0:22:28	1.98%

Route No.		Description	Length	AM Observed Time	AM Modelled Time	Difference	IP Observed Time	IP Modelled Time	Difference	PM Observed Time	PM Modelled Time	Difference
			(km)	[HH:MM:SS]	[HH:MM:SS]	%	[HH:MM:SS]	[HH:MM:SS]	%	[HH:MM:SS]	[HH:MM:SS]	%
33	331	A421/B4033 roundabout --> A421 Kents Hill Roundabout	2.927	0:05:08	0:04:49	-6.06%	0:02:42	0:03:10	17.55%	0:03:09	0:03:33	12.84%
	332	A421 Kents Hill Roundabout --> A421/B4033 roundabout	4.456	0:04:28	0:04:44	6.09%	0:04:07	0:04:23	6.27%	0:05:15	0:05:32	5.39%
34	341	A41/A4421 roundabout --> A41/at Waddesdon Hill	13.225	0:12:37	0:12:21	-2.14%	0:13:20	0:11:19	-15.08%	0:11:45	0:12:18	4.67%
	342	A41/at Waddesdon Hill --> A41/A4421 roundabout	12.991	0:11:47	0:11:46	-0.15%	0:11:27	0:11:10	-2.41%	0:11:11	0:11:48	5.53%
35	351	A41/at Blackgrove road --> A41 /B488 junction	17.259	0:33:02	0:27:40	-16.28%	0:22:22	0:20:49	-6.94%	0:25:35	0:23:01	-10.01%
	352	A41 /B488 junction --> A41/at Blackgrove road	17.191	0:32:07	0:26:32	-17.39%	0:22:10	0:21:00	-5.27%	0:31:44	0:23:48	-25.01%
36	361	A418/A4129 --> A418/near Coppice	16.693	0:27:02	0:24:03	-11.02%	0:21:21	0:19:16	-9.77%	0:30:52	0:23:15	-24.66%
	362	A418/near Coppice --> A418/A4129	16.793	0:32:00	0:23:31	-26.50%	0:21:06	0:19:27	-7.81%	0:25:32	0:21:42	-15.01%
37	371	A418/near Coppice --> A4146/A418 roundabout	11.871	0:13:38	0:14:47	8.37%	0:12:40	0:13:31	6.78%	0:13:23	0:15:50	18.36%
	372	A4146/A418 roundabout --> A418/near Coppice	11.862	0:15:55	0:15:58	0.35%	0:12:31	0:13:16	5.93%	0:12:30	0:14:42	17.57%
38	381	A404/A308 Bisham roundabout --> A404/at Holmer Green Road	10.212	0:30:33	0:23:08	-24.29%	0:16:38	0:18:25	10.74%	0:23:59	0:22:28	-6.36%
	382	A404/at Holmer Green Road --> A404/A308 Bisham roundabout	10.341	0:31:15	0:24:26	-21.82%	0:16:14	0:18:02	11.08%	0:19:59	0:21:19	6.66%
39	391	A404/at Holmer Green Road --> A404/at Green Street	15.203	0:23:26	0:21:58	-6.25%	0:17:36	0:19:13	9.23%	0:19:01	0:20:17	6.67%
	392	A404/at Green Street --> A404/at Holmer Green Road	15.217	0:24:45	0:22:33	-8.87%	0:18:12	0:19:32	7.31%	0:20:32	0:21:54	6.66%

Table 11-11: Comparison of Modelled Journey Times Against Observed

The above tables demonstrate that the TAG criteria are not fully met, however 74%, 86% and 77% of journey time routes in the AM, IP, and PM are in accordance with the 15% criteria. Given the wide scope of the model, this level of journey time validation is deemed acceptable, however improvements will be required once the model is applied for a specific purpose. It is also notable that the differences in times are not consistently positive or negative, suggesting there is no underlying bias of too quick or too slow journey times in the model. There are some routes with large difference in the modelled compared to the observed. Therefore, if this model was used in those specific areas it would be necessary to replicate the observed delays more accurately.

