A12 Chelmsford to A120 widening scheme

TR010060

7.3 Combined Modelling and Appraisal Report

Appendix B: Transport Model Package Report

APFP Regulation 5(2)(q)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

Volume 7

August 2022

Infrastructure Planning

Planning Act 2008

A12 Chelmsford to A120 widening scheme

Development Consent Order 202[ ]

7.3 COMBINED MODELLING AND APPRAISAL REPORT APPENDIX B: TRANSPORT MODEL PACKAGE REPORT

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Planning Inspectorate Scheme Reference	TR010060
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Author	A12 Project Team, National Highways

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Rev 1	August 2022	DCO Application

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1. Introduction

1.1 Purpose of the report

The Transport Model Package Report is one of a series of documents that set out the scheme's traffic modelling and economic assessment. These include:

- Transport Data Package Report
- Transport Model Package Report
- Transport Forecasting Package Report
- Economic Appraisal Package Report
- Appraisal Summary Table and Worksheets
- Distributional Impacts Report

Each of these documents are provided as appendices to the overall Combined Modelling and Appraisal (ComMA) Report.

The purpose of the Transport Model Package is to report on the development and suitability of the new base year model created for the A12 scheme's current stage (known as PCF Stage 3, the stage of National Highways' Project Control Framework where a single scheme option is developed following a Preferred Route Announcement).

1.2 Report structure

The remainder of this document is set out as follows:

- Chapter 2 – Key Features of the Model
- Chapter 3 – Model Standards
- Chapter 4 – Calibration and Validation Data
- Chapter 5 – Network Development
- Chapter 6 – Trip Matrix Development
- Chapter 7 – Network Calibration and Validation
- Chapter 8 – Route Choice Calibration and Validation
- Chapter 9 – Prior Matrices Validation
- Chapter 10 – Trip Matrix Calibration and Validation
- Chapter 11 – Assignment Calibration and Validation
- Chapter 12 – Variable Demand Model Building and Validation
- Chapter 13 – Summary and Conclusions

2. Key Features of the Model

2.1 Introduction

An updated base year transport model for the A12 Chelmsford to A120 widening scheme is being developed to support the scheme's Development Consent Order application (DCO). This forms the second part of the previously agreed two-phase traffic modelling strategy for A12 PCF Stage 3, which was to:

- Produce a 'Stat Con' model with a base year of 2016 to support the scheme through Statutory Consultation.
- Update the model in Spring/Summer 2021, to produce a 'DCO model' with a base year of 2019. This is to support DCO submission.

The Stat Con model used traffic count and journey time data which was almost entirely from 2016. The reason for producing a DCO model is to incorporate more recent traffic data.

This chapter provides an overview of the model development processes used to create the new A12 base model.

2.2 Proposed uses of the model

The new model will be used to assess a single preferred A12 option. It will be used to inform scheme design as well produce traffic forecasts which will be inputs for environmental and economic appraisal of the scheme, as well as used in operational traffic modelling of junctions.

2.3 Use of A120 traffic model as a starting point

The traffic modelling requirements for the project during PCF Stage 3 specified that a new base year transport model should be developed, which should be a modified version of the 'A120 traffic model'. This A120 model was originally developed by Essex County Council to support the A120 Braintree to A12 scheme appraisal. The A120 model was to be used as a starting point for the following reasons:

- The A120 model had better calibration / validation within the study area than the previous PCF Stage 2 A12 model (PCF Stage 2 is the previous stage of National Highways' Project Control Framework, where a preferred route is identified).
- The A120 is based on National Highways' SERTM regional traffic model. This is key to ensuring future traffic data updates (such as new mobile phone

demand data and new freight model data) can be incorporated, as they will be in a SERTM compatible format.

- Interactions between the A12 and A120 schemes can be assessed within a single traffic model.

2.4 Detailed modelled area and external area

The A12 model network includes all of England, Scotland and Wales. This allows all in-scope trips and the full trip lengths to be included in the model.

The network is divided into two key parts, the Fully Modelled Area and the External Area. The extents of these areas are described as follows:

- Fully Modelled Area: This is coded based on the area over which proposed interventions are expected to have influence and is further subdivided as follows:
  - Detailed Simulation Area: This represents the main scheme area, where the greatest impacts from the scheme will occur and therefore has the greatest level of accuracy and detail in the model, i.e. along the A12, Chelmsford, Colchester, Maldon, Witham and Braintree. With the exception of Chelmsford, Colchester and Maldon urban areas, almost all roads are included, with junctions explicitly modelled in detail, including saturation flows, checking correct turn availability, signal timings where required, and correct priority at both priority junctions and signalised junctions. Speed flow curves were added to links where appropriate.
  - Rest of Fully Modelled Area (Buffer Area): This is the area over which impacts of the interventions are considered to be quite likely but relatively weak in magnitude. This area has somewhat larger zones corresponding to Middle-Layer Super Output Areas (MSOA) (SERTM zones) and less network detail than for the simulation area. This area roughly corresponds to the rest of the county of Essex outside the simulation area as well as some key strategic links that provide access into or through Essex such as the A14 and M11.
- External Area: In this area impacts of interventions would be so small as to be reasonably assumed to be negligible. The network is increasingly coarse the further away from the simulation area and links are included with the purpose being to link external trips from other regions in the UK to the Fully Modelled Area. This part of the network was based on a coarser version of the SERTM network and includes the fixed speeds used in SERTM for this area.

In the initial network derived from the A120 model, Braintree, Witham, Coggeshall and Marks Tey were modelled to a very fine level of detail. For the A12 model, the network coding for these areas of the model has been retained, but it was not deemed necessary to model Chelmsford, Colchester or Maldon to this level of detail when the simulation network was extended to cover these areas.

All main roads are included, as well as those secondary routes and local routes in residential areas (especially 'rat-runs') that are likely to carry traffic movements which could use the scheme, and that are significant in relation to the capacity of the scheme. Transport schemes completed between 2016 (Stat Con base model year) and 2019 (DCO base model year) within the simulation area were identified and coded into the model.

The simulation area, Rest of the Fully Modelled network and external area are illustrated in Plate 2-1 below. A more detailed map showing the buffer and simulation areas is given in Plate 2-2.

Plate 2-1 Local model network by area type

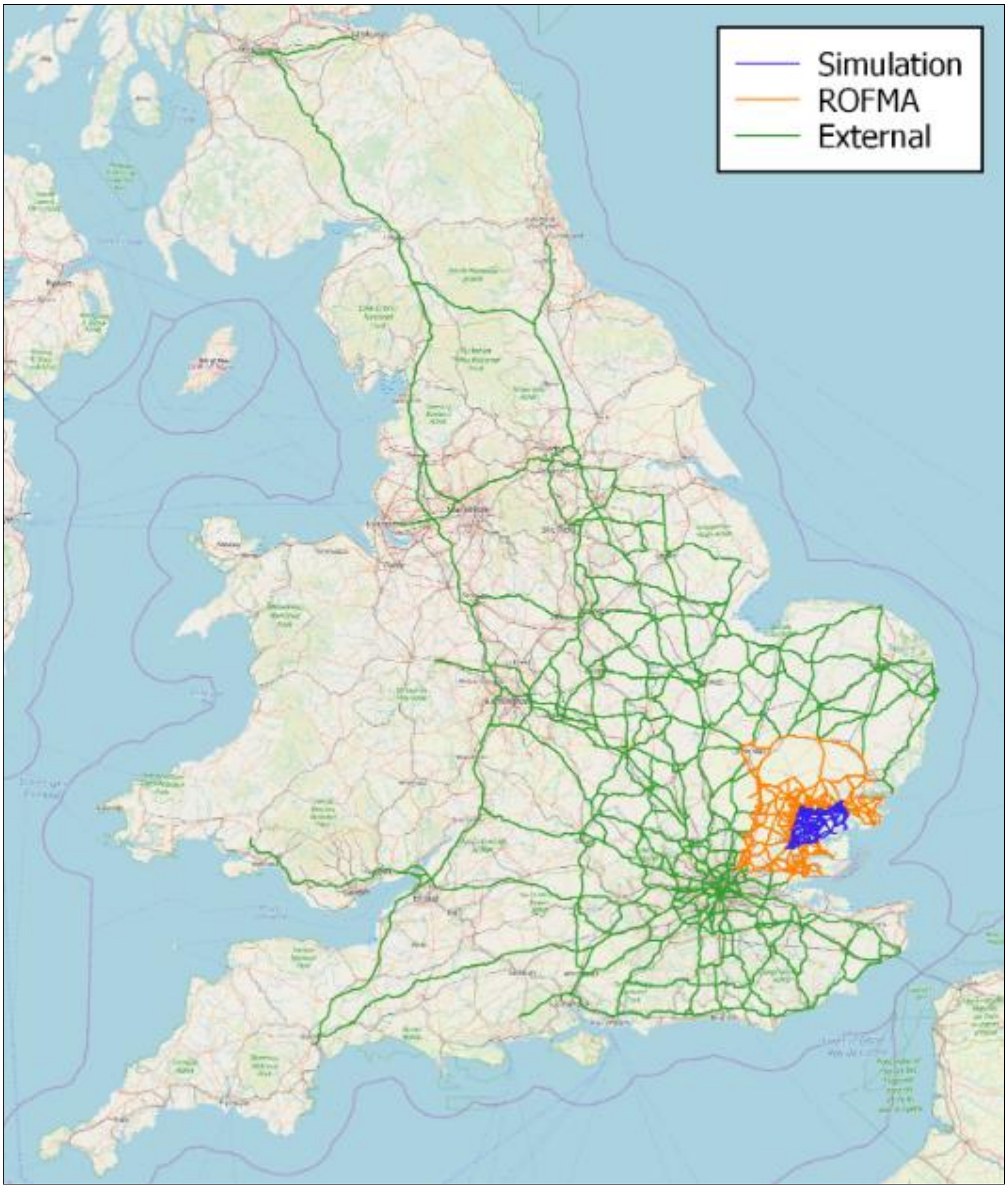
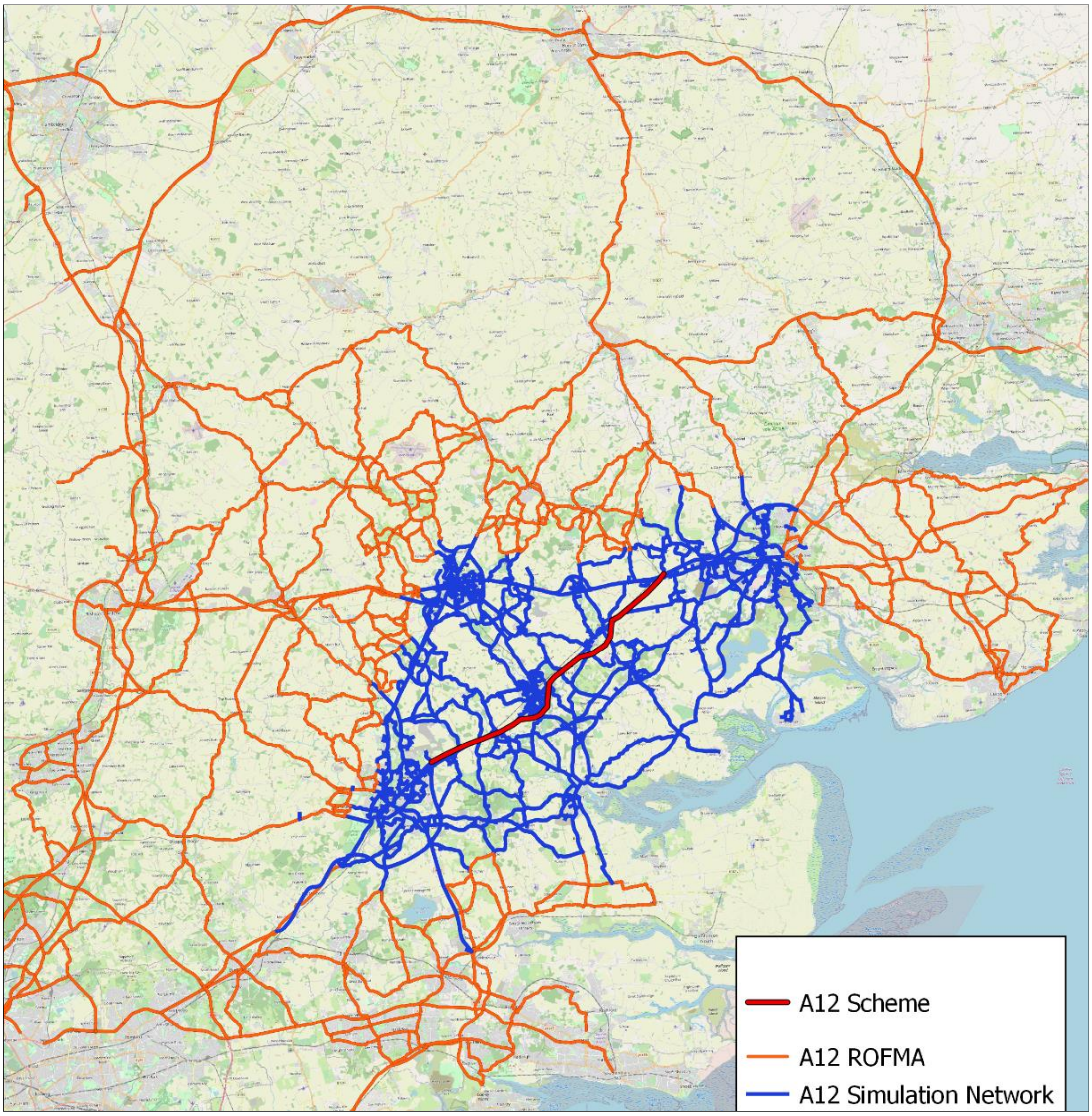


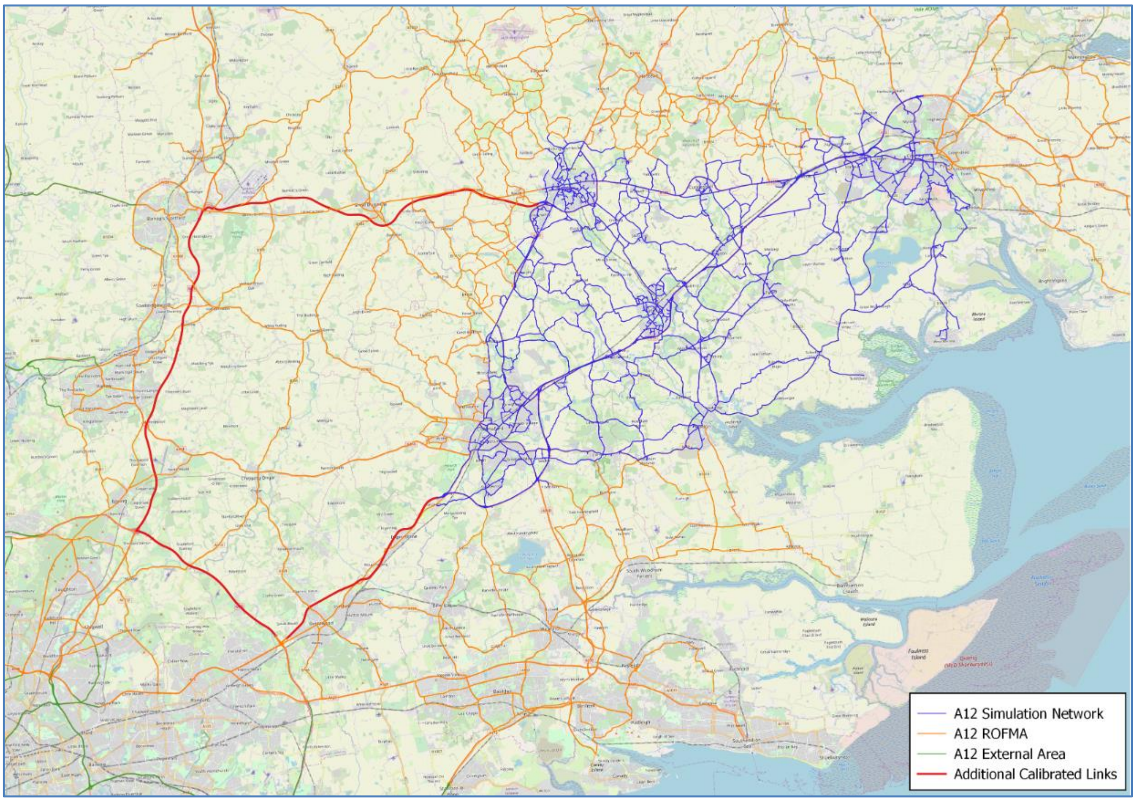
Plate 2-2 Local model network – buffer and simulation area



It was identified from previous modelling that reassignment may occur between the M11/A120 route and the A12 due to the scheme. The previous assessment identified significant greenhouse gas impacts from the scheme, which were considered to be potentially an overestimate because traffic reductions on the M11 were outside the traffic reliability area therefore could not be considered within the assessment.

To ensure that any traffic reductions on the M11 can be included during the PCF Stage 3 assessment, it was proposed to calibrate these links against traffic flow and journey time data. This provides a robust base for traffic flow and speed changes along those links in future year scenarios with and without the scheme. The links of interest are shown in Plate 2-3. Note that traffic data for these links would be provided for the greenhouse gas assessment only, and not for detailed noise and air quality assessments.

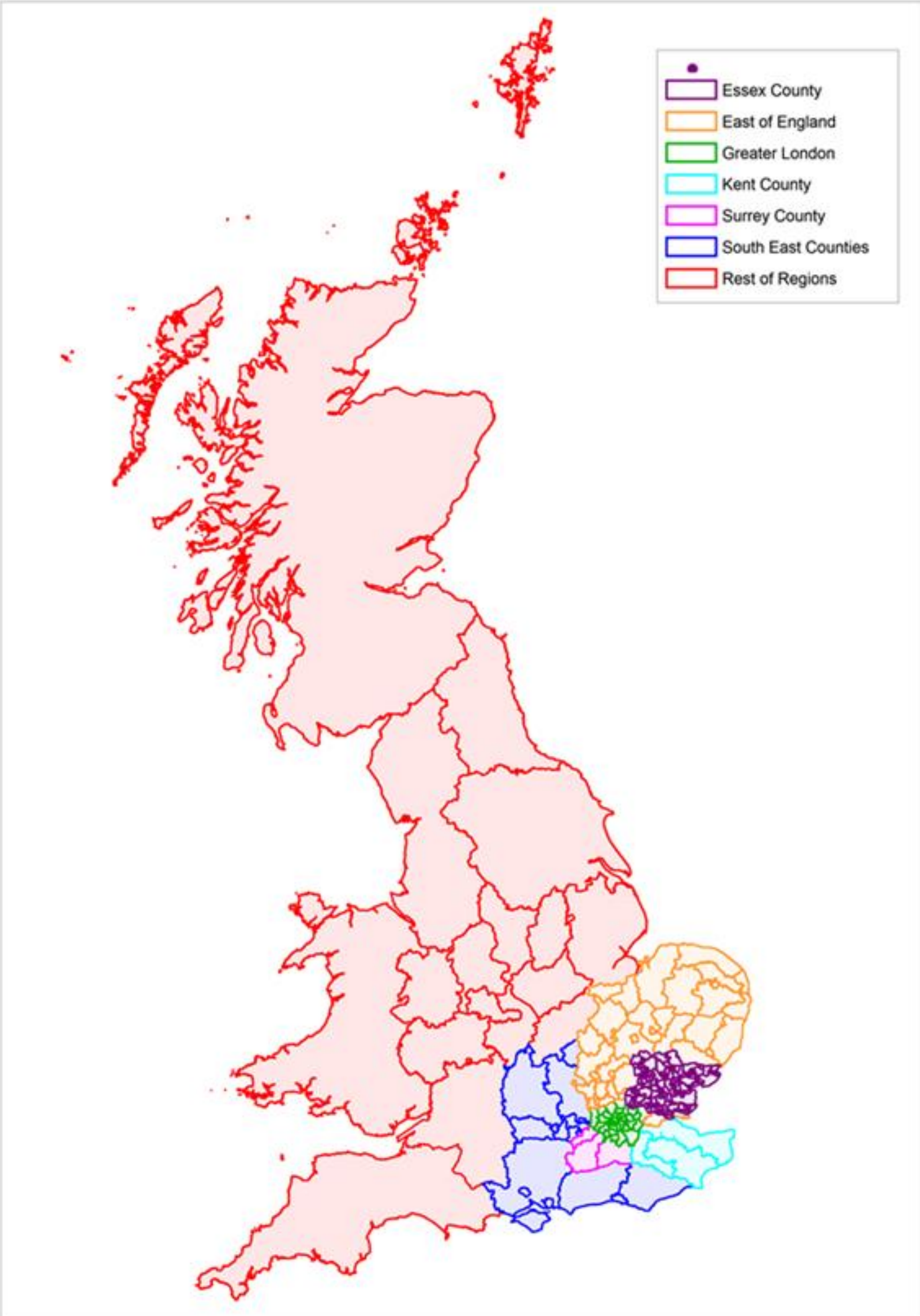
Plate 2-3 Local model network – additional calibrated links



2.5 Zoning system

The A12 model has adopted a similar approach to its zoning system as that of the previous A120 model, in that the initial zoning system was a compressed version of the zoning system received from SERTM which contained 250 zones. The compressed zoning system is shown in Plate 2-4.