12. Summary of Model Development, Standards Achieved and Fitness for Purpose

12.1 Summary of Model Development

The Buckinghamshire Strategic Transport Model (BSTM) has been developed in PTV's VISUM 2021 software platform for the highway model component. No PT Model was developed as it was out of the scope of this work.

The BSTM is focussed on the area contained within the Buckinghamshire county boundary (the Area of Detailed Modelling) and in the 'bulge' areas which are adjacent to the Buckinghamshire county boundary (Milton Keynes, Bicester, Slough and Uxbridge). In these 'bulge areas', the method to capture delays is similar to that of the Rest of the Fully Modelled Area. However, the network density in the bulge areas is higher compared to the Rest of Fully Modelled Area. For the Rest of the Fully Modelled Area (including the areas that border Buckinghamshire), the highway network is also detailed with link capacity restraints. Beyond this, the level of detail in the model is gradually reduced. The South East of England is modelled to a lower level of detail and the remainder of mainland Great Britain is based on a skeleton network of key roads without capacity restraint. In the Fully Modelled Area the highway network therefore includes a very granular representation, with all except very minor local residential roads included. In the external model area, only major highways deemed to be of importance for strategic routing are coded.

The highway and public transport assignment models represent an average neutral 2019 weekday for the AM, average IP, and PM peak hours/periods.

The highway prior matrix development process was largely driven by the use of aggregated and anonymised mobile network data (MND) provided specifically for this study by Telefonica. Other data sources such as 2011 Census Journey to Work (JTW), National Travel Survey data (NTS), National Trip End Model (NTEM v7.2) and bespoke synthetic matrices were used to augment the MND and to correct for known biases. The Heavy Goods Vehicle matrices (HGV) and Light Goods Vehicle (LGV) movements were derived from the South East Regional Transport Model (SERTM), with a base year of 2015. These matrices were converted to the BSTM zone system and uplifted to 2019, the base year for the BSTM.

The development of the model has proceeded with consultation with both Highways England (HE) and the Department for Transport (DfT). These have led to a number of key considerations that were included in the modelling methodology, as detailed below:

Consideration	Response
Model base year	Owing to impacts of the COVID pandemic, a 2019 base year was chosen. This has been recognised by both HE and DfT as a pragmatic solution to atypical travel patterns post-2019.
Different peak hours across different areas of the model	This does present difficulties given that, for example, trips on the Strategic Road Network, and other longer distance trips, tend to have early peak hours than intra-urban trips. No single modelled peak hour can solve this problem, but as a proportionate and pragmatic approach, the modelled peak hour has been selected based on the totality of all traffic counts available in the model, thus ensuring the model is most representative of the peak hour corresponding with the data used to calibrate the model. This also has implications for the development of trip matrices, when deriving factors to convert trips from 24 hour to peak hour. There was insufficient data to differentiate peak hours for trips of different lengths, so a single factor was applied for all trip lengths. This approach was recognised by DfT as an appropriate pragmatic approach given the lack of data with which more detailed 'length-specific' factors could be derived.
Use of an HGV factor of 2.0, rather than 2.5	A PCU factor of 2.5 would, in contrast, overestimate road space taken up by HGVs on the MRN and minor roads, which could in turn lead to an overestimation of scheme