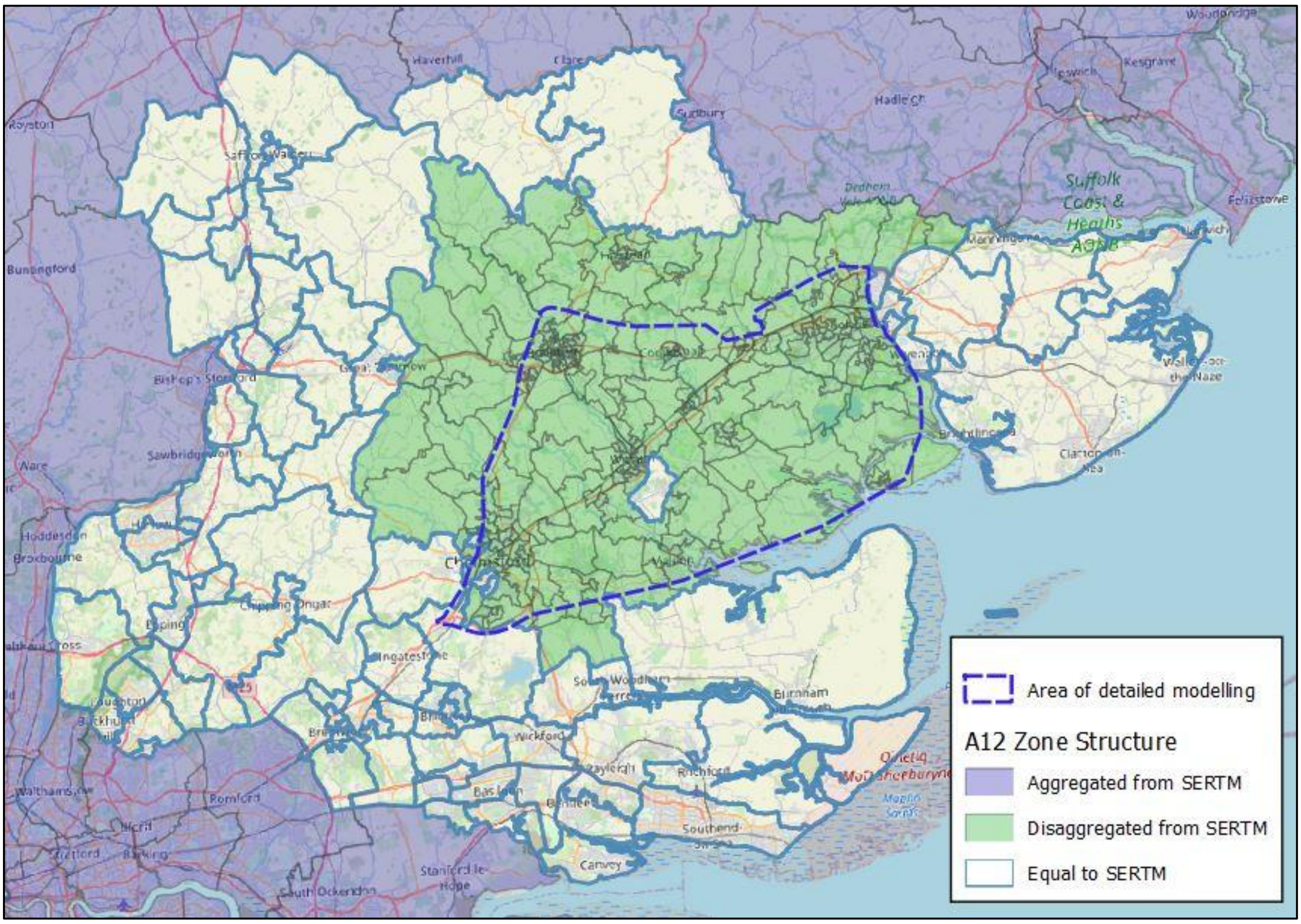
Plate 2-4 Compression of SERTM zones for A12 model



The zoning system received from SERTM was then disaggregated in the simulation area and its periphery to provide more detail in the geographic area of interest. Zones were disaggregated to Lower-Layer Super Output Area (LSOA) and, in some cases, Output Area (OA) level.

As well as zone disaggregation, a few zones to the west of Chelmsford were aggregated, where less detail was required. Zones which were disaggregated and aggregated between the SERTM and A12 zoning systems are shown in Plate 2-5.

Plate 2-5 A12 zone disaggregation and aggregation



In total 37 zones from the A120 zoning system were disaggregated to create 129 zones in the A12 model where greater detail was required. Similarly, nine zones from the A120 zoning system have been aggregated into two A12 model zones.

In total 61 zones from the SERTM zoning system were disaggregated to create 338 zones in the A12 model where greater detail was required. Similarly, 2,131 zones from the SERTM zoning system have been compressed and aggregated into 104 A12 model zones. There were 88 zones which were equivalent between SERTM and the A12 zoning systems, 16 of which represent ports and airports.

Zones representing the car parks at Hatfield Peverel Station, Witham Station, Kelvedon Station, Marks Tey Station and Sandon Park and Ride were also added during the model calibration stage.

A small number of changes to the zoning system were needed in the Colchester and Chelmsford areas compared to the Stat Con model. These changes were needed to improve the accuracy of the demand loading onto the network. The changes consisted of splitting zones or adjusting the zone connectors.

In total, the A12 zoning system consists of 579 zones, however 43 of these are dummy zones which hold no traffic and have been created for future year developments. Not including these there are 536 zones which are considered base year model zones.

2.6 Zone sectoring

For ease of analysis and understanding of the trip making patterns, the zoning system is grouped together into sectors. As with the zoning system itself, the sectors are more refined within the detailed modelled area, becoming coarser further out from the detailed area. A system of eighteen sectors was developed. This sector system is shown in Plate 2-6 and Plate 2-7.

Plate 2-6 A12 sector system

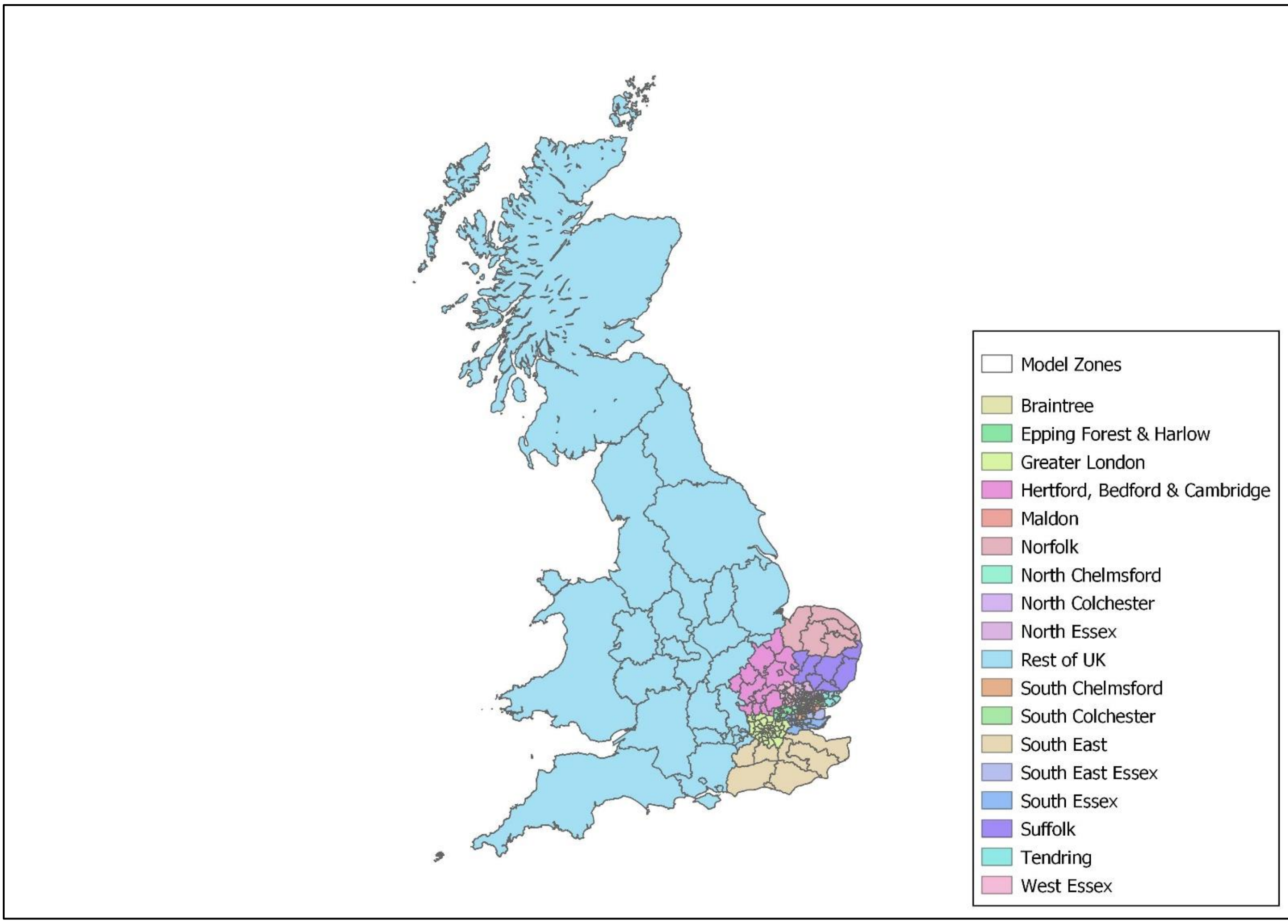
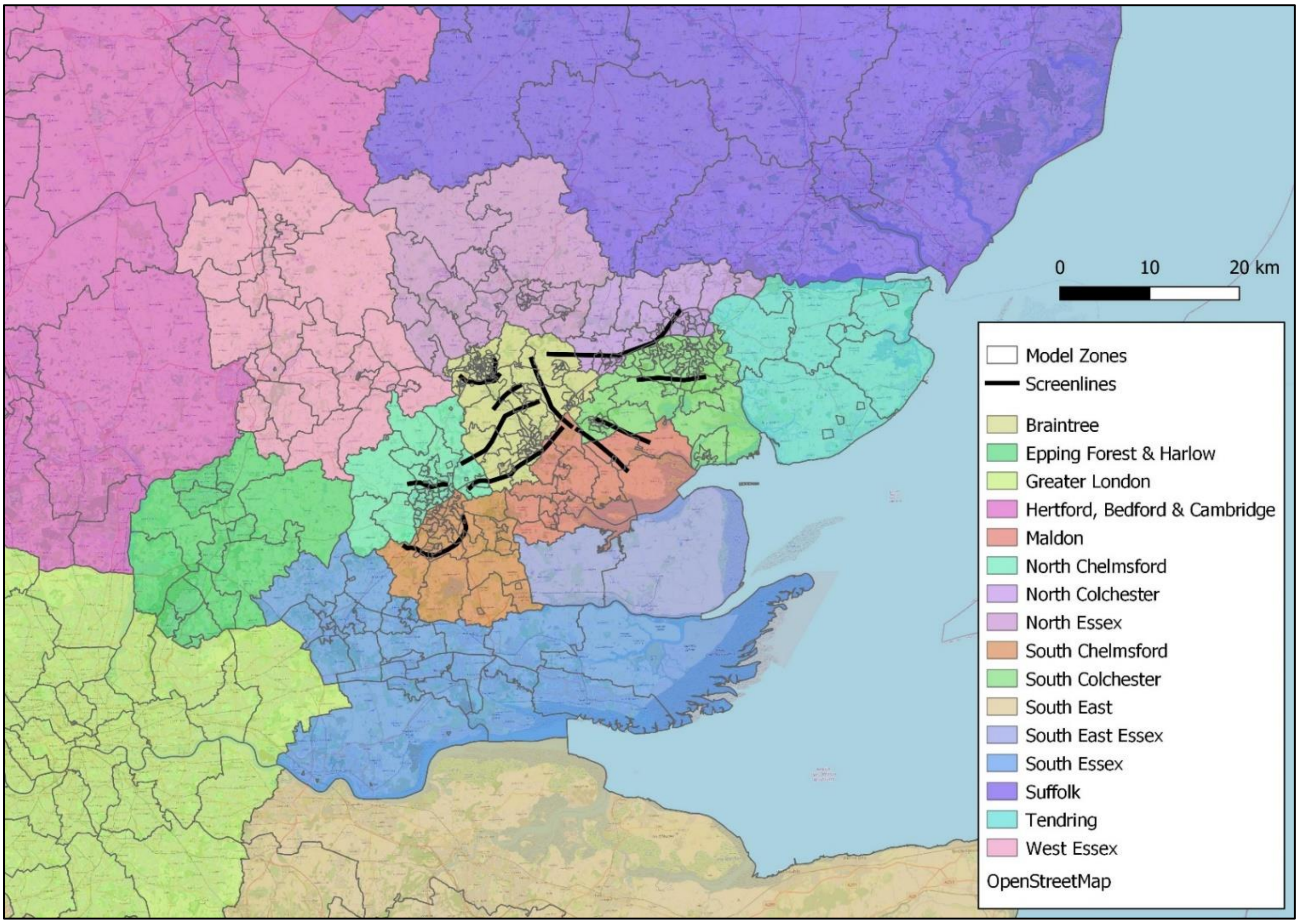


Plate 2-7 A12 sector system – buffer and simulation areas



2.7 Centroid connectors

The disaggregation and aggregation of zones required changes in some existing connectors and additional connectors to be added for new zones.

The connection from zones to the network in the simulation area have been placed in locations designed to represent real life entry points onto the network i.e. residential roads off the main highway network.

2.8 Time periods

The A12 Stage 3 DCO model represents peak hours, the times of which came from an analysis of traffic count data. Further detail on the analysis of the peak flows can be found in Appendix A 'Transport Data Package' of the ComMA report.

The three modelled hours are:

- AM peak hour (07:30-08:30)
- Average weekday inter-peak hour (10:00-16:00)
- PM peak hour (17:00-18:00)

2.9 User classes

The model segregates trips by vehicle type and trip purpose, as summarised in Table 2-1.

Table 2-1 Purpose / user class / vehicle class correspondence

Purpose	User class (UC)	Vehicle Class (VC)
Car Employer Business	UC1	VC1
Car Commute	UC2	
Car Other	UC3	
LGV	UC4	VC2
HGV	UC5	VC3

Each user class has a PCU factor of 1, except for HGVs. HGVs have an average PCU factor of 2.5 applied. This reflects the disproportionately greater impact HGVs have on capacity compared to cars and LGVs, due to the increased road space that they occupy and their lower acceleration and performance characteristics. A PCU factor of 2.5 is advised by TAG unit M3.1 Appendix D.7.2 for motorways and all-purpose dual carriageways, which form the key roads in the A12 study area.

2.10 Assignment methodology

Assignment is the process that traffic models use to predict the routes that road users take between their origin and their destination. Route selection is based on travel costs.

Travel cost (and in particular time) is assumed to depend on the flows in the network. The default assignment procedure within SATURN was used, which is based on Wardrop's Principle of traffic equilibrium. This principle states that "Drivers choose routes such that, at equilibrium, no individual trip maker can reduce his/her cost of travel by unilaterally changing route".

Such a model makes a number of assumptions, in particular:

- That network conditions and travel demand do not vary within the modelled period;
- That travellers in the network have had a long–term experience with these conditions, so that they perceive the travel costs correctly and know the "best" routes to take; and
- That all drivers within a particular User Class perceive travel costs in the same way. Costs are a combination of time and vehicle running cost, termed 'generalised cost'.

The model therefore provides a representation of average driver behaviour under long term conditions of recurrent congestion and uses a particular assignment algorithm known as Frank-Wolfe in order to achieve this in an industry standard manner.

2.11 Generalised cost formulations and parameter values

Generalised cost

VOT (Value of Time) and VOC (Vehicle Operating Costs) components are fixed values that help to inform the generalised cost formulation in route assignment. Generalised cost is the sum of the monetary (e.g. fuel or fare) and non-monetary (e.g. time) travel costs of a journey. VOT and VOC provide values that can be applied as coefficients to the journey distance and journey time of a particular route. TAG Unit M3-1 section 2.8.1 provides the formula for the calculation of generalised cost as follows:

$$\boldsymbol{Generalised\ Cost} = \boldsymbol{Time} + \left(\frac{\boldsymbol{VOC} * \boldsymbol{Distance}}{\boldsymbol{VOT}}\right) + \left(\frac{\boldsymbol{Tolls}}{\boldsymbol{VOT}}\right)$$

The parameters are influenced by a range of factors which include the purpose of travel, the speeds travelled by vehicles, and the number of passengers within a car.

The VOT and VOC used in the A12 DCO model have been based on the May 2021 version of the TAG Data Book (v1.15). These are presented in Table 2-2.

Calculations were undertaken using perceived values of time and distance (i.e. with VAT for non-business and without VAT for business trips), and as per guidance and processes advised by both TAG and National Highways TPG, using National Highways' VOT/VOC calculation worksheet.

When calculating the vehicle operating cost (VOC), the average speeds for each user class and each time period from the simulation area were taken from the previously validated PCF 3 A12 Stat Con model.

Table 2-2 Generalised cost parameters for 2019 (2010 prices in pence)

User Class	Period					
	AM		Inter peak		PM	
	PPM	PPK	PPM	PPK	PPM	PPK
Car Employer Business	30.92	12.27	31.68	12.27	31.36	12.27
Car Commute	20.73	6.01	21.07	6.01	20.81	6.01
Car Other	14.31	6.01	15.24	6.01	14.98	6.01
LGV	22.41	13.60	22.41	13.60	22.41	13.60
HGV	44.63	37.44	44.63	37.44	44.63	37.44

PPM = Pence per Minute – VOT coefficient, PPK = Pence per Kilometre – VOC coefficient

VOT values for LGVs represent an average LGV given in Table A1.3 of TAG Data Book. It should also be noted that as per the guidance in TAG Unit M3.1 paragraph 2.8.8, HGV ppm values are twice those given in TAG Unit A1.3. This relates to the fact that the value given in TAG Unit A1.3 relates to the driver’s time and does not take account of the influence of owners on the routeing of these vehicles.

Software parameters

SATURN uses a large number of assignment parameters. Parameters related to convergence criteria are provided in Table 2-3.

Table 2-3 Convergence criteria coded in SATURN

Parameter	Description	Model Coding	SATURN Manual Default
RSTOP	Measure of convergence of the assignment-simulation loops. The loops stop if ISTOP percent of link flows change by less than PCNEAR percent.	99	95
PCNEAR	% change in flows judged to be “near” in successive assignments.	1	5
NISTOP	The number of successive loops which must satisfy the ISTOP criteria.	4	4
MASL	Maximum number of assignment / simulation loops.	50	15
NITA	Maximum number of assignment iterations.	20	20
NITS	Maximum number of simulation iterations.	40	20
STPGAP	Critical gap value used to terminate assignment-simulation loops	0.003	1
KONSTP	The stopping criteria for assignment-simulation loops.	5	-

By setting the parameter KONSTP to ‘5’ SATURN seeks to terminate the assignment only when proximity (STPGAP) and stability (ISTOP/PCNEAR/NISTOP) measures are both satisfied. The criteria coded into SATURN are either consistent with, or more onerous than the requirements laid out in TAG Unit M3.1 are presented in Table 2-4. Using more onerous criteria gives an increase in confidence in the robustness and stability of the model.

Table 2-4 TAG convergence criteria

Convergence Type	Convergence Measure	Acceptable Values
Proximity Indicator	Delta (denoted δ) and % GAP	<0.1% or at least stable with convergence fully documented and all other criteria met
Stability Indicator	% of links with flow change < 1%	Four consecutive iterations, with >98% links meeting criteria
	% of links with cost change < 1%	Four consecutive iterations, with >98% links meeting criteria
	% change in total user costs	Four consecutive iterations, with <0.1% links meeting criteria (SUE only)

2.12 Capacity restraint mechanisms

Capacity restraint is the process by which speeds are adjusted to ensure they are consistent with the assigned traffic flows. TAG Unit M3.1 recommends that capacity restraints are applied throughout the Fully Modelled Area for models of congested areas. The restraints have been applied either to the links in the form of speed flow curves or to junctions via priority rules, gap acceptance and saturation flow. Further detail on network coding is given in Chapter 5 of this report.

2.13 Software packages and versions

The following software packages and versions were used:

- The highways model has been developed in SATURN V11.4.07H
- The variable demand model has been developed in DIADEM v7.0.2

3. Model Standards

3.1 Introduction

The criteria used for calibration and validation of the model, and convergence standards applied to check the stability and reliability of the assignment results, are based on the measures set out in TAG Unit M3.1.

3.2 Validation criteria and acceptability guidelines

The validation of the highway assignment has been quantified using the following measures taken from TAG unit M3.1 paragraph 3.3.5:

- Assigned flows and counts totalled for each screenline as a check on the quality of the trip matrices;
- Assigned flows and counts on individual links 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.

Screenlines

For the assessment of screenline flows, the criteria to meet is set out in Table 3-1.

Table 3-1 Screenline flow validation criterion

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

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

- Screenlines should normally be made up of five links or more;
- 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 other screenlines used as constraints in matrix estimation and for screenlines used as independent validation.
- The comparison should be presented by vehicle type.