Consideration	Response
could underestimate road space taken up by HGVs on the SRN	benefits should the model be used for scheme appraisal. Given that most of the links in the model are NOT on the SRN, a factor of 2.0 was chosen. With the condition that when the modelled flows are extracted for separate assessment on the SRN, a PCU factor of 2.5 was used, this approach was considered acceptable to HE.
Lack of highway links in external areas south and west of Buckinghamshire	The "Rest of the Modelled Areas" was extended to the south and west, with additional links added to the highway network to ensure a fuller selection of route choice for relevant trips in Berkshire and Oxfordshire.
Construction of the M4 smart motorway scheme during the model's base year	Relevant sections of the M4 in Berkshire were coded with 50mph reduced speeds, and reduced capacity to reflect narrow lanes.
Volume-delay curves	The model includes volume-delays curves calibrated to be consistent with those of HE's Regional Transport Models
Development of HGV trip matrices	The model makes use of data from HE's Regional Transport Models, 2015 base year (the most recent version available at the time), updated to 2019 levels.
Sources of count data for SRN	SRN count data has been taken from HE's own 'WebTRIS' database
Inclusion of SRN links in calibration and validation screenlines	In accordance with HE's recommendation, counts on the SRN will not be entirely on calibration or validation screenlines, but a mix of the two. Furthermore, it was confirmed that SRN links do not form any gaps in screenlines.
Inclusion of SRN links in route checks	In accordance with HE's recommendations, the routes checked in the model included those on the SRN as well as local routes.

Table 12.1: Modelling considerations

As the above reflects, the development of the model has been mindful of the concerns of both HE and DfT, and taken on board their recommendations, with the aim to ensure that the model will be found satisfactory when used for assessing impacts on the SRN, or for scheme appraisal following TAG methodologies.

TAG principles have been followed to enable reporting of model calibration and validation quality in a manner which is consistent with guidance. The standards achieved are summarised in Section12.2. Due to the very large area covered by the model, and therefore the very high volume of traffic counts and journey time routes used in the highway assignment calibration and validation, it was recognised that meeting all of the TAG recommended criteria for modelled flows and journey times would be unrealistic. Nonetheless, the model has achieved a high standard of validation given the intended uses of the model; it is expected to be a useful tool for identifying key changes in travel behaviour and potential transport network constraints. **As with all strategic models, the impact of uncertainty on the model results will need to be carefully considered through a range of sensitivity tests when applying the model.**

As with all models of this type, additional checks will be required during the forecasting phase of the project to ensure the model is predicting impacts as expected. These checks will be documented in subsequent deliverables.

12.2 Summary of Standards Achieved

The standards to which the model aims to conform are set out in Section 3. Table 12-2, on the next page, summarises how the model has actually performed against those standards.

Model Aspect	Criterion	Acceptability Guideline	Actual Model Performance
Matrix validation	Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines	Criteria is met for some screenlines, however given the wide scope if the model, this is deemed acceptable.
Matrix estimation	Matrix zonal cell values	Slope within 0.98 and 1.02 Intercept near zero R^2 in excess of 0.95	Model meets the criteria for cars and all vehicles.
	Matrix zone trip ends	Slope within 0.99 and 1.01 Intercept near zero R^2 in excess of 0.98	Model meets the criteria for cars and all vehicles.
	Trip length distributions	Means within 5% Standard deviations within 5%	Change in average and standard deviation trip lengths is minimal and well within guidelines for cars and all vehicles.
	Sector to sector level matrices	Differences within 5%	Does not meet the criterion in all time periods. However, according to guidelines, the criteria is to be applied regardless of the number of trips in the sector. For sector-to-sector movements with relatively few trips it is more difficult to stay within the 5% criteria, although this could have been achieved if larger sectors were selected. Noting that in some cases there are relatively few trips, changes expressed as GEH values provide greater insight into the significance of some of these percentage changes. Across all peaks, over 99% of the trip changes are within a GEH of 5.
Assignment convergence	Delta and %GAP	Less than 0.1%	GAP value of less than 0.1% is met in all time periods, and the change in GEH and queue length shows stability in the model.
Link calibration	Individual flows within 100 veh/hr of counts for flows less than 700 veh/hr	> 85% of cases	AM peak: > 85% criteria met for car flows (87%) and nearly met for total vehicles (84%). Interpeak: > 85% criteria met for car flows (97%) and total vehicles (95%). PM peak: > 85% criteria met for car flows (88%) and total vehicles (85%). In summary, criteria were satisfied in nearly all time periods for both cars and total vehicles.
	Individual flows within 15% of counts for flows from 700 veh/hr to 2,700 veh/hr	> 85% of cases	
	Individual flows within 400 veh/hr of counts for flows more than 2,700 veh/hr	> 85% of cases	
	GEH < 5 for individual flows	> 85% of cases	

Link validation	Same as for link calibration, but for independent counts		AM peak: > 85% criteria is not met for car flows (83%) and total vehicles (77%). Interpeak: > 85% criteria is not met for car flows (77%) and total vehicles (69%). PM peak: > 85% criteria is not met for car flows (73%) and total vehicles (70%). In summary, criteria were not satisfied for any time period, but the proportion of the validated count data is deemed satisfactory given the intended uses of the model (ranging from 71% to 84%).
Journey times	Modelled times along routes should be within 15% of surveyed time, or 1 minute if higher	> 85% of all routes	74%, 86% and 77% of journey time routes in the AM, IP, and PM. Given the wide scope of the model, this level of journey time validation is deemed acceptable, however improvements will be required once the model is applied for a specific purpose.

Table 12-2: Summary of Standards Achieved

12.3 Assessment of Fitness for Purpose

As demonstrated in this Local Model Validation Report (LMVR), the BSTM has been constructed in a manner consistent with guidance and performs well against the standards set out in TAG, with some limitations, taking the model scope into consideration. Modelled flows and journey times compare favourably to observations, both for independent data, and data used as part of the model building process. This should serve to give confidence and provide reassurance that the model is representative of current conditions.

Although the updated model does not quite meet all suggested validation guidelines, given the intended uses of the model this is deemed acceptable, particularly in light of the rigorous development of the separate component parts of the highway assignment model (i.e. the network and trip matrices). In some models, particularly models of the size of the BSTM, which has large urban areas, it may be difficult to achieve the link flow and journey time validation quality guidelines without matrix estimation bringing about changes greater than the limits shown in Table 3-4 in Section 3.1. In these cases, the limits set out should be respected, the impacts of matrix estimation should be reduced so that they do not become significant, and a lower standard of model validation reported. In other words, matrix estimation should not be allowed to make significant changes to the prior matrices in order to meet the validation quality standards.

It is considered that the model provides a good overall representation of current travel conditions for those areas included within the modelled network and that therefore the model is likely to be fit for purpose for strategic assessments such as for the Local Transport Plan 5.

It is acknowledged that simply reaching a good level of validation does not in itself qualify the model to be a suitable tool for assessing the impacts of any given transport strategy, land development or transport scheme. Therefore, any application of the model for a specific purpose should always first assess the suitability of the model for that task and at time of writing, no specific application has yet been identified. However, as evidenced by this report, the model is considered to be an excellent starting point for any given highway-based assessment purpose. Further local revalidation in specific areas may be appropriate once specific applications and uses have been identified. When a specific use has been identified, the suitability of the model for that purpose should be reviewed prior to its use. Any use of the model aside from the assessment of strategic transport planning studies, is subject to such a review and therefore this explicitly excludes the model's use for development management purposes at this stage.

Appendix A. – Volume Delay Function Technical Note

Appendix B. – Link Types and Parameters

Appendix C. – Kimber Guidance

Appendix D. – Network Checklist

Appendix E. – Route Checking

Appendix F. – Matrix Zonal Cell Value Changes

Appendix G. – Matrix Trip End Changes

Appendix H. – % Changes Sector to-Sector

Appendix I. – Absolute Changes Sector-to-Sector

Appendix J. – GEH Values Sector-to-Sector

Appendix K. – Calibration Count Summary

Appendix L. – Validation Count Summary

Appendix M. – Screenline Summary

Appendix N. – Journey Time Validation

Appendix O. – Matrix Trip Length Changes (Pre ME vs Post ME)

Appendix P. – Matrix Trip Length Changes (Initial Prior vs Final Prior)