It should be noted here that it was not always possible to draw up screenlines consisting of more than five links. This is due to the rural nature of parts of the study area. Similarly, some screenlines contain a mix of both rural and urban roads and high and low flow roads.

The GEH statistic is often more appropriate than percentage differences when comparing the closeness of two data sets of low numbers, such as the observed and modelled HGV volumes, which are generally much lower than car totals. This is because GEH takes into account the magnitude of the numbers involved.

Link based calibration and validation

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.

These criteria are detailed in Table 3-2 and include reference to the GEH statistic measuring the difference between modelled and observed flows. The GEH statistic is defined below:

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

Where: M is the modelled flow on a link, and C is the observed flow.

Table 3-2 Link flow validation criteria

Criteria	Description of Criteria	Acceptability Guideline
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	> 85% of cases
	Individual flows within 400 veh/hr of counts for flows more than 2,700 veh/hr	> 85% of cases
2	GEH < 5 for individual flows	> 85% of cases

TAG guidance unit M3.1, paragraph 3.3.12, states that the above comparison of modelled and observed flows should be presented for total vehicle flows and for car flows, but not for LGV and HGV flows due to there being insufficient accuracy in the individual link counts for these vehicle types. In addition, the above information should be presented by time period.

Data collection sites used in the development and validation of the base year model are presented within Chapter 3.

Journey times

TAG also contains acceptability guidelines for the validation of journey times. This criterion is provided in Table 3-3.

Table 3-3 Journey time validation criterion

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

3.3 Impact of matrix estimation

TAG provides guidance regarding the acceptable changes to the highway 'prior' matrices that should result from the application of matrix estimation. This guidance is provided in Table 3-4.

Table 3-4 Significance of matrix estimation changes

Measure	Significance Criteria
Matrix zonal cell values	Slope within 0.98 and 1.02 Intercept near zero R2 in excess of 0.95
Matrix zone trip ends	Slope within 0.99 and 1.01 Intercept near zero R2 in excess of 0.98
Trip length distributions	Means within 5% Standard deviations within 5%
Sector to sector level matrices	Differences within 5%

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.

3.4 Convergence criteria and standards

To confirm that the model outcomes are reliable, the stability of the assignment should be assessed. This ensures that any flow changes occur directly as a result of the scheme, rather than as a result of random flow changes due to poor convergence. TAG advises that the model should converge to a point in which routes obey Wardrop's First Principle of Traffic Equilibrium. TAG unit M3.1 paragraph 2.7.3 defines this 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."

In order to assess this, SATURN uses the following measures of convergence:

- Proximity to the assignment objective; and
- Stability of model outputs between consecutive iterations.

The first measure relates to how close the model is to a converged solution, which varies depending on the preferences of the user or software package being used. In SATURN this equates to how close the model is to Wardrop's Principle of Equilibrium and is measured using the Delta (or Gap) function.

The Delta value therefore represents the excess cost incurred by failing to travel on the route with the lowest generalised cost and is expressed relative to that minimum route cost. The excess cost is summed over each route between each O/D pair and multiplied by the number of trips between each O/D pair. This is divided by the minimum cost summed over each route between each O/D pair, also multiplied by the number of trips between each O/D pair. For the model to be considered sufficiently well converged, the gap value must be less than 0.1%.

The second measure relates to the level of flow change on links between iterations.

A summary of the convergence criteria provided by TAG is provided in Table 3-5.

Table 3-5 Convergence criteria

Measure of Convergence	Base Model Acceptable Values
Delta and %Gap	Less than 0.1% or at least with convergence fully documented and all other criteria met
Percentage of links with flow change < 1%	Four consecutive iterations greater than 98%
Percentage of links with cost change < 1%	Four consecutive iterations greater than 98%
Percentage change in total user costs	Four consecutive iterations less than 0.1%

The convergence criteria should be satisfied to give confidence that the model results are stable, consistent and robust.

4. Calibration and Validation Data

4.1 Introduction

This chapter provides a summary of the calibration and validation data used for the creation of the base model. Further information can be found in Appendix A 'Transport Data Package' of the ComMA report.

4.2 Traffic counts for calibration and validation

A number of existing traffic count datasets were used in developing the A12 Stage 3 DCO traffic model. These are:

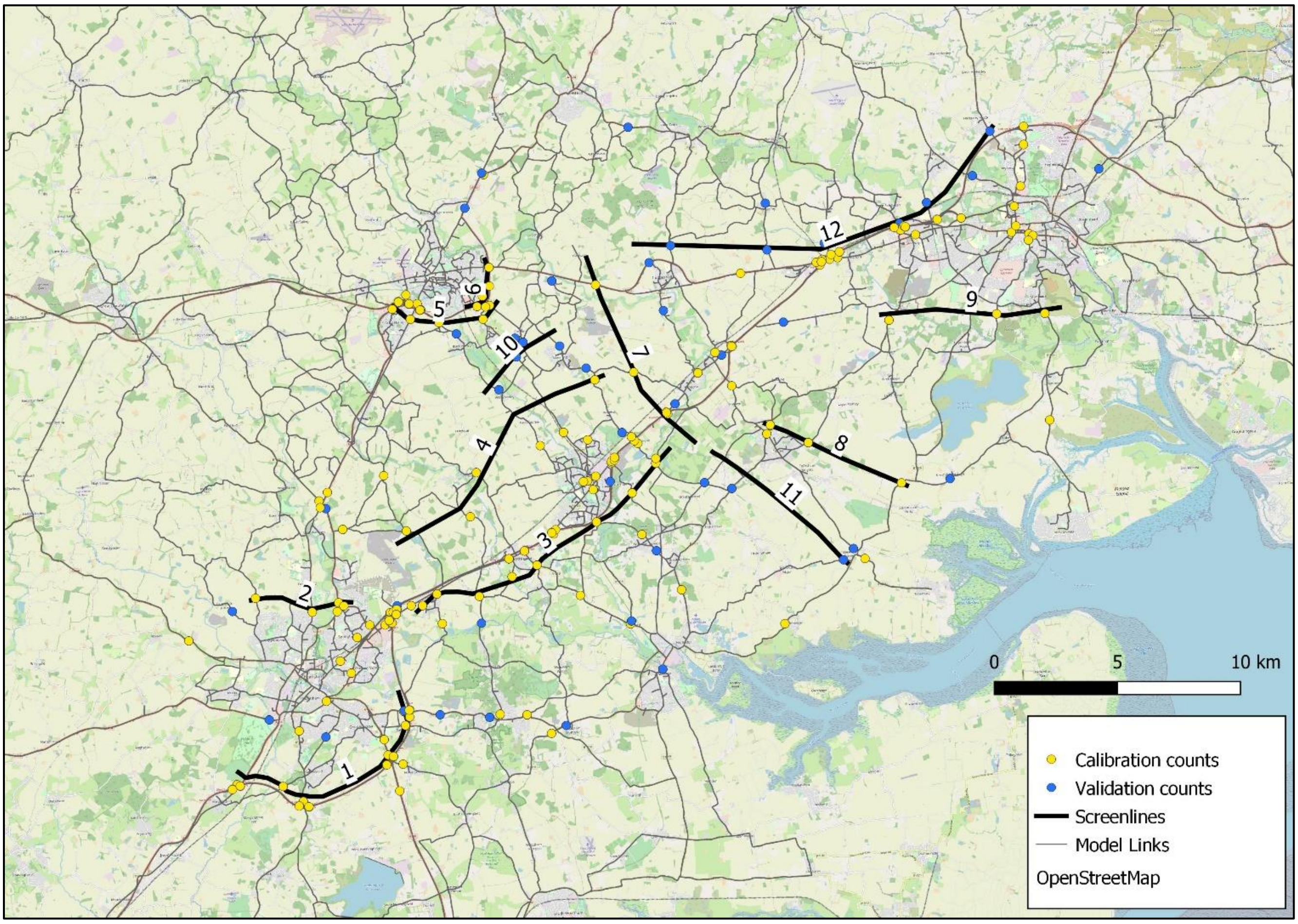
- Counts collected for the A12 PCF Stage 2 model (2016)
- Counts collected for the A120 Braintree to A12 model (2016)
- Counts obtained from Essex County Council (ECC) (Between 2016 and 2019)
- Counts obtained from National Highways' TRIS (Between 2016 and 2019)

While it was intended that 2020 data would also be collected, these surveys were cancelled due to the Coronavirus outbreak. As such, only existing traffic data was used in the model. The existing traffic data included:

- Automatic Traffic Count (ATC)
- Manual Classified Count:
    - Manual Classified Counts on Link (MCC)
    - Manual Classified Turning Counts (MCTC)

From this data, 12 bi-directional screenlines were constructed to capture the total flow of vehicles within the study area. The count sites and screenlines used in the calibration and validation process are illustrated in Plate 4-1 .

Plate 4-1 Location of calibration and validation count sites



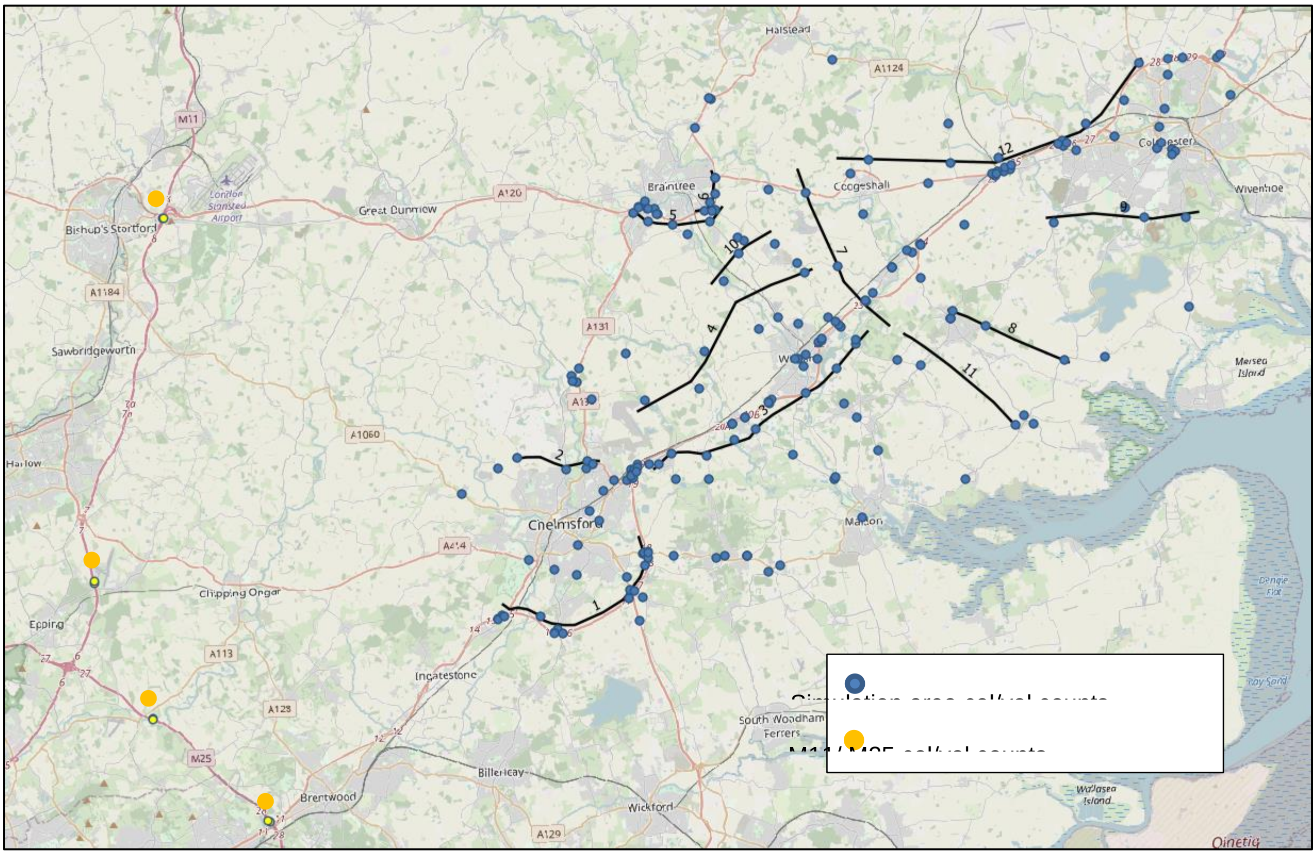
In addition to the screenlines, independent counts for both calibration and validation have been included to ensure the robustness of the model. There were 404 counts in total that were used in the model calibration and validation process. Of these, 313 counts were used to calibrate the model and 91 counts were used to validate the model. This information is summarised in Table 4-1.

Table 4-1 Summary of calibration and validation count sites

Count type	Number of sites
Calibration Screenline	86
Validation Screenline	28
Individual Calibration Site	227
Individual Validation Site	63

Of the total calibration sites, eight count sites located within the buffer network were also included within matrix estimation with the aim of ensuring the right levels of traffic along the M11 and M25. Calibration and validation count sites are shown in Plate 4-2.

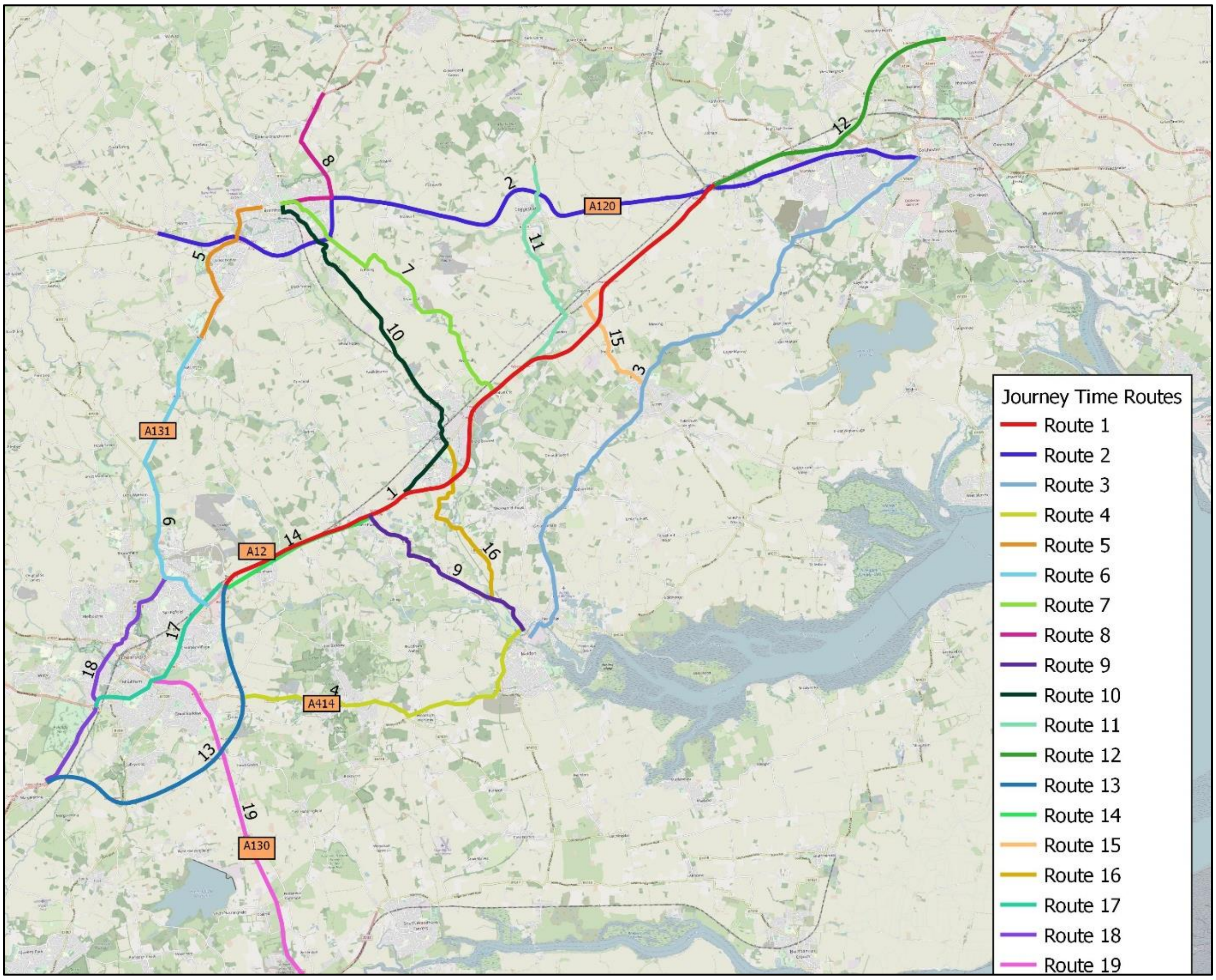
Plate 4-2 Location of calibration and validation count sites – buffer area



4.3 Journey time routes for validation

Within the fully modelled area, 19 journey time routes have been identified to validate the A12 Stage 3 model with respect to journey times. The journey time routes are shown in Plate 4-3 . These represent movements going north to south and east to west, which cover the modelled area evenly.

Plate 4-3 Simulation area journey time routes



Journey time routes vary between 4km and 31 km. Although the TAG guidelines mention that routes should not be longer than 15 km, three of the 19 journey time routes are longer than this due to the size of rural areas between the key locations within the study area.

Table 4-2 provides a list of all journey time routes within the model.

Table 4-2 Journey time routes

Route ID	Location	Direction	Length (km)
1	A12 Junction 19 - 25	NB	25.3
		SB	25.3
2	A120 Braintree to A12	EB	30.9
		WB	30.7
3	Maldon Road Colchester to Maldon	NB	25.5
		SB	25.2
4	Maldon Road Maldon to Chelmsford	EB	12.7
		WB	12.9
5	A131 Great Leighs to Braintree	NB	6.5
		SB	6.6
6	A131 Chelmsford to Great Leighs	NB	11.6
		SB	11.5
7	Cressing Road Braintree to Rivenhall	NB	12.0
		SB	12.0
8	A131 Braintree Gosfield Road	NB	5.7
		SB	5.8
9	B1019 Maldon to Hatfield Peverel	NB	7.5
		SB	7.5
10	B1018 Witham to Braintree	NB	14.3
		SB	14.4
11	B1024 Kelvedon to Coggeshall	NB	8.9
		SB	8.9
12	A12 Junction 25 - 29	NB	10.9
		SB	11.0
13	A12 Junction 15 - 19	NB	14.6
		SB	14.3
14	B1137 Boreham to Hatfield Peverel	NB	5.7
		SB	5.7
15	B1023 Feering to Tiptree	NB	4.4
		SB	4.4
16	B1018 Witham to Maldon	NB	7.2
		SB	7.2
17	Chelmsford to A12 Junction 19	EB	6.9
		WB	7.0
18	A12 Junction 15 to Chelmsford	NB	9.1
		SB	9.1
19	A130 to Chelmsford	NB	12.6
		SB	12.9

Observed travel times for the journey time routes have been calculated using DfT GPS data obtained from Teletrac Navman, which provides a large sample of journey time data across the links in the scheme appraisal area. The journey time data is summarised for the links in the Ordnance Surveys Integrated Transport Network (ITN), and the link data was combined to provide average times and speeds on the identified routes. Further detail on the checking of the journey time data can be found in Appendix A 'Transport Data Package' of the ComMA report.

5. Network Development

5.1 Introduction

This chapter outlines how the model network was developed. The simulation area, rest of the fully modelled network and external area are illustrated in Section 2.4.

5.2 Detailed description of network coding

Within the simulation area, each node has been modelled in detail with the inclusion of saturation flows, correct turn availability, signal timings where required, and correct priority at both priority junctions and signalised junctions. Speed flow curves and free flow speed parameters were added to links based initially on the DfT GPS data (source: Teletrac Navman). Further detail is provided below.

Link length and classification

The A12 model has been produced based upon the existing A120 model, therefore the majority of the road network already existed in the model. However, it was necessary to extend the simulation area as outlined in Section 2.4. The extent of this new simulation network was initially outlined in GIS. The GIS-based network was then converted to a buffer SATURN network, which was then converted to detailed simulation network.

GIS and Google Maps were used to determine the following:

- Link length
- Link start and end coordinates (node locations)
- Road link classification

Fixed speeds and speed-flow curves

Speeds were applied to the model network either as “fixed speed” on a link, i.e. which does not vary by traffic volume, or by using “Speed Flow Curves” where the vehicle speed can be plotted depending on traffic volume between two defined points on the curve. These two points are:-

(i) the speed where flow is at link capacity: and

(ii) the free flow speed attainable if there were no other vehicles using it and consequently no congestion. This upper limit of Free Flow speed is governed by speed limits or link topography if this is a lower constraint.

The DfT GPS data was initially used to estimate free-flow journey times on the transport network. Free-flow speed is the speed travelled along a section or route if there were no delay as a result of other road users and is therefore largely a function of the road geometry. Free-flow journey times are estimated by taking the median of all observed 2016 DfT GPS data between 21:00 and 05:00 with the exclusion of observations where night-time road works or excessive speeding may have influenced the median free-flow speed.

On the external network, fixed speeds were used as there was expected to be no traffic flow changes in this area due to the scheme which would affect speeds. These speeds were based on the 2015 DfT GPS dataset released by National Highways as used for the Regional Transport Models (RTM).

On road links, increasing traffic volumes result in decreasing speeds. It is also the case that different types of roads have different levels of capacity; for example, motorways and dual carriageways have a greater capacity than urban roads. Both the above characteristics are modelled within SATURN using speed-flow curves.

The DCO model uses the A120 model SFC's as a starting point, which is based on the RTM network coding manual. TAG guidance advises that speed-flow curves are applied (in general) on rural and inter-urban links, with fixed speeds applied within the urban areas. This is the approach used in the A120 model, however, when coding the extension of the simulation network for Chelmsford, Colchester and Maldon, it was decided to also include speed-flow curves on links in urban areas as they were not modelled in such fine detail.

A total of 136 different link types accommodating all different combinations of location categories (urban/suburban/village/rural), levels of development, road type (A, B or C road), road widths/condition, number of lanes, vehicle restrictions and type of model link (simulation or buffer) was produced. For each link type, a speed-flow curve was defined.

Where appropriate, in the Fully Modelled Area links have been assigned a speed-flow curve by matching their link characteristics and observed free-flow speed to the catalogue of SFCs.

The full list of link types, along with free flow speed, capacity, and parameters for the volume-delay functions is given in Appendix A.

As far as HGV speeds are concerned, the "CLICKS" facility in SATURN has been used. This recognises that for certain high speed link types, e.g. Motorways or Dual Carriageways, HGVs are not legally permitted to reach the maximum speed permitted for cars and in these cases the HGVs maximum speed is capped to a level below other vehicle classes to correspond to the limit for their vehicle type. This "CLICKS" data was applied by means of a FILVSD file which capped HGV maximum speeds dependent on the Capacity Index of the link concerned.

5.3 Junction types and characteristics

Signalised junctions

Signal staging and timings were coded into the A12 model using observed data provided by Essex County Council and signal timings from the previous A12 Stage 2 model. Some alterations were made to SATURN signal timings to improve count and journey time validation where necessary.

Junction coding includes the coding of saturation capacities for turning movements at each junction. Saturation capacities reflect the maximum number of PCUs per hour that can make a particular turning movement depending on a number of variables relating to the junction type, priority rules and other impedances. The A120 model used saturation flows based on calculations given in Research Report 67 (Kimber, McDonald and Hounsell, Transport Research Laboratory, 1986).

The A12 Stage 3 model uses the same values for coding, these are shown in Table 5-1 for signalised junctions.

Table 5-1 Standard turn saturation flows for signalised junctions

Location	1 Lane			2 Lanes			3 Lanes	4 Lanes
	Left Turn	Straight	Right Turn	Left Turn	Straight	Right Turn	All	All
Urban	1,300	1,500	1,360	2,610	3,000	2,730	-	-
Suburban	1,550	1,700	1,580	3,090	3,400	3,160	6,000	8,000
Rural	1,860	2,000	1,890	3,720	4,000	3,770	6,000	8,000

Priority junctions

The coding of priority junctions is based on the direct application of SATURN give-way and opposed traffic turn priority markers to represent the individual movements at a junction.

As with the signalled junctions an initial set of saturation flows for priority junctions was given in the A120 coding manual. These are outlined in Table 5-2.

Table 5-2 Standard turning saturation flows (PCUs per lane) for priority junctions

Location	Major-to-Minor			Minor-to-Major		
	Left Turn	Straight	Right Turn	Left Turn	Straight	Right Turn
Urban	1,300	1,500	1,300	1,300	1,500	1,360
Suburban	1,550	1,700	1,550	1,550	1,700	1,580
Rural	1,860	2,000	1,860	1,860	2,000	1,890

Roundabouts

For roundabouts, the classifications of saturation flows and other roundabout parameters (such as circulating capacity and the time to circulate the roundabout) are based on the roundabout size and the number of lanes approaching the roundabout. Roundabouts have been classified as mini-roundabouts, ‘normal’ roundabouts with single or flared approaches, and 'large' roundabouts with two or more lane approaches.

Within the current setup of SATURN, saturation flows are applied at an entry-level and not for individual turns. If different saturation flows are provided by turning movements then SATURN will use the maximum of these for all movements. Therefore, the values detailed in the table below are saturation flows for a given entry to a roundabout and are coded for all movements on a given arm.

Table 5-3 Roundabout saturation flows

Roundabout Type	Circulating Capacity (PCUs/hr)	GAPR Values (sec)	Lanes at Stop Line	Time to Circulate (sec)	Total Saturation Flow (PCUs/hr)
Mini	1,440	2.5	1	5	1,100
Normal single-lane entry	1,600	2.25	1	10	1,100
Normal with flared approach	1,800 – 3,200	2.0 – 1.125	2	10	1,650
Large with dual two-lane approach	3,200 – 3,600	1.125 – 1.0	2	15	2,200
			3	15	3,200

GAPR values are the gap acceptance values for SATURN.

It should be noted that typically, the roundabout node type was only used for small or mini roundabouts, while larger roundabouts were coded as a series of priority junctions. This enabled the distance between entry arms and time to circulate the roundabout to be taken into account and provided a better fit to the observed conditions.

In the detailed simulation area, for majority of junctions, gap values were used based on the roundabout type and for the remaining junctions, the standard SATURN default gap value of 2 was used.

5.4 Public transport services

In total 38 bus routes and their frequencies have been coded into the A12 model. Bus timetable and routing information was extracted from the interactive Essex Public Transport map (CartoGold) developed by Essex County Council. Bus routes that start, terminate, or go through the simulation area have been included. The bus routes range from those isolated to the town centres to the more strategic bus routing.

5.5 Freight transport restrictions

In order to prevent HGVs routing onto rural and restricted roads, a combination of time penalties and bans has been applied to links where appropriate. Google Maps and OSM maps were used to identify the links that needed restrictions. Bans were imposed on the network for links where there was a visible height or weight restriction for HGVs, e.g. weak or low bridge. Penalties were used generally where there was no legal restriction but for calibration purposes where needed to discourage HGVs from routing via clearly unsuitable narrow country lanes. Plate 5-1 shows HGV bans while Plate 5-2 shows HGV time penalties present in the A12 model.

Plate 5-1 Modelled HGV bans

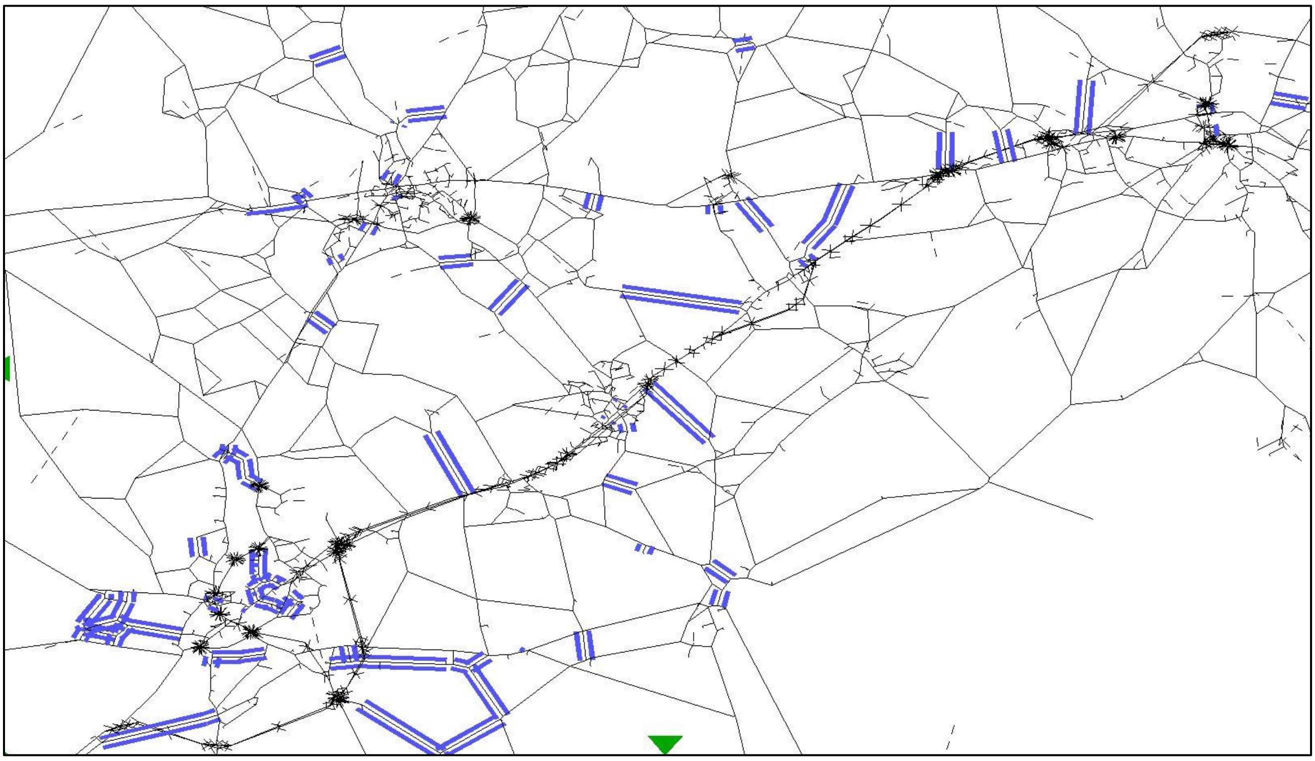
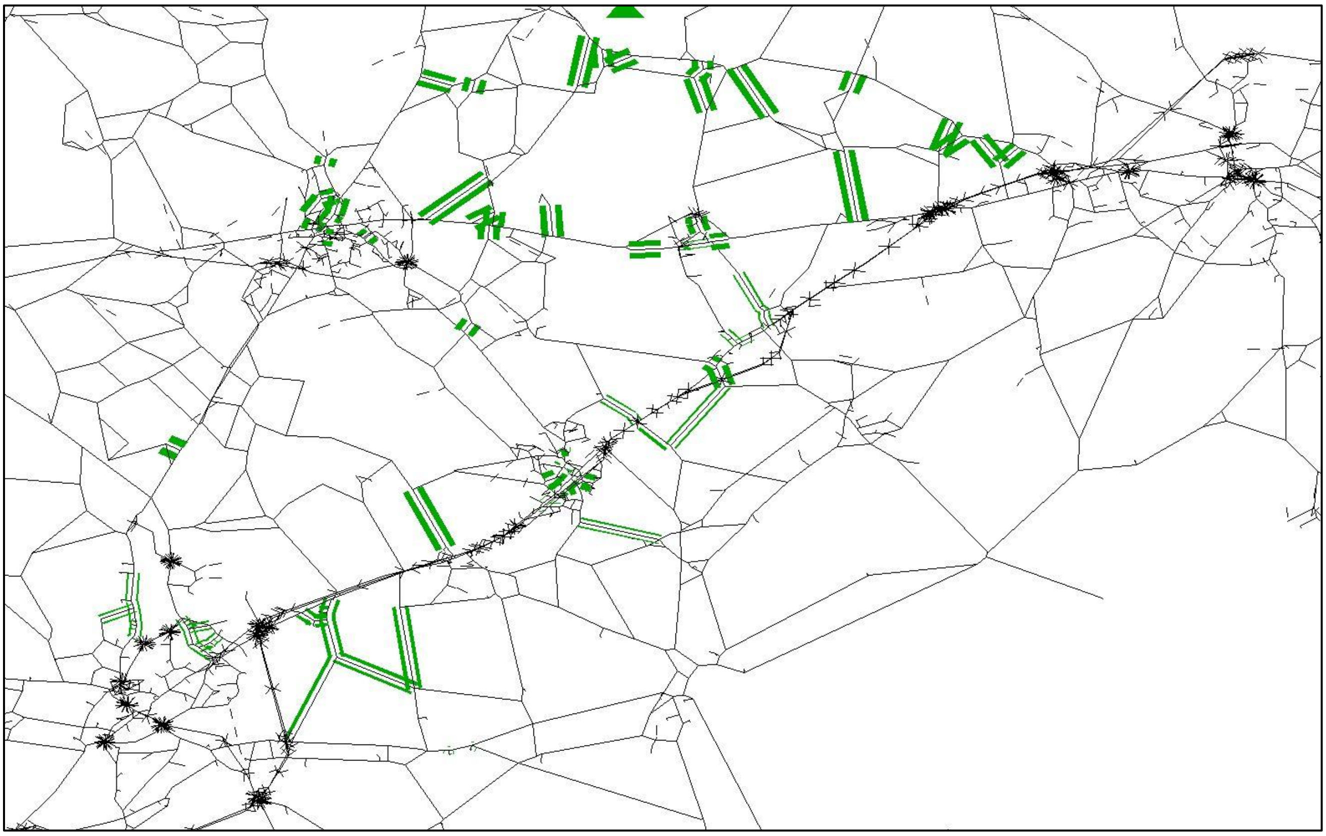


Plate 5-2 Modelled HGV time penalties



6. Trip Matrix Development

6.1 Introduction

The traffic modelling requirements for A12 PCF Stage 3 proposed that the updated DCO model should incorporate new origin/destination data that was being procured as part of the Regional Traffic Model (RTM) update. This data was due to be available in early 2021. However, due to methodological inconsistencies between how the 2015 and 2021 RTM matrices were developed, this approach was not possible.

It was therefore agreed with National Highways' Transport Planning Group that the DCO model's origin/destination data would still be based on that from the South East Regional Transport Model Design Fix 3 (SERTM DF3) 2015 data.

The 2019 matrix development methodology uses the SERTM DF3 prior matrices to produce the A12 Stage 3 DCO model prior matrices.

The aggregated demand from SERTM has been disaggregated to the A12 zoning system and then factored from 2015 to 2019 using National Trip End Model (NTEM 7.2) and Road Traffic Forecast (RTF18).

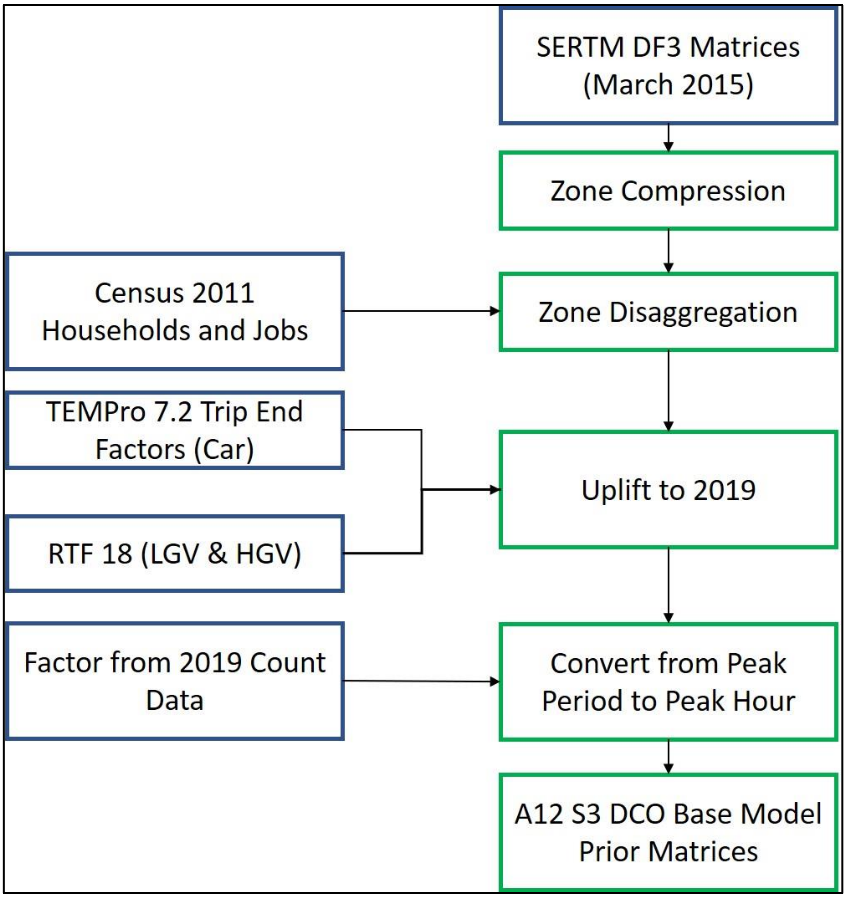
Finally, the demand matrices were converted from average hour peak period demand to a peak hour demand.

The demand matrix development process is discussed in the following sections:

- SERTM Demand Aggregation/Disaggregation
- Uplifting to 2019
- Converting Peak Period Demand to Peak Hour Demand

The base year demand methodology is summarised in Plate 6-1 .

Plate 6-1 Base year demand methodology



6.2 Matrix development

SERTM demand aggregation and disaggregation

Following the same approach as the A12 Stat Con Model, SERTM 2015 demand was used to develop the demand matrices. The first step in the process was to aggregate and disaggregate the SERTM demand in line with the A12 zoning system to allow a greater level of detail within the simulation area and less detail in the external area.

For the disaggregation, the number of jobs and households from Census (2011) was used. A zone equivalence table between SERTM zoning system, A12 zoning system and Census was set up.

Each SERTM matrix OD pair was split based on the relative proportions of households and/or jobs in the Census OA origin zone and destination zone depending on the time period and user class. For example, AM peak commuter trips from OA zone A to OA zone B depended on the relative number of households in zone A compared to the SERTM zone total and the relative number of jobs in zone B compared to the SERTM zone total. The trips at OA level were then aggregated to match the A12 zoning system.

The assumptions for each time period and user class are outlined Table 6-1 below. Intra-zonal trips were present in the SERTM prior matrices and as such included in the disaggregated matrices.

Table 6-1 Assumptions for use of demographic data to split SERTM zones

Period	User Class			Origin	Destination
AM	UC1	Car	Employer's Business	Jobs	Jobs
AM	UC2	Car	Commuter	Households	Jobs
AM	UC3	Car	Other	Households	Jobs
AM	UC4	LGV	Light Goods Vehicle	Jobs	Jobs
AM	UC5	HGV	Heavy Goods Vehicle	Jobs	Jobs
IP	UC1	Car	Employer's Business	Jobs	Jobs
IP	UC2	Car	Commuter	Jobs+Households	Jobs+Households
IP	UC3	Car	Other	Jobs+Households	Jobs+Households
IP	UC4	LGV	Light Goods Vehicle	Jobs	Jobs
IP	UC5	HGV	Heavy Goods Vehicle	Jobs	Jobs
PM	UC1	Car	Employer's Business	Jobs	Jobs
PM	UC2	Car	Commuter	Jobs	Households
PM	UC3	Car	Other	Jobs+Households	Jobs+Households
PM	UC4	LGV	Light Goods Vehicle	Jobs	Jobs
PM	UC5	HGV	Heavy Goods Vehicle	Jobs	Jobs

Uplifting to 2019 base year

The SERTM base year is 2015, however, the A12 Stage 3 DCO base year model represents 2019. It was therefore necessary to adjust the demand.

For car trips, National Trip End Model (NTEM) via TEMPro 7.2 was used to factor the demand. The growth was applied at Middle Layer Super Output Area (MSOA) level in the internal area and GB level in the external area.

To growth the LGV and HGV trips, the DfT Road Traffic Forecasts (RTF18) dataset was used. An average factor from all roads for Eastern England was used. These factors were derived for LGV and HGV trips separately.

Target trip end totals were calculated based on the 2015 trip end totals and the trip end growth factors. A furness procedure was then used to update the 2015 demand matrices to 2019 using the target trip end totals described above. This was doubly constrained for all time periods and purposes since matrices are in OD format.

Converting peak period demand to peak hour demand

As SERTM represents average peak period demand rather than the single AM and PM peak hours used in the A12 model, the following factors were applied to convert to peak hour models:

- AM peak hour (07:30-08:30)
  - Car: 1.128
  - LGV: 1.076
  - HGV: 1.031

- Average weekday inter-peak hour (10:00-16:00)
  - No factor required

- PM peak hour (17:00-18:00)
  - Car: 1.089
  - LGV: 1.05
  - HGV: 1.023

These factors were derived from analysis of observed daily traffic flow profiles in the modelled area and applied globally to all OD movements. More detail on the analysis of peak flows can be found in the *Transport Data Package (DCO model update) – Report* (*HE551497-JAC-HTE-SCHW-RP-TR-0046*).

6.3 Validation of matrices

The output demand matrices were validated against the demand for the A120 Braintree to A12 transport model and NTS / NTEM as secondary data sources. The following validation checks were undertaken:

- Sector-to-sector changes compared to A120 Braintree to A12 transport model by time period.
- Trip purpose proportions comparison to A120 Braintree to A12 transport model.
- Trip end comparison at sector level to A120 Braintree to A12 transport model and at Local Authority level to NTEM.

All the validation checks above were carried out on the demand before being converted to peak hour demand. For each of the checks listed, there was no significant change compared to the A120 Braintree to A12 model. Any changes were minor and localised to sector boundary differences between models.

The output adjusted matrices were used as prior demand matrices and assigned within SATURN for calibration and validation of the wider link counts and screenlines.

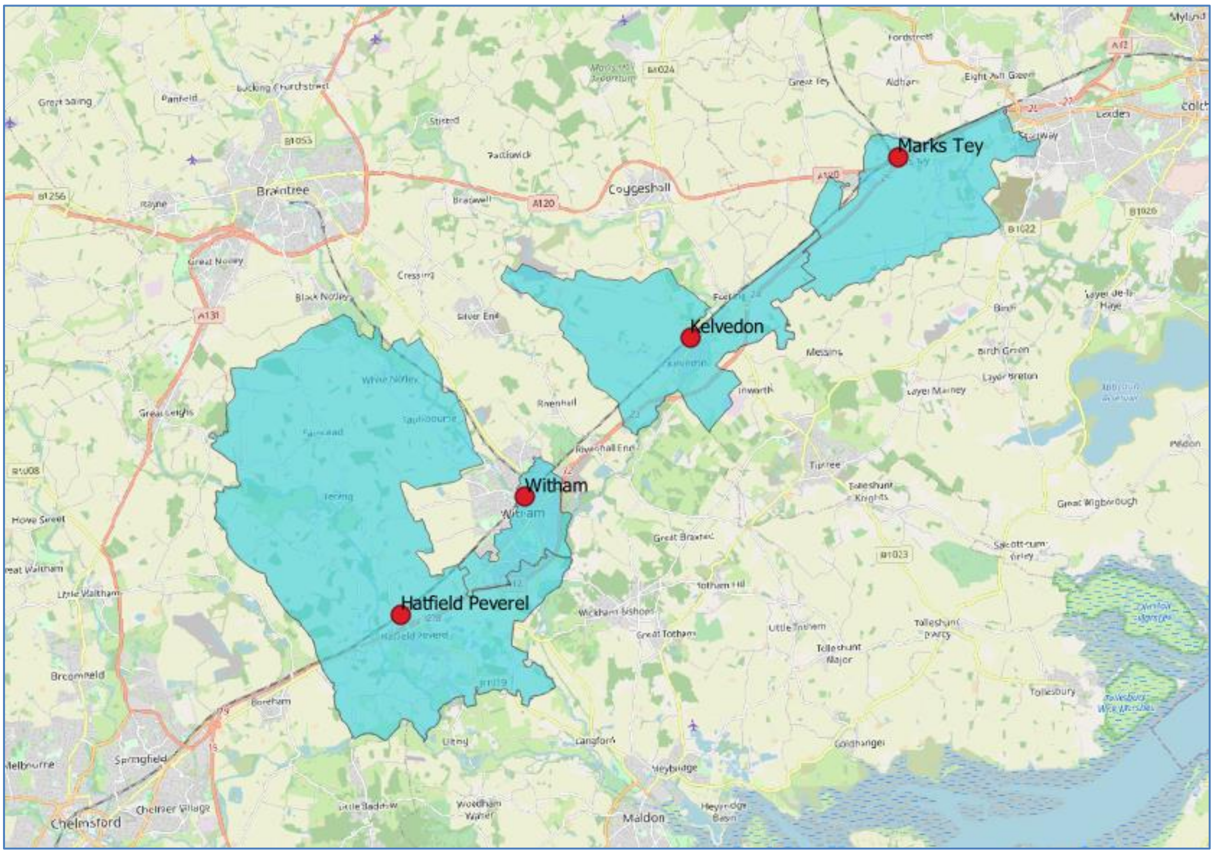
6.4 Rail station car parks and Park & Ride car park demand

During model calibration it became apparent there was a potential lack of demand on local roads to and from rail stations and Sandon Park & Ride site in all time periods.

The SERTM demand for the zones containing the four rail stations and Sandon P&R were examined and compared to car parking availability, local count data, and figures from station demand usage and it was decided the demand was too low in these zones.

The four stations considered are shown in Plate 6-2.

Plate 6-2 Station SERTM zones plot



The lack of trips can be attributed to the SERTM demand methodology. A trip captured within the underlying Mobile Phone Origin-Destination (MPOD) data, with rail as the main mode of travel, is represented as a PT trip from true origin to true destination (e.g. home to work location, with no corresponding car access/egress leg to the station added to the highways demand[1]). This means car access trips to

[1] Further reading on the methodology applied to MPOD derived trips can be found in the SERTM Model Validation Report (Highways England, 0003-UA008080-UT22R-04-MVR).

stations are not present in the underlying demand. It has been assumed the same is true for P&R sites.

To improve local link counts, station and P&R access trips were added to the demand based on observed data rather than relying on Matrix Estimation (ME).

Station car access demand has been added by first deriving the trip ends to and from newly created rail stations zones, split by time period and purpose, and then secondly, distributing those trips across local zones.

To derive station access trip ends ORR station usage data and survey results of mode of station access have been analysed. Annual total usage was converted to average day usage. The time of day (ToD) splits to convert from all day flows to modelled peak hour flows were taken from an MCTC count covering the access road to Witham station car park (Easton Road). The ToD splits support strong tidality of rail usage common with commuting patterns and crowding on rail services.

The Sandon P&R trip ends were taken directly from count data available from the site access road.

Trip distributions were based on developing catchment areas for stations and P&R site which covered the areas most likely to access the rail network and P&R site. Trips were distributed with respect to household numbers per zone. Finally, NRPS journey purposes were applied.

The final demand trip ends are summarised in Table 6-2.

Table 6-2 Car (all purposes) station access trip ends

Site	Zone Number	Trip End	Parked at or near station		
			AM	IP	PM
Hatfield Peverel Station	23026	O	20	10	52
		D	100	8	13
Witham Station	23027	O	74	36	195
		D	376	30	48
Kelvedon Station	23028	O	41	20	107
		D	206	16	26
Marks Tey Station	23029	O	29	14	78
		D	149	12	19
Sandon Park & Ride	24020	O	27	91	323
		D	320	66	31
Total		O	191	171	755
		D	1151	132	137

7. Network Calibration and Validation

7.1 Introduction

A number of checks have been undertaken on the network coding to ensure the model reflects realistic road conditions.

7.2 Network checks

The first check that was undertaken was to assess the network structure and connectivity. As part of this check, zone connectors were assessed to ensure they appropriately represent the loading of the zone onto the local road network.

A further check was to focus on one-way links and restricted links. Due to the rural nature of the study area, some roads are not suitable for certain vehicle types, due to weight, width or height restrictions. These roads have vehicle type bans to restrict their use, which were checked to ensure they reflect reality.

Additional checking focused on the coded attributes of the links and junctions. This included checking whether an appropriate number of lanes, capacity and turn restrictions had been applied. For junctions, it was also checked that the correct junction type had been coded and their key characteristics represented. Software warnings produced by SATURN were also reviewed, which highlighted any illogical coding of junctions.

The lengths of all links were derived using GIS measurement, but these were also checked using SATURN, by comparing the coded lengths against the “crow–fly” link lengths.

Bus routes were checked against maps to ensure that they had been coded correctly and with the right frequency.

As a result of the network checks undertaken for the base model, some improvements were made to the network. These improvements included modifications to the location of centroid connectors from certain zones to more accurately represent the road network.

During calibration, it was necessary to make a change to one of the speed flow curves adopted from the A120 modelling. SFC 2 was adjusted primarily to allow for higher speeds at or approaching capacity. This was to allow for Journey Time validation to be met. Table 7-1 shows the adjustment.

Table 7-1 SFC adjustment

Description	Free-flow Speed kph	Speed at Capacity kph	Capacity	n	Index
Rural 2 lane Motorway	112	67	4600	2.90	2
Previously: Rural 2 lane Motorway	112	45	4860	3.85	

Some local roads such as Easthorpe Road and Kelvedon Road west of Messing needed to be coded with reduced capacity and speeds to reflect the fact that they are single track roads with passing places. A new SFC to represent these roads was included in the model. A capacity of 150 in each direction was adopted based on the study *'The capacity of single-track rural lanes: an initial investigation (Sweet, TRICS,2012)'*, which recommends using a total capacity of 100-300 vehicles/hr.

Table 7-2 New Local Road SFC

Description	Free-flow Speed kph	Speed at Capacity kph	Capacity	n	Index
Village Single Carriageway (reduced capacity)	47	30	150	2.45	136

It should also be noted, that in order to create delay on the SATURN network between J19 – J20a A12 northbound, it was decided to model this section of road as a 2-lane road in the PM, but 'correctly' model it with 3 lanes in the AM and IP. The justification for this is that in the PM peak, the majority of mainline traffic continues along the A12, and is required to use 2 lanes at the next junction (J20a). Traffic is signposted to get into the correct lane well in advance of the next junction and queueing occurs because the effective capacity of the road is that of a 2-lane section of road, as opposed to a 3-lane section road.

8. Route Choice Calibration and Validation

The network was validated using an assessment of route choice. This involved examining shortest paths and minimum generalised cost routes through the network because modelled routing forms a key part of ensuring that journey times and vehicle flows match observed data. The modelled routes will depend on:

- Appropriateness of the zone sizes and modelled network structure and the realism of the connections to the modelled network (centroid connectors);
- Accuracy of the network coding and the appropriateness of the simplifications adopted;
- Accuracy with which delays at junctions and times along links are modelled, which are dependent not only on data and/or coding accuracy and appropriateness but also on the appropriateness of the approximations inherent in the junction flow/delay and link speed/flow relationships; and
- Accuracy of the trip matrices which, when assigned, will lead to the times used in the route choice process (via the flow/delay and speed/flow relationships).

Major urban areas covered by the network were identified, and routes between them checked against local knowledge, common sense, and routes suggested by Google Maps.

The urban areas identified are listed below:

- Chelmsford
- Colchester
- Braintree
- Witham
- Maldon
- London (M25 / A12 Junction)
- Tiptree
- Kelvedon
- Hatfield Peverel

According to TAG Unit M3.1, the number of routes that should be checked is defined by:

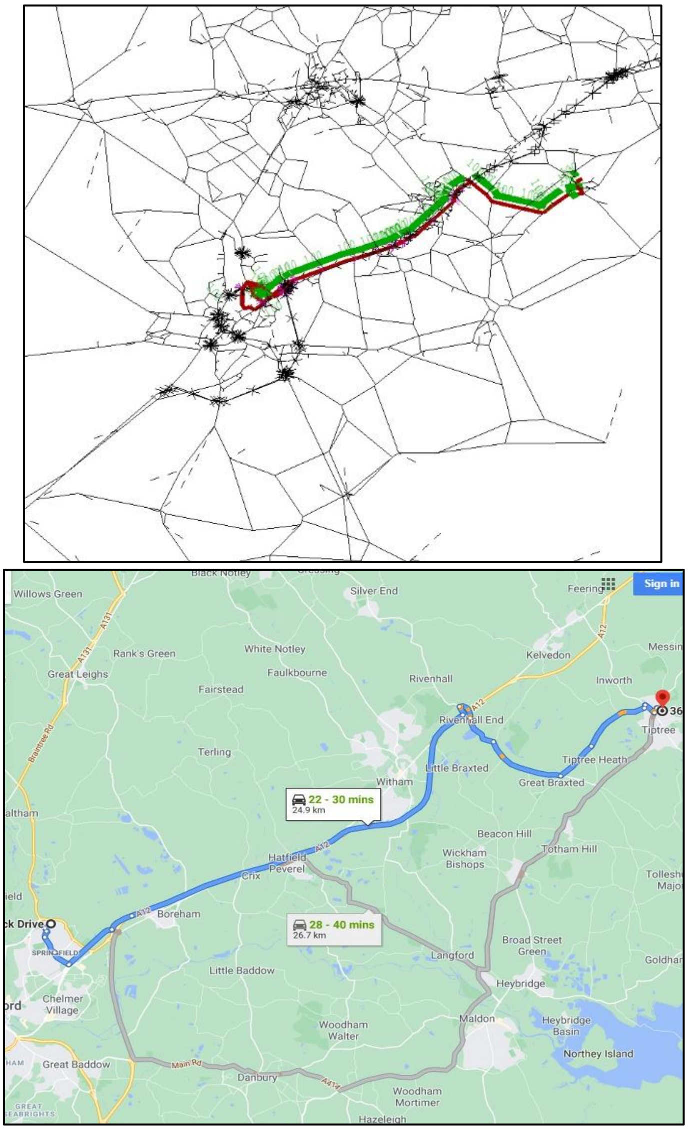
$$Number\ of\ OD\ pairs = (number\ of\ zones)^{0.25} * number\ of\ user\ classes$$

On that basis, with 536 core zones and 5 user classes, a minimum of 24 OD pairs should be checked. All combinations of OD pairs from the above list were checked in three time periods. This exceeds the guidance above on the number of routes required. The routes selected also meet advised criteria as they:

- Relate to a significant number of trips
- Are of significant length
- Pass through areas of interest
- Include both directions of travel
- Link different compass areas
- Coincide with journey time routes as appropriate

An example route choice check compared to Google Maps is shown in Plate 8-1, with the route shown in red. All the routes from the SATURN model were checked against routes shown by Google Maps. The modelled network was adjusted to correct the route where necessary. In most cases a change of link type or junction capacity was sufficient to correct the route. In a small number of cases a centroid connector was amended.

Plate 8-1 Example route choice check



A summary of the route choice validation results for UC2 (car commute) and UC5 (HGVs) for AM, IP and PM modelled periods are shown in Table 8-1 to Table 8-6. Dark green represents an exact match, lighter green an acceptable alternative with similar time given in Google Maps, red shows where there is a discrepancy between SATURN and Google Maps.

Table 8-1 Routes checked in the AM period for UC2 (Car Commute)

UC2 From / To	1	2	3	4	5	6	7	8	9
1. Chelmsford									
2. Colchester									
3. Braintree									
4. Witham									
5. Maldon									
6. London (M25/A12)									
7. Tiptree									
8. Kelvedon									
9. Hatfield Peverel									

Table 8-2 Routes checked in the AM period for UC5 (HGV)

UC5 From / To	1	2	3	4	5	6	7	8	9
1. Chelmsford									
2. Colchester									
3. Braintree									
4. Witham									
5. Maldon									
6. London (M25/A12)									
7. Tiptree									
8. Kelvedon									
9. Hatfield Peverel									

Table 8-3 Routes checked in the IP period for UC2 (Car Commute)

UC2 From / To	1	2	3	4	5	6	7	8	9
1. Chelmsford									
2. Colchester									
3. Braintree									
4. Witham									
5. Maldon									
6. London (M25/A12)									
7. Tiptree									
8. Kelvedon									
9. Hatfield Peverel									

Table 8-4 Routes checked in the IP period for UC5 (HGV)

UC5 From / To	1	2	3	4	5	6	7	8	9
1. Chelmsford									
2. Colchester									
3. Braintree									
4. Witham									
5. Maldon									
6. London (M25/A12)									
7. Tiptree									
8. Kelvedon									
9. Hatfield Peverel									

Table 8-5 Routes checked in the PM period for UC2 (Car Commute)

UC2 From / To	1	2	3	4	5	6	7	8	9
1. Chelmsford									
2. Colchester									
3. Braintree									
4. Witham									
5. Maldon									
6. London (M25/A12)									
7. Tiptree									
8. Kelvedon									
9. Hatfield Peverel									

Table 8-6 Routes checked in the PM period for UC5 (HGV)

UC5 From / To	1	2	3	4	5	6	7	8	9
1. Chelmsford									
2. Colchester									
3. Braintree									
4. Witham									
5. Maldon									
6. London (M25/A12)									
7. Tiptree									
8. Kelvedon									
9. Hatfield Peverel									

The above tables show that all routes checked were either an exact match or very similar.

It should be noted that there is no option in Google Maps routing to select HGV appropriate routes. When undertaking the route choice check for userclass HGV deviation from the exact match route could often be attributed to a HGV restriction in the model.

9. Prior Matrices Validation

9.1 Introduction

This section provides the result of assigning the final prior matrices to the SATURN network and comparing it against the calibration and validation screenlines before running ME.

9.2 Prior matrices calibration and validation results

A map of all screenlines used within the model is shown in Plate 9-1.

Plate 9-1 Location of screenlines and counts

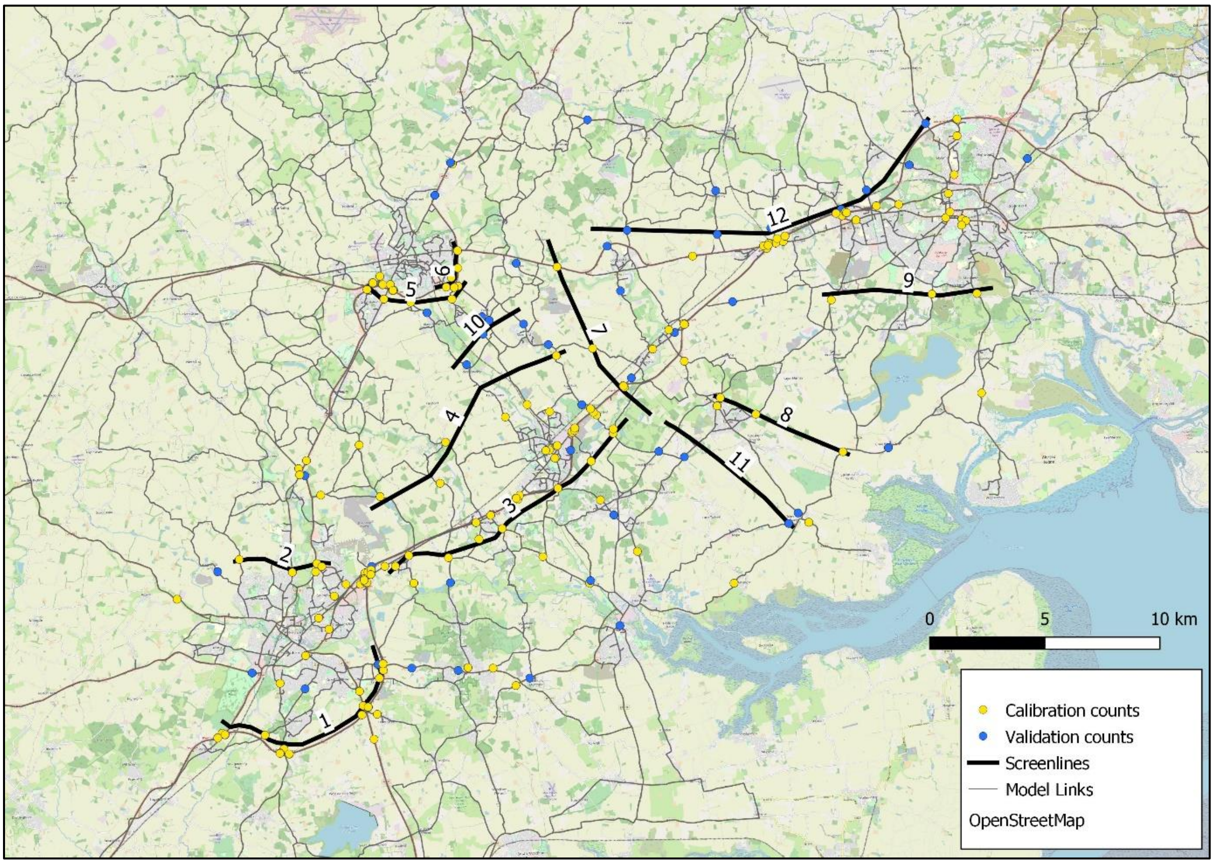


Table 9-1,Table 9-2 and Table 9-3 shows the pre-ME validation of screenline flows for AM, IP and PM time periods respectively.

Table 9-1 Calibration and validation screenlines – all vehicles – AM Peak

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
AM							
1	NB	4492	4502	50%	11	0	0%
1	SB	4111	3993	67%	-118	2	-3%
2	NB	1990	1812	67%	-178	4	-9%
2	SB	2219	1672	67%	-548	12	-25%
3	NB	2844	3005	63%	161	3	6%
3	SB	1773	1790	100%	17	0	1%
4	NB	1688	2243	50%	555	13	33%
4	SB	2132	2104	50%	-28	1	-1%
5	NB	3038	2836	60%	-202	4	-7%
5	SB	2927	2719	80%	-207	4	-7%
6	NB	1120	1046	100%	-73	2	-7%
6	SB	1646	1643	33%	-4	0	0%
7	EB	3873	4283	80%	409	6	11%
7	WB	4363	4831	80%	468	7	11%
8	EB	673	833	67%	159	6	24%
8	WB	849	775	67%	-74	3	-9%
9	NB	1428	1023	50%	-404	12	-28%
9	SB	1133	856	75%	-278	9	-24%
10	NB	1294	1650	50%	356	9	27%
10	SB	1447	1318	75%	-129	3	-9%
11	EB	579	546	100%	-33	1	-6%
11	WB	1290	997	67%	-293	9	-23%
12	NB	1947	2177	71%	230	5	12%
12	SB	2656	2603	86%	-53	1	-2%
Screenline Total		**51513**	**51256**		**-257**		**-0.50%**

Table 9-2 Calibration and validation screenlines – all vehicles – IP Peak

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
IP							
1	NB	2527	2423	100%	-104	2	-4%
1	SB	2656	2530	83%	-127	2	-5%
2	NB	1648	1308	33%	-339	9	-21%
2	SB	1675	1201	33%	-474	13	-28%
3	NB	1365	1208	63%	-157	4	-11%
3	SB	1443	1179	88%	-265	7	-18%
4	NB	1009	1085	83%	76	2	8%
4	SB	994	1178	83%	184	6	18%
5	NB	2051	1769	80%	-282	6	-14%
5	SB	2020	1792	80%	-228	5	-11%
6	NB	1413	966	33%	-447	13	-32%
6	SB	1427	1107	67%	-320	9	-22%
7	EB	3199	3263	100%	64	1	2%
7	WB	2980	3170	100%	190	3	6%
8	EB	486	419	100%	-67	3	-14%
8	WB	442	451	100%	9	0	2%
9	NB	940	524	50%	-415	15	-44%
9	SB	909	559	50%	-351	13	-39%
10	NB	761	969	100%	209	7	27%
10	SB	757	932	100%	175	6	23%
11	EB	548	420	100%	-127	6	-23%
11	WB	505	382	100%	-123	6	-24%
12	NB	1639	1543	86%	-96	2	-6%
12	SB	1637	1578	86%	-59	1	-4%
Screenline Total		**35031**	**31959**		**-3072**		**-8.77%**

Table 9-3 Calibration and validation screenlines – all vehicles – PM Peak

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
PM							
1	NB	3597	3751	67%	154	3	4%
1	SB	4159	4008	50%	-152	2	-4%
2	NB	2108	2179	100%	72	2	3%
2	SB	2085	1585	67%	-500	12	-24%
3	NB	2037	2151	75%	115	3	6%
3	SB	2566	2038	63%	-528	11	-21%
4	NB	1941	1914	67%	-27	1	-1%
4	SB	1714	1747	100%	33	1	2%
5	NB	3089	2751	80%	-338	6	-11%
5	SB	3072	2444	60%	-628	12	-20%
6	NB	1677	1139	33%	-537	14	-32%
6	SB	1581	1417	100%	-164	4	-10%
7	EB	4575	4901	100%	326	5	7%
7	WB	3612	4166	80%	554	9	15%
8	EB	860	801	100%	-59	2	-7%
8	WB	574	694	67%	120	5	21%
9	NB	1247	863	50%	-384	12	-31%
9	SB	1211	852	50%	-359	11	-30%
10	NB	1380	1377	100%	-4	0	0%
10	SB	1375	1295	100%	-80	2	-6%
11	EB	1044	899	100%	-145	5	-14%
11	WB	616	519	100%	-97	4	-16%
12	NB	2501	2266	71%	-234	5	-9%
12	SB	2019	2261	71%	241	5	12%
Screenline Total		**50637**	**48018**		**-2619**		**-5.17%**

Using the prior matrices, few of the screenlines meet TAG flow criteria. However, across the whole model the demand is fairly similar to the observed. Overall, the modelled flow is lower than the observed.

At this stage, given the confidence in the network and route choice calibration, it was decided to use matrix estimation in order to further improve the fit between model demand and observed counts.

10. Trip Matrix Calibration and Validation

10.1 Matrix estimation

Following the prior matrix assignment and refinement of the modelled network, the trip matrices underwent a process of 'matrix estimation' whereby trip matrices were adjusted such that the resulting assigned flows match the count data better.

The following parameters were used for matrix estimation:

- XAMAX – 2.0
- Number of iterations – 6

It is important when running a matrix estimation process that the original 'prior' (to estimation) trip matrices are not distorted in such a way that the underlying trip patterns are altered.

A combination of short screenlines and standalone counts were used as constraints in matrix estimation, these were derived from count data and applied at the Car, LGV and HGV level.

In a few cases, (e.g. zones which represent stations or where zonal demand had been derived from observed counts), these zones were frozen in the matrix estimation process to ensure that the trips were not altered in the process.

To check that the effects of matrix estimation are minimised, the guidelines set out within TAG unit M3-1 were applied to the prior-ME matrices and post-ME matrices, as detailed in Table 10-1.

Table 10-1 Significance of matrix estimation changes

Measure	Significance Criteria
Matrix zonal cell values	Slope within 0.98 and 1.02 Intercept near zero R2 in excess of 0.95
Matrix zone trip ends	Slope within 0.99 and 1.01 Intercept near zero R2 in excess of 0.98
Trip length distributions	Means within 5% Standard deviations within 5%
Sector to sector level matrices	Differences within 5%

The significance of matrix estimation for each measure listed in the above table are described in the following sections of this report.

10.2 Matrix total changes

The overall change in demand between prior and post matrix estimation is shown in Table 10-2. When external to external trips are excluded, the change in the matrix totals between prior and post matrix estimation is 1.4% in the AM, 8.8% in the IP and 4.9% in the PM.

Table 10-2 Matrix estimation changes

Time Period	Vehicle Type	Prior matrix estimation	Post matrix estimation	Difference	% Difference
AM	Car	5230857	5222499	-8357	-0.2%
	LGV	622934	622392	-542	-0.1%
	HGV	302605	298858	-3747	-1.3%
	All	6156395	6143750	-12645	-0.2%
IP	Car	4051874	4051872	-2	0.0%
	LGV	559679	560427	748	0.1%
	HGV	283668	282358	-1311	-0.5%
	All	4895222	4894656	-565	0.0%
PM	Car	5887179	5883681	-3498	-0.1%
	LGV	489199	488590	-609	-0.1%
	HGV	190185	187489	-2696	-1.4%
	All	6566563	6559760	-6803	-0.1%

It can be seen that car and LGV matrices change by less than 1% within each time period. HGV matrix changes are higher compared to other vehicle classes. This is as anticipated and is due to the relatively poorer quality of the data used to construct these matrices.

10.3 Matrix cell value changes

Table 10-3 shows the cell values of the prior matrix plotted against the values in the same cell of the post matrix. It is required 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. These criteria are met for each time period and vehicle type, indicating that the prior matrices have not been significantly distorted by matrix estimation.

Table 10-3 Summary of matrix cell value changes – total matrix

Time Period	Vehicle Type	Intercept	Slope	R^2
AM	Car	-0.02	1.00	1.00
	LGV	0.00	1.00	1.00
	HGV	-0.01	1.00	1.00
	All	-0.04	1.00	1.00
IP	Car	0.00	1.00	1.00
	LGV	0.00	1.00	1.00
	HGV	0.00	1.00	1.00
	All	0.00	1.00	1.00
PM	Car	-0.01	1.00	1.00
	LGV	0.00	1.00	1.00
	HGV	-0.01	1.00	1.00
	All	-0.02	1.00	1.00

As an additional check, Table 10-4 presents the results for zones with less than 1,000 trips. Excluding trips greater than 1,000 from the results ensures that cells with many trips do not mask changes occurring to cells with lower values. The required criteria are met for each time period and vehicle type.

Table 10-4 Summary of matrix cell value changes – trips less than 1,000

Time Period	Vehicle Type	Intercept	Slope	R^2
AM	Car	-0.02	1.00	1.00
	LGV	0.00	1.00	1.00
	HGV	-0.01	1.00	1.00
	All	-0.03	1.00	1.00
IP	Car	0.00	1.00	1.00
	LGV	0.00	1.00	1.00
	HGV	0.00	1.00	1.00
	All	0.00	1.00	1.00
PM	Car	-0.01	1.00	1.00
	LGV	0.00	1.00	1.00
	HGV	-0.01	1.00	1.00
	All	-0.02	1.00	1.00

10.4 Matrix trip end changes

The second integrity check requires changes in trip ends to be plotted and for the trend line to meet the following criteria:

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

As before, the results are provided for both the full matrix and for trips less than 1,000. The latter test ensures that cells with many trips do not mask changes occurring to row and column totals with lower values. These results are shown in Table 10-5 and Table 10-6, respectively.

Table 10-5 Impact of matrix estimation on trip ends – total matrix

Time Period	Vehicle Type	Origin Trip-Ends			Destination Trip-Ends		
		Intercept	Slope	R^2	Intercept	Slope	R^2
AM	Car	-12.89	1.00	1.00	-13.03	1.00	1.00
	LGV	-0.77	1.00	1.00	-0.68	1.00	1.00
	HGV	-5.64	1.00	1.00	-5.81	1.00	1.00
	All	-18.52	1.00	1.00	-18.86	1.00	1.00
IP	Car	0.96	1.00	1.00	0.85	1.00	1.00
	LGV	1.36	1.00	1.00	1.43	1.00	1.00
	HGV	-1.88	1.00	1.00	-1.93	1.00	1.00
	All	0.74	1.00	1.00	0.72	1.00	1.00
PM	Car	-4.52	1.00	1.00	-4.72	1.00	1.00
	LGV	-0.95	1.00	1.00	-0.90	1.00	1.00
	HGV	-4.14	1.00	1.00	-4.20	1.00	1.00
	All	-9.09	1.00	1.00	-9.37	1.00	1.00

Table 10-6 Impact of matrix estimation on trip ends – trips less than 1,000

Time Period	Vehicle Type	Origin Trip-Ends			Destination Trip-Ends		
		Intercept	Slope	R^2	Intercept	Slope	R^2
AM	Car	7.63	0.95	0.97	2.90	0.99	0.98
	LGV	1.75	0.97	1.00	1.71	0.98	1.00
	HGV	0.52	0.96	1.00	0.26	0.97	1.00
	All	10.31	0.95	0.97	5.26	0.98	0.98
IP	Car	9.75	0.98	0.98	8.49	0.99	0.98
	LGV	2.13	0.99	1.00	2.23	1.00	1.00
	HGV	1.40	0.98	1.00	0.67	0.98	1.00
	All	10.65	1.00	0.98	10.93	0.99	0.98
PM	Car	8.52	1.00	0.97	12.82	0.97	0.97
	LGV	0.32	0.99	1.00	0.79	0.98	1.00
	HGV	-0.33	0.97	1.00	-0.51	0.97	1.00
	All	9.52	0.99	0.97	13.87	0.97	0.97

Table 10-5 shows that Slope and R^2 values meet the required criteria. It also shows that vehicle type car has a negative intercept in AM and PM time periods, which can be attributed to the inclusion of calibration counts on Motorway links in the external area, which were significantly lower than the prior modelled demand, and so through matrix estimation demand in this part of the network has been reduced to calibrate to the observed data.

The regression analysis for trips less than 1,000 presented in Table 10-6 show that in most instances the Slope and R^2 criteria are either met, or very close to being attained. All time periods show a positive intercept value which is result of matrix estimation increasing demand within the simulation area, consistent with the pre-ME screenline results shown in Table 9-1.

For all time periods, the regression plots were examined, and outliers investigated. Outliers from the regression line were related to zones which were close to matrix estimation calibration sites. In all cases, it was considered reasonable that the trips should increase or decrease by the amount resulting from matrix estimation.

10.5 Trip length distributions

TAG unit M3-1 advises that both the mean and standard deviation of the post-ME trip lengths should not differ by more than 5% from those of the prior matrices. The results presented in Table 10-7 excludes zones with greater than 1,000 trips. The impact of matrix estimation is expected to be minimal on these trips and therefore including them may mask the actual impact on trip length distributions.

Table 10-7 Impact of matrix estimation on trip length distribution – trips less than 1,000

Time Period	Vehicle Type	Measure	Prior (km)	PostME (km)	% Difference
AM	Car	Mean	11.49	11.30	1.7%
		St Dev	39.36	38.86	1.3%
	LGV	Mean	13.83	13.62	1.5%
		St Dev	41.68	41.10	1.4%
	HGV	Mean	45.61	43.60	4.4%
		St Dev	100.82	97.85	3.0%
	All	Mean	13.41	13.11	2.2%
		St Dev	44.63	43.82	1.8%
IP	Car	Mean	10.98	10.87	1.0%
		St Dev	40.91	40.60	0.8%
	LGV	Mean	11.92	11.88	0.4%
		St Dev	39.79	39.55	0.6%
	HGV	Mean	46.47	45.46	2.2%
		St Dev	102.19	100.72	1.4%
	All	Mean	13.14	12.98	1.2%
		St Dev	46.59	46.13	1.0%
PM	Car	Mean	11.66	11.52	1.2%
		St Dev	40.32	39.96	0.9%
	LGV	Mean	15.13	14.93	1.3%
		St Dev	44.00	43.50	1.1%
	HGV	Mean	48.08	46.10	4.1%
		St Dev	105.30	102.50	2.7%
	All	Mean	13.41	13.11	2.2%
		St Dev	44.63	43.82	1.8%

Plate 10-1 to Plate 10-6 compare the trip length distributions in distance bands for prior and post matrices for all time periods for both cars and HGVs. These figures show that the matrix estimation process has not made any significant impact on the number of trips within all distance bands except for HGV, where an increase is observed for the long-distance trips.

Plate 10-1 Trip length distribution profile – AM peak car

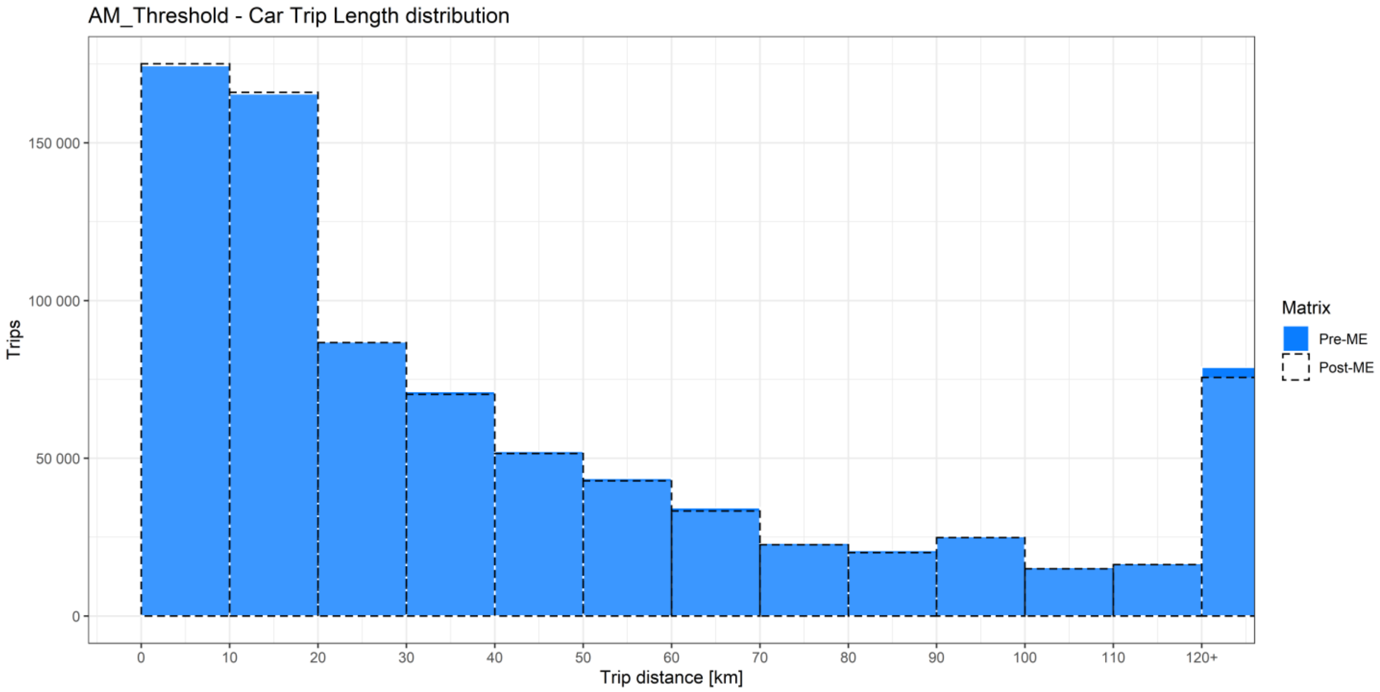


Plate 10-2 Trip length distribution profile – IP peak car

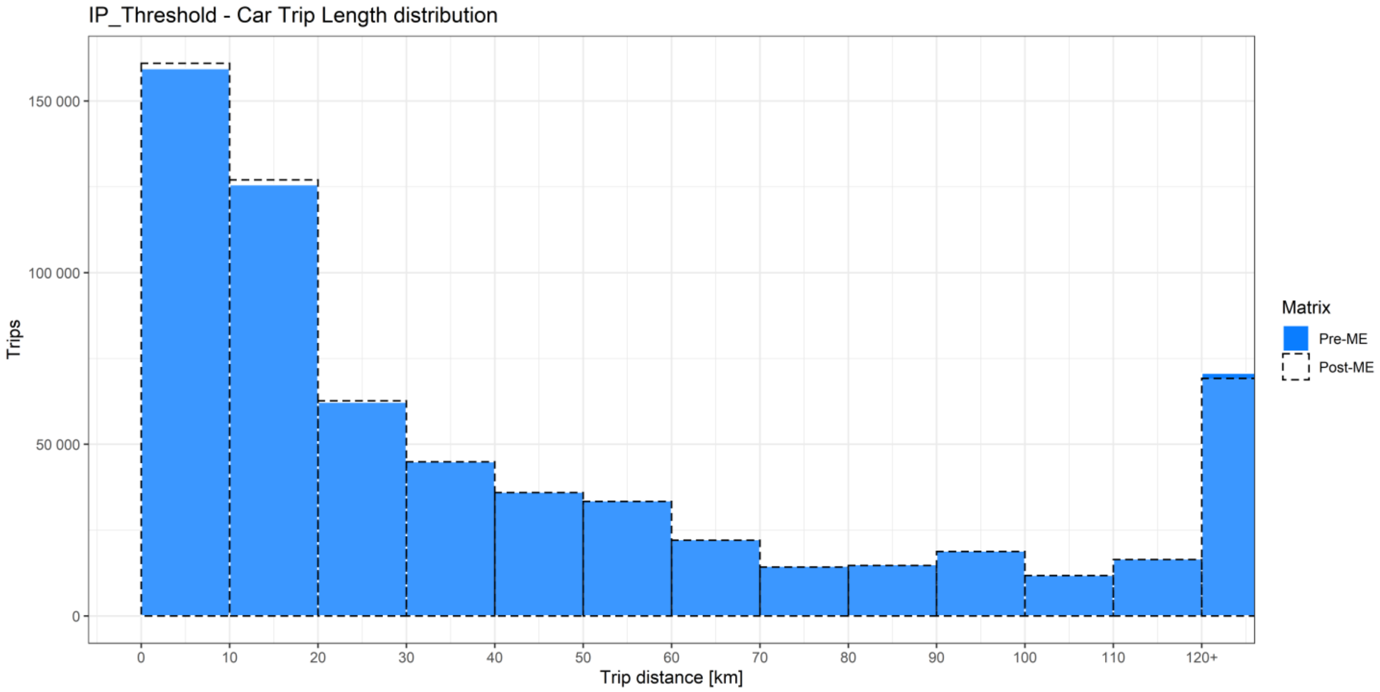


Plate 10-3 Trip length distribution profile – PM peak car

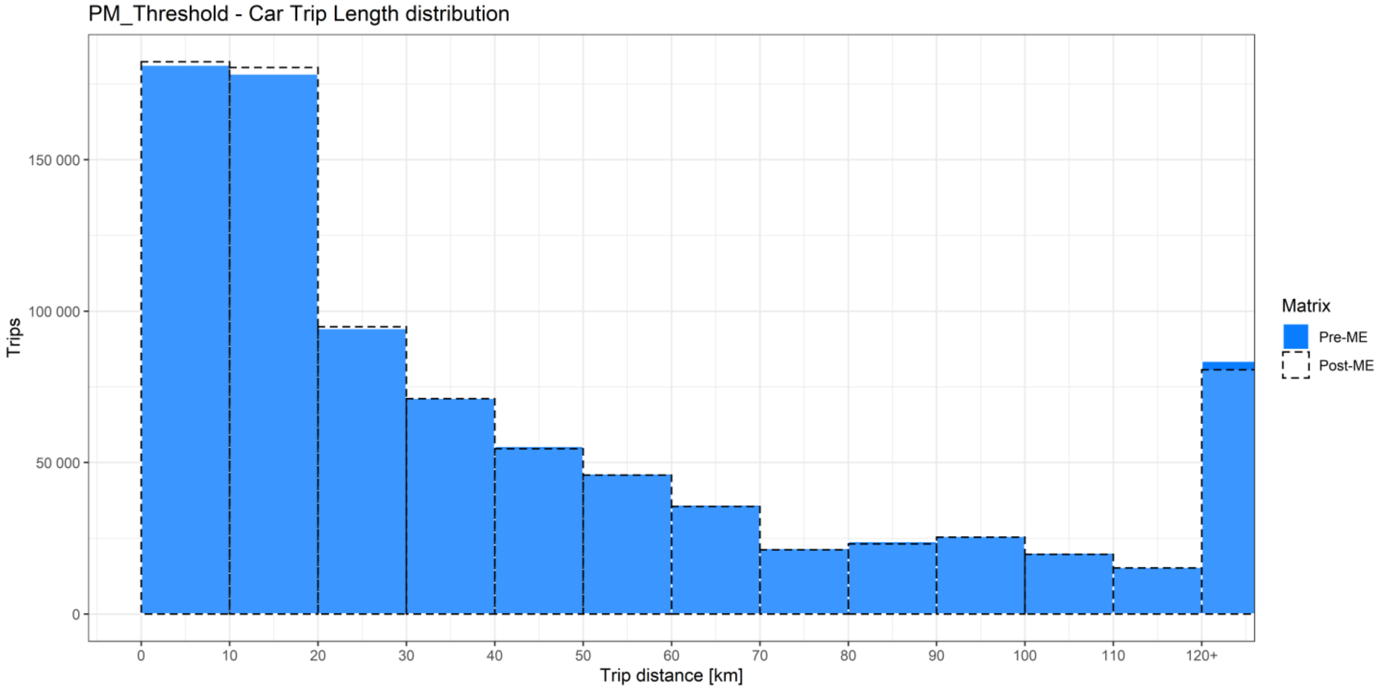


Plate 10-4 Trip length distribution profile – AM peak HGV

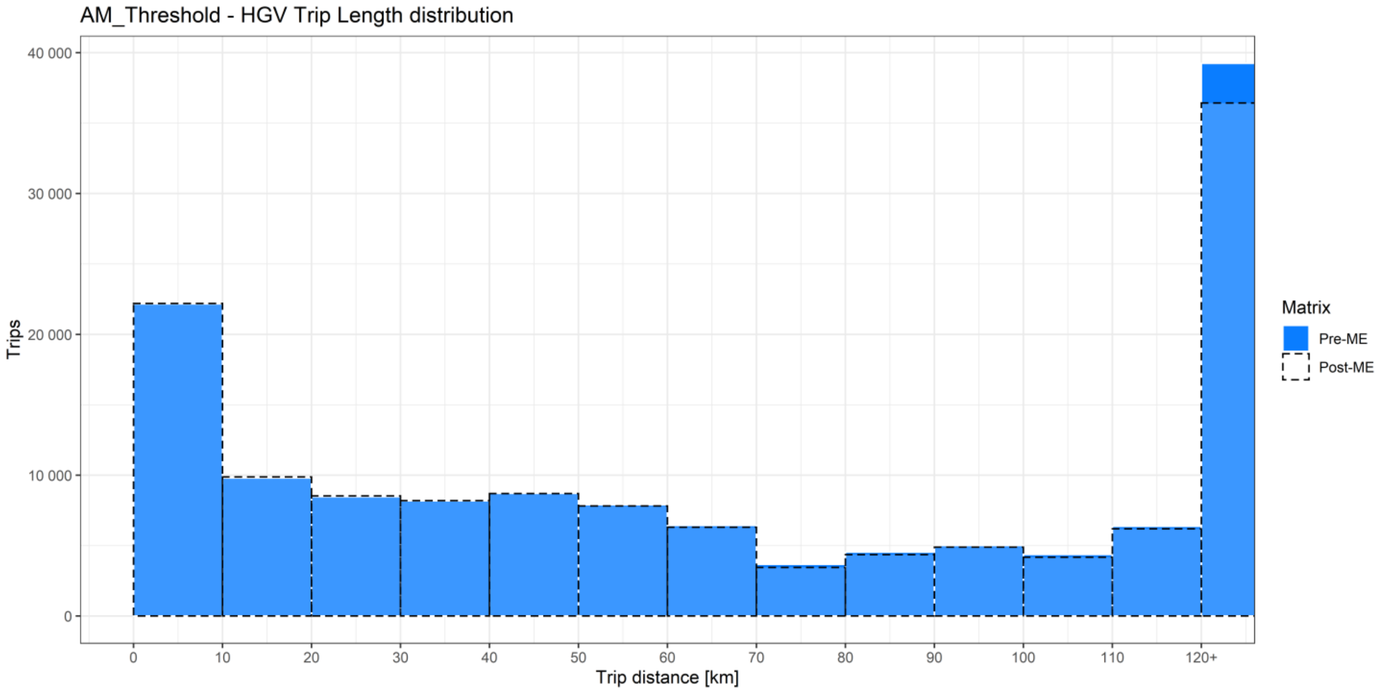


Plate 10-5 Trip length distribution profile – IP peak HGV

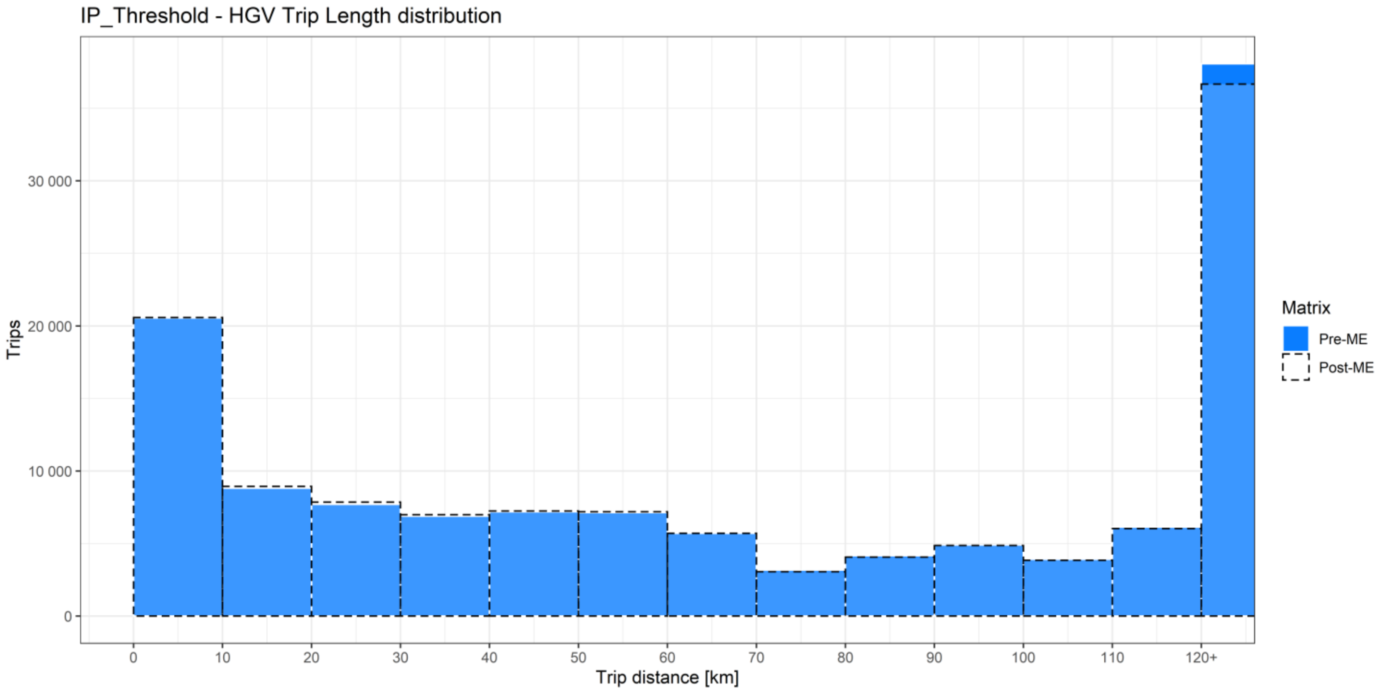


Plate 10-6 Trip length distribution profile – PM peak HGV

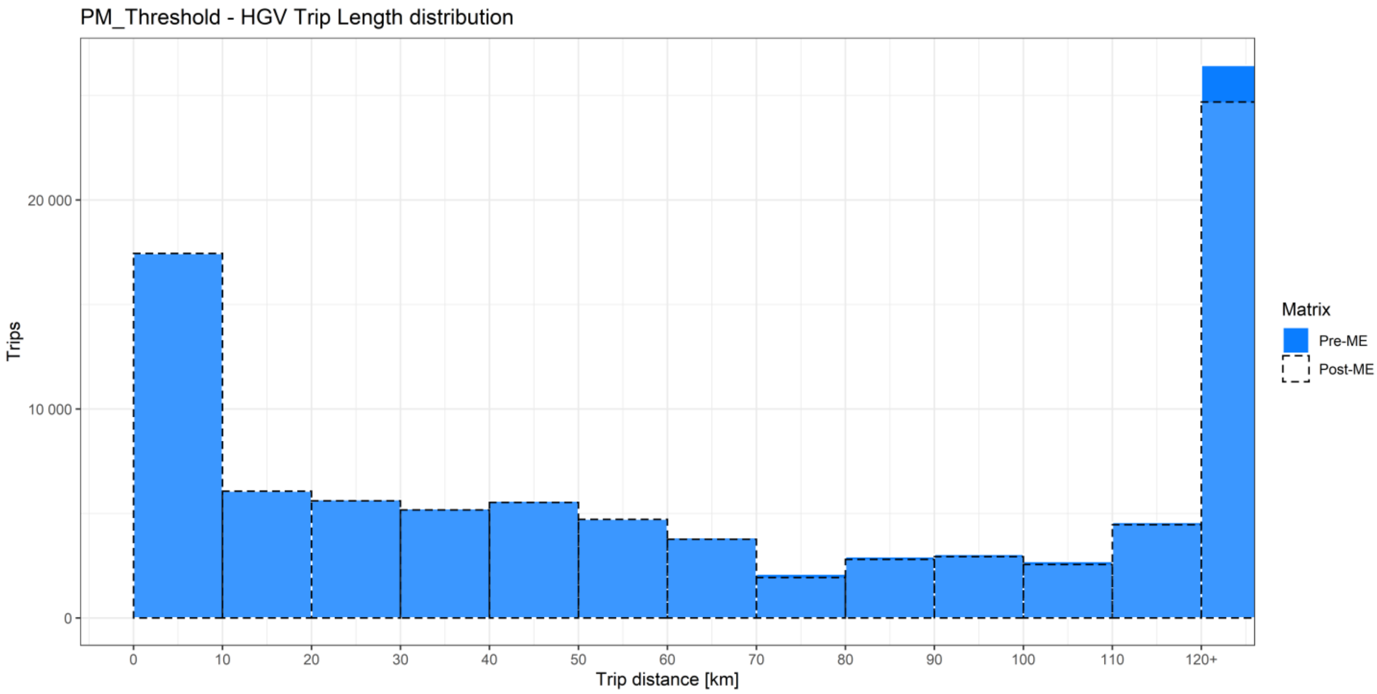


Plate 10-1 to Plate 10-6 show that the matrix estimation process has not had a significant impact on the number of trips within all distance bands, except for HGV, where a decrease is observed for long-distance trips. This change in trip length is considered acceptable given the HGV prior matrices are based on data which is less detailed at a local level.

10.6 Sector to sector movements

Finally, the matrix cells were checked on a sector basis. TAG guidance advises that trips should not change by more than 5% as a result of matrix estimation. Table 10-8 lists the sectors in the internal and external parts of the model. These are shown geographically in Plate 10-7.

Table 10-8 Model internal and external sectors

No.	Sector Name	Sector Type
1	South Colchester	Internal
2	North Chelmsford	Internal
3	Maldon	Internal
4	North Essex	External
5	Tendring	Internal
6	South Essex	External
7	West Essex	External
8	Greater London	External
9	South East	External
10	Norfolk	External
11	Hertford, Bedford & Cambridge	External
12	Rest of UK	External
13	Suffolk	External
14	South Chelmsford	Internal
15	South East Essex	External
16	Braintree	Internal
17	North Colchester	Internal
18	Epping Forest & Harlow	External

Plate 10-7 A12 sector system – buffer and simulation areas

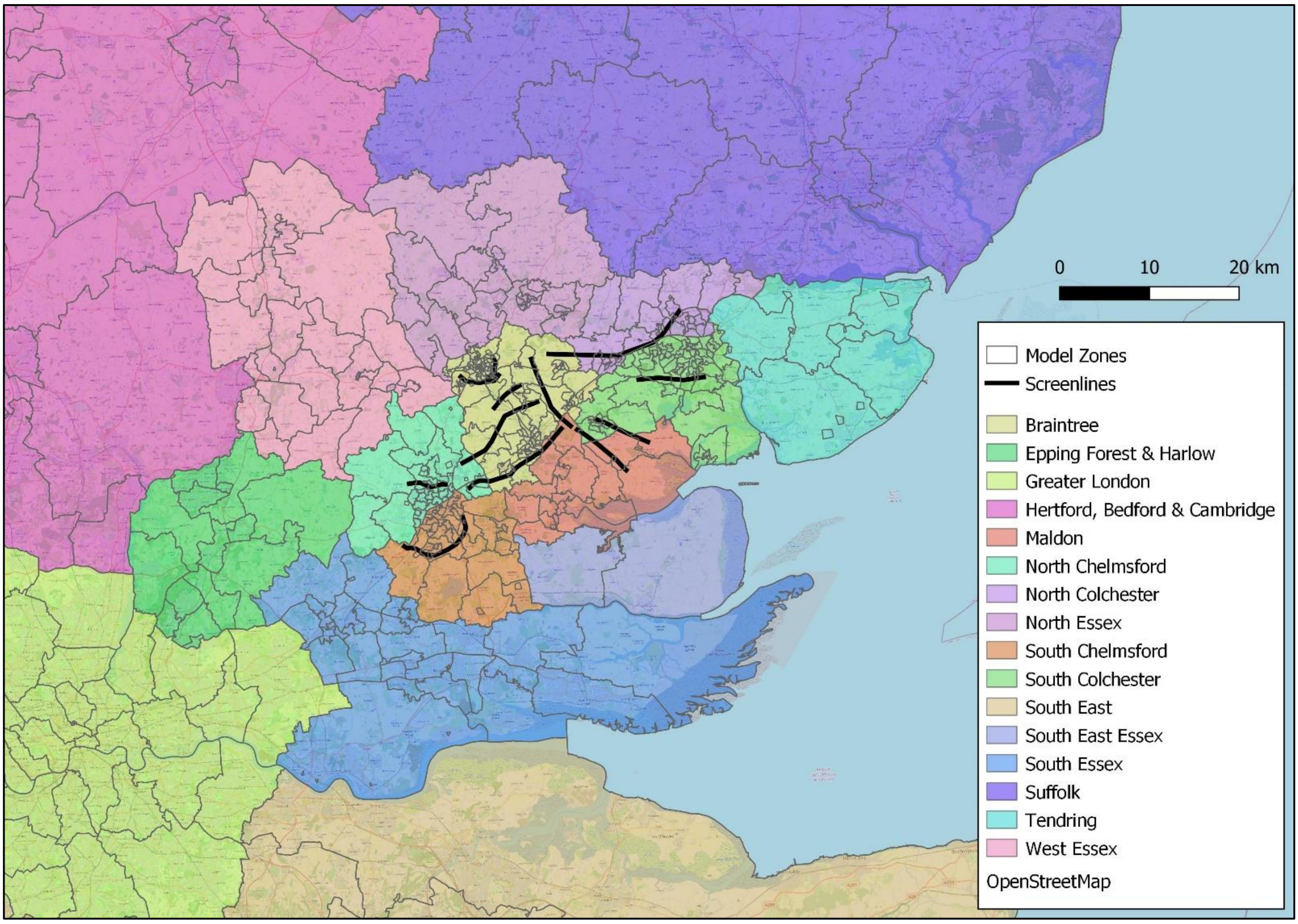


Table 10-9 (AM), Table 10-12 (IP) and Table 10-15 (PM) show the total trip differences between the matrices prior to matrix estimation and post matrix estimation. It is assumed that a change of less than 50 vehicles can be considered minor given the size of the sectors and a high percentage change for these movements is considered acceptable on account of the low number of trips.

Table 10-10 (AM),Table 10-13 (IP) and Table 10-16 (PM) show the percentage differences between the prior and post matrices. Only cell values that change by more than 50 vehicles and have a percentage difference greater than 5% are presented.

In order to assess this combination of the absolute and relative change the GEH statistic was also calculated. Table 10-11 (AM), Table 10-14 (IP) and Table 10-17 (PM) present the GEH values to help further investigate the significance of these changes.

In all tables, the external to external sectors are shaded grey.

Table 10-9 Sector to sector changes – all AM trips

OS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	-118	-19	154	25	-19	-7	34	6	11	7	5	-8	-123	3	22	142	108	-6
2	-8	94	8	13	-15	88	-146	11	17	-3	1	-12	-27	481	-5	118	5	28
3	-11	53	48	-4	-6	37	7	3	3	-1	-1	-8	-8	95	10	9	12	-14
4	8	-52	-17	-15	3	-51	-3	-32	-8	0	-10	-4	-18	-37	-2	-23	21	-1
5	-47	-70	-35	-17	0	-92	1	-44	-22	5	-16	-107	-245	-65	-6	-81	-69	-27
6	-67	91	-35	-23	-85	-95	-48	-1122	-7	-53	-698	-644	-266	205	1	-141	-25	-214
7	3	20	11	3	-2	-105	-13	-189	-67	-21	-153	-56	-41	43	-5	48	7	-14
8	-7	19	15	13	-84	-383	164	-107	-79	-63	-305	-130	-191	-26	5	74	1	165
9	-14	-20	-2	-2	-83	-6	-71	-190	0	-122	-572	-534	-254	-25	0	-8	-8	-152
10	0	-7	-5	0	-5	-57	-17	-117	-50	0	-15	-17	0	-11	-2	-10	-3	-8
11	-8	8	-2	1	-19	-528	-58	-581	-477	-28	-295	-54	-72	15	-2	14	-1	-4
12	-3	-4	-1	8	-20	-562	-19	-276	-541	-29	-64	0	-127	-26	-4	17	-4	1
13	3	-63	-42	-17	-1	-252	5	-346	-170	0	-55	-244	0	-79	-12	-62	-33	-75
14	-1	134	-41	11	-9	49	6	-34	-17	-3	-17	-35	-34	96	-16	57	1	-16
15	12	-32	38	-1	-3	2	-6	-4	0	0	-7	-5	-5	-69	0	-20	0	-3
16	44	-6	20	-127	-19	-98	83	30	18	-4	-33	-22	-120	168	-4	169	62	-7
17	160	-13	-16	5	44	-11	14	8	7	-3	1	0	-122	-10	-5	66	117	-3
18	0	16	3	5	-2	-232	15	-226	-126	-10	-126	-10	-41	13	1	23	1	-20

Table 10-10 Sector to sector % changes – all AM trips

OS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1			42%										-12%			18%		
2		5%				7%	-32%							20%		16%		
3		21%												15%				
4		-27%				-45%												
5		-42%				-51%						-59%	-22%	-44%		-26%	-8%	
6	-24%	9%			-39%			-10%		-47%	-45%	-31%	-50%	7%		-25%		-25%
7						-40%		-23%	-48%		-6%	-27%						
8					-46%		31%			-28%			-41%			39%		
9					-75%		-35%			-64%	-28%		-68%					-34%
10						-45%		-46%	-55%									
11						-36%			-27%									
12						-32%							-12%					
13		-38%				-50%		-44%	-52%			-15%		-41%		-15%		-56%
14																10%		
15														-12%				
16				-11%		-14%	11%						-32%	17%			17%	
17	6%												-16%			22%	15%	
18						-25%			-35%									

Table 10-11 Sector to sector GEH values – all AM trips

OS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1			7										4			5		
2		2				2	8							9		4		
3		3												4				
4		4				5												
5		6				8						10	8	6		5	2	
6	4	3			6			11		6	20	15	13	4		6		8
7						7		7	6		3	4						
8					7		7			5			10			5		
9					10		6			11	14		16					8
10						6		8	6									
11						15			12									
12						15							4					
13		5				13		14	11			6		6		3		8
14																2		
15														3				
16				4		4	3						7	5			3	
17	3												5			4	4	
18						8			7									

Table 10-12 Sector to sector changes – all IP trips

OS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	542	-3	-3	63	94	-4	10	9	5	3	2	-1	25	-11	-4	182	26	-1
2	1	232	68	2	-8	116	-25	12	5	-3	-4	-2	-8	341	25	129	3	16
3	64	59	68	-3	-6	30	6	17	5	-1	3	13	-3	57	10	62	7	3
4	36	1	-3	-18	1	-11	4	4	0	0	0	2	-5	-1	-1	-7	9	4
5	40	-7	2	-1	0	-16	0	-2	1	5	-12	-34	-1	-12	-3	6	30	-7
6	-1	83	-17	8	-26	30	0	-293	-1	-32	-321	-381	-60	108	5	95	8	-76
7	8	-46	6	2	0	-5	-10	-34	-15	-18	-75	-32	-24	28	-4	122	3	0
8	17	-31	8	12	-24	-169	117	-21	-12	-85	-143	-60	-129	-66	0	102	12	140
9	4	-19	4	-3	-52	-5	-26	-40	0	-93	-277	-330	-109	-25	0	9	4	-48
10	1	-2	-1	0	1	-28	-11	-106	-23	0	-9	-15	0	-4	-1	-4	-2	-11
11	-1	-8	-23	1	-18	-199	-49	-260	-150	-21	-141	-30	-32	-23	-5	31	3	-8
12	2	-15	-8	5	-11	-252	-12	-147	-190	-21	-33	0	-50	-39	-4	34	4	9
13	16	-13	-3	-9	-53	-89	-17	-157	-60	0	-31	-66	0	-19	-4	-50	-18	-33
14	-2	524	24	4	-8	28	14	20	8	-2	3	0	-14	147	-10	91	5	13
15	2	20	14	-1	-7	5	2	1	0	-1	2	0	-6	10	0	-1	-4	0
16	134	124	89	-55	-3	15	140	60	16	-3	17	19	-61	38	-1	384	35	28
17	265	-2	3	19	-2	0	4	3	3	-1	-1	0	-30	-8	-2	37	53	-1
18	-3	9	-9	3	-7	-61	7	-26	-25	-15	-41	-5	-29	-21	-3	21	-1	1

Table 10-13 Sector to sector % changes – all IP trips

OS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	8%			50%	9%											37%		
2		18%	56%			18%								19%		25%		
3	25%	53%	11%											23%		18%		
4																		
5																		
6		15%									-32%	-23%	-20%	7%		37%		-14%
7																36%		
8							24%			-23%			-21%	-18%		62%		
9					-48%					-51%	-18%		-38%					
10								-32%										
11						-18%			-12%									
12						-15%												
13					-7%	-32%		-28%	-31%			-5%				-21%		
14		27%												6%		23%		
15																		
16	26%	23%	22%	-6%			44%	45%					-24%			10%		
17	13%																8%	
18						-9%												

Table 10-14 Sector to sector GEH values – all IP trips

OS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	6			5	3											8		
2		6	5			4								8		5		
3	4	5	3											3		3		
4																		
5																		
6		3									11	10	4	3		5		3
7																6		
8							5			5			6	4		7		
9					6					8	7		7					
10								6										
11						6			4									
12						6												
13					2	6		7	5			2				3		
14		11												3		4		
15																		
16	6	5	4	2			7	5					4			6		
17	6																2	
18						2												

Table 10-15 Sector to sector changes – all PM trips

OS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	74	-4	-107	46	-32	-35	11	9	5	-3	1	-4	-79	-49	-13	178	-12	-4
2	6	104	140	-15	-23	145	-93	29	8	-6	-9	-5	-37	359	-22	146	16	8
3	161	37	71	-14	-20	-12	18	3	4	-1	0	0	-28	-25	24	75	25	-6
4	21	11	3	-15	0	-19	9	5	3	0	-1	-1	-16	3	-2	86	7	-1
5	79	-2	-8	7	0	-17	5	4	6	0	-9	-22	-70	-16	-3	20	62	-6
6	-43	-40	69	-36	-160	-34	-19	-667	-1	-75	-450	-460	-246	67	6	-63	-25	-140
7	4	-97	11	-13	-11	-65	-18	-45	-53	-27	-124	-62	-74	4	-9	95	1	-1
8	-7	-30	35	5	-99	-403	206	-62	-85	-90	-263	-60	-241	-91	-1	167	6	157
9	-10	-24	-1	-7	-42	-8	-42	-255	0	-90	-379	-411	-143	-34	0	-16	-4	-69
10	0	-2	-1	0	-13	-33	-10	-107	-38	0	-9	-13	0	-5	-1	-3	-8	-9
11	-2	-15	-10	-5	-38	-440	-83	-337	-428	-33	-379	-31	-139	-7	-9	6	-3	-11
12	-2	-12	6	3	-18	-512	3	-164	-466	-59	-57	0	-143	-27	-4	21	-2	5
13	-25	-15	-13	-13	-210	-110	-5	-183	-70	0	-29	-75	0	-47	-6	-22	-47	-29
14	26	280	141	-13	-15	0	-19	21	10	-9	-12	-9	-50	127	-27	306	36	-6
15	7	3	18	-3	-12	2	-2	1	0	-1	-3	-2	-9	0	0	-1	-3	-1
16	313	254	160	-113	-18	-60	52	36	14	-6	-25	-18	-106	47	-7	548	134	-4
17	286	-1	-19	13	10	-17	2	1	2	-3	-6	-7	-62	-27	-4	27	115	-4
18	-2	14	-2	-6	-12	-181	26	-83	-105	-15	-84	-5	-80	-23	-5	20	0	12

Table 10-16 Sector to sector % changes – all PM trips

OS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1			-24%										-10%			27%		
2		8%	70%			13%	-32%							19%		16%		
3	42%		11%													15%		
4																10%		
5	11%												-8%				17%	
6			20%		-54%			-8%		-52%	-43%	-31%	-56%			-11%		-21%
7		-28%				-27%			-38%		-6%	-22%	-18%			14%		
8					-35%		27%			-27%			-37%	-14%		39%		
9										-63%	-30%		-64%					-31%
10								-33%										
11						-33%			-29%									
12						-29%							-13%					
13					-17%	-37%		-30%	-32%			-7%						
14		14%	30%											5%		34%		
15																		
16	41%	37%	25%	-10%		-13%	15%						-25%			13%	43%	
17	12%												-8%				15%	
18						-21%			-33%				-46%					

Table 10-17 Sector to sector GEH values – all PM trips

OS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1			5										3			6		
2		3	9			4	6							8		5		
3	7		3													3		
4																3		
5	3												2				3	
6			4		11			7		7	16	13	14			3		6
7		6				4			5		3	4	4			4		
8					7		7			5			10	4		7		
9										9	12		12					5
10								7										
11						13			12									
12						13							4					
13					6	7		8	5			2						
14		6	6											3		9		
15																		
16	10	9	6	3		3	3						6			8	7	
17	6												2				4	
18						7			6				7					

The results of the sector-to-sector analysis indicate that several sector pairs change by more than 50 trips and more than 5%.

This is to be expected given the use of SERTM matrices, which uses 2015 origin-destination data even though some traffic patterns may have changed by 2019. It is acknowledged that ME results in some noticeable changes at sector level, but the overall scale of variation from the prior is relatively minor and considered acceptable. The biggest changes are discussed further in this section.

The majority of sector pairs with a percentage change greater than 5% and a GEH greater than 5 lie in the external part of the network. In almost all of these significant external sector changes there is a decrease in trips between prior and post matrices. This supports the results already shown and is due to matrix estimation reducing the number of trips on the TRA links, i.e., M11, M25 in order to improve flow calibration in these areas.

There are few sector pairs located in the detailed model simulation area which have a GEH greater than 5. This area is the main focus of the matrix estimation process, that is to improve the trip distribution where SERTM zones at MSOA level were split to LSOA and OA. Impacts on the prior matrices are therefore expected.

The biggest changes for internal sectors were observed for the following sector pairs:

- Between sector 2 (North Chelmsford) and sector 14 (South Chelmsford): These sectors are adjacent to each other, and both are big sectors, with 36 and 43 zones respectively. The primary reason for a significant change in trips here is due to the location of screenline 1 which covers these two sectors. It has been assumed that shorter trips between adjacent zones and sectors may not have been fully captured by the mobile phone data used to derive the SERTM matrices. As such, during the ME process trips between these zones have been increased to match observed count data.
- Internally within sector 1 (South Colchester): This sector consists of 75 zones. The prior demand is derived from 2015 data and the model year is 2019. In this sector, there have been several new developments that were built within these years, therefore the distribution patterns in this prior matrix may require additional adjustment via matrix estimation.
- Internally within sector 2 (North Chelmsford): The increase is again mainly because the prior demand under-represents short distance trips as they are not fully captured by the mobile phone data used to derive the SERTM matrices. As such, during the ME process trips within this sector have been increased to match observed count data.
- Between sector 16 (Braintree) and sector 1 (South Colchester): Sector 16 is a large sector which covers Braintree, Witham, Coggeshall and Kelvedon. In all time periods matrix estimation has increased the number of trips between zones in this sector and the zones in South Colchester. It would appear that there were not a sufficient number of trips in these sectors to match observed count data. Given the importance of these movements to the scheme

appraisal, it was considered acceptable to allow larger matrix estimation changes to ensure the flows calibrated well.

- Between sector 17 (North Colchester) and sector 1 (South Colchester):The changes have been brought by matrix estimation based on the counts along A12 junctions between J25 and J27. Given the importance of these movements to the scheme appraisal, it was considered acceptable to allow larger matrix estimation changes to ensure the flows calibrated well.
- Between sector 2 (North Chelmsford) and sector 3 (Maldon): The impact of matrix estimation has been to increase the number of trips from the Maldon sector to the North Chelmsford sector in the AM, with the opposite directionality in the PM. Within the IP model, both directions saw a significant increase in trips. It is known that the SERTM matrices missed the car leg of rail trips, and it's possible this increase in trips is due to missing car trips between towns such as Danbury and Maldon to Chelmsford to access the train station.

Documentation provided with the SERTM prior matrices[2] identified two caveats that also help to explain the impacts of matrix estimation on sector to sector trips:

- "Due to the uncertainty in identifying short trips in mobile data, short trips in the matrices are sourced from developed synthetic matrices" and;
- "Trip ends in mobile data can only be identified reliably at a certain spatial resolution. Therefore, the matrices could be subject to zone allocation errors (trips being allocated to the neighbouring zones) in locations where SERTM zones are relatively small."

It is considered that the combination of the relatively small size of the prior matrix SERTM zones in this area of the model and the further disaggregation of these same zones in the A12 model explain some of the more significant impacts from matrix estimation observed.

The original SERTM matrices were calibrated at a more disaggregate level as it catered primarily for strategic movements. It is to be expected that the finer zone structure necessary for the A12 model would involve greater calibration to validate closely at a more detailed level. This would also likely be apparent at a sector level too.

In general, it is considered that the matrix estimation achieves a balance between minimising the impact on the observed data in the prior matrices while improving the distribution of the trips where SERTM zones were disaggregated to LSOA and OA level in the simulation area and its periphery.

It is acknowledged that a more significant change in the matrices has occurred in the area around the M25 and M11 TRA calibration counts.

[2] AECOM, 24th February 2017: *Information Note for Design Freeze 3 SERTM Matrices*

11. Assignment Calibration and Validation

11.1 Introduction

This chapter details the calibration and validation results, in relation to the required model standards, as outlined in Chapter 3.

11.2 Model convergence

Model assignment of trips to the highway network was undertaken based on the 'Wardrop User Equilibrium' principle, which seeks to minimise travel costs on all routes for traffic flows in the network through an iterative process. Convergence of the model was monitored to check the stability of the traffic model, i.e. whether traffic flows remain stable between successive iterations, providing a robust platform for further modelling.

The convergence results are shown in Table 11-1.

Table 11-1 Model convergence results

Time Period	Assignment Simulation Loop	Loop	Proximity Indicators		Stability Indicators		
			% Delta	% Gap	% Flow	% Delays	RAAD
AM	17	14	0.0007	0.0012	99.1	99.4	0.01
		15	0.0011	0.0009	99.2	99.6	0.01
		16	0.0007	0.0011	99.3	99.6	0.01
		17	0.0006	0.0007	99.3	99.6	0.01
IP	12	9	0.0003	0.00022	99.3	100	0.01
		10	0.0002	0.00018	99.3	99.9	0.01
		11	0.0001	0.00016	99.5	100	0.01
		12	0.0001	0.00009	99.8	100	0.00
PM	17	14	0.0003	0.00048	99.6	99.8	0.00
		15	0.0003	0.00031	99.6	99.8	0.00
		16	0.0003	0.00048	99.8	99.8	0.00
		17	0.0003	0.00026	99.8	99.9	0.00
% Delta: Less than 0.1% or at least stable with convergence fully documented and all other criteria met							
%Gap: Less than 0.1% or at least stable with convergence fully documented and all other criteria met							
% Flow: Link Flows Differing by < 1% Between Assignment & Simulation							
% Delays: Turn Delays Differing by < 1% Between Assignment & Simulation							
RAAD: % Relative Average Absolute Difference in Link Flows							

The results indicate that the model achieves a high level of convergence. The base year model proximity is significantly lower than the TAG requirement of 0.1%. Similarly, the stability indicators are significantly higher than the TAG requirement of greater than 98% of links changing by less than 1% during four consecutive iterations. The values for all time periods across all four iterations range from 99.1% to 99.8% for flows and 99.4% to 100% for turn delays.

11.3 Calibration of individual site locations

As outlined in Chapter 3, the performance of the model in terms of comparisons with count data are measured in two ways. The first of these is the GEH statistic, as defined below:

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

Where M is the modelled flow on a link, and C is the observed count.

The second is made by reference to the following table, extracted from TAG Unit M 3-1.

Table 11-2 Link flow validation criteria

Size of observed flow	Criteria for valid modelled flow
< 700 vehicles/hour	Modelled flow within 100 vehicles/hour of observed flow
700-2,700 vehicles/hour	Modelled flow within 15% of observed flow
> 2,700 vehicles/hour	Modelled flow within 400 vehicles/hour of observed

TAG advises that in ordinary circumstances the practitioner should aim to reach a state where 85% of modelled links have a GEH of less than 5 or satisfy the criterion in link flow.

As discussed in Chapter 4, 313 counts were used to calibrate the model with 86 of these on screenlines and the remaining 227 counts used as independent link counts. A comparison of modelled flows against observed flows is provided in Table 13-1.

Table 11-3 Calibration link flow comparison with observed flows

Criteria	AM		IP		PM	
	Compliant	Compliant %	Compliant	Compliant %	Compliant	Compliant %
All Vehicles						
Number of links meeting Acceptability criteria (hourly flow)	276	88%	290	93%	278	89%
Number of links meeting Acceptability criteria (GEH)	264	84%	278	89%	267	85%
Number of links meeting Acceptability criteria (GEH OR Hourly flows)	280	89%	291	93%	280	89%
Cars						
Number of links meeting Acceptability criteria (hourly flow)	282	90%	294	94%	277	88%
Number of links meeting Acceptability criteria (GEH)	269	86%	280	89%	274	88%
Number of links meeting Acceptability criteria (GEH OR Hourly flows)	286	91%	295	94%	283	90%

The results show that over 85% of calibration sites meet the link flow criteria for all peaks, as required by TAG. This gives confidence that the modelled flows match the observed flows for all individual links selected for calibration purposes.

11.4 Calibration screenlines

For counts that are arranged along screenlines, TAG has an additional criterion for total screenline flows. It requires that total modelled flows on all links crossing a screenline should be within 5% of the observed totals.

Calibration screenlines are shown geographically in Plate 11-1.

Plate 11-1 Location of calibration and validation screenlines and counts

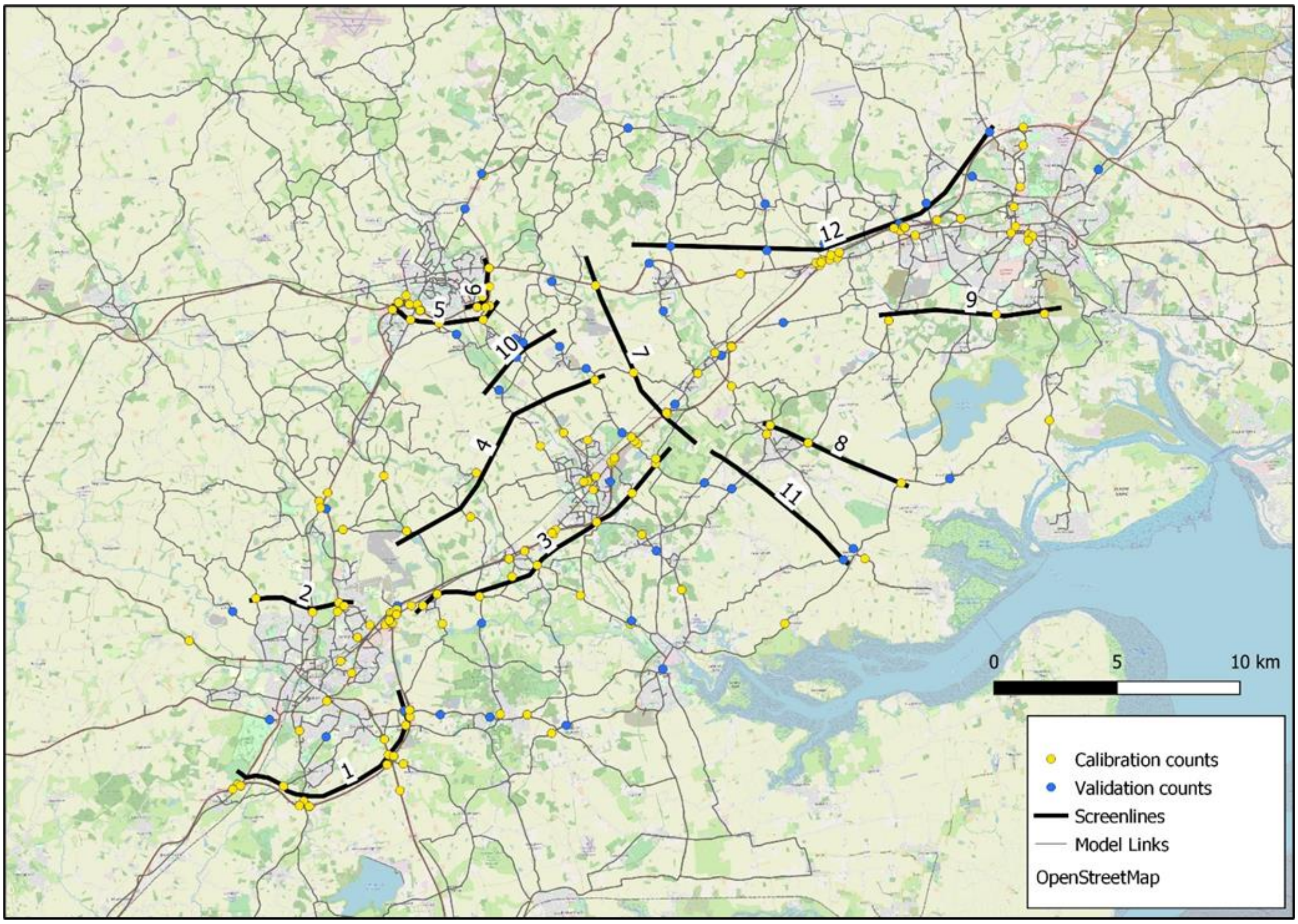


Figure 11-1 Location of calibration and validation screenlines and counts

The performance of the model along the calibration screenlines for total vehicles and for cars is summarised in Table 11-4 to Table 11-9.

Table 11-4 Calibration screenlines – all vehicles – AM

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
AM							
1	NB	4492	4478	50%	-13	0	0%
1	SB	4111	4119	67%	9	0	0%
2	NB	1990	1995	67%	5	0	0%
2	SB	2219	2118	67%	-101	2	-5%
3	NB	2844	2872	100%	28	1	1%
3	SB	1773	1819	100%	46	1	3%
4	NB	1688	1714	100%	25	1	2%
4	SB	2132	2166	83%	35	1	2%
5	NB	3038	3023	80%	-15	0	0%
5	SB	2927	2949	40%	22	0	1%
6	NB	1120	1102	100%	-18	1	-2%
6	SB	1646	1654	33%	8	0	0%
7	EB	3873	3861	100%	-13	0	0%
7	WB	4363	4406	100%	43	1	1%
8	EB	673	713	100%	40	2	6%
8	WB	849	836	100%	-13	0	-2%
9	NB	1428	1423	50%	-5	0	0%
9	SB	1133	1099	100%	-34	1	-3%

Table 11-5 Calibration screenlines – all vehicles – IP

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
IP							
1	NB	2527	2526	67%	-1	0	0%
1	SB	2656	2661	100%	5	0	0%
2	NB	1648	1646	100%	-1	0	0%
2	SB	1675	1693	100%	17	0	1%
3	NB	1365	1384	100%	20	1	1%
3	SB	1443	1453	100%	9	0	1%
4	NB	1009	1022	100%	13	0	1%
4	SB	994	1034	100%	40	1	4%
5	NB	2051	2054	80%	4	0	0%
5	SB	2020	2015	80%	-5	0	0%
6	NB	1413	1413	67%	-1	0	0%
6	SB	1427	1435	67%	8	0	1%
7	EB	3199	3196	100%	-3	0	0%
7	WB	2980	2980	100%	0	0	0%
8	EB	486	503	100%	17	1	4%
8	WB	442	454	100%	12	1	3%
9	NB	940	939	50%	-1	0	0%
9	SB	909	888	50%	-21	1	-2%

Table 11-6 Calibration screenlines – all vehicles – PM

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
PM							
1	NB	3597	3597	83%	0	0	0%
1	SB	4159	4171	67%	12	0	0%
2	NB	2108	2134	100%	27	1	1%
2	SB	2085	2083	33%	-2	0	0%
3	NB	2037	2106	100%	69	2	3%
3	SB	2566	2574	100%	8	0	0%
4	NB	1941	1943	100%	2	0	0%
4	SB	1714	1750	100%	36	1	2%
5	NB	3089	3085	100%	-4	0	0%
5	SB	3072	3055	60%	-17	0	-1%
6	NB	1677	1703	100%	27	1	2%
6	SB	1581	1580	100%	-1	0	0%
7	EB	4575	4584	100%	9	0	0%
7	WB	3612	3619	100%	7	0	0%
8	EB	860	857	100%	-3	0	0%
8	WB	574	590	100%	16	1	3%
9	NB	1247	1202	50%	-45	1	-4%
9	SB	1211	1212	50%	1	0	0%

Table 11-7 Calibration screenlines – Cars – AM

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
AM							
1	NB	3937	3930	17%	-7	0	0%
1	SB	3525	3531	17%	6	0	0%
2	NB	1747	1751	33%	4	0	0%
2	SB	2012	1902	33%	-109	2	-5%
3	NB	2573	2594	100%	20	0	1%
3	SB	1546	1588	100%	42	1	3%
4	NB	1530	1523	83%	-8	0	0%
4	SB	1960	1961	83%	0	0	0%
5	NB	2707	2688	40%	-19	0	-1%
5	SB	2673	2690	40%	17	0	1%
6	NB	912	911	67%	-1	0	0%
6	SB	1402	1405	67%	4	0	0%
7	EB	2902	2897	100%	-4	0	0%
7	WB	3338	3352	100%	14	0	0%
8	EB	596	595	100%	-1	0	0%
8	WB	733	718	100%	-16	1	-2%
9	NB	1271	1268	100%	-3	0	0%
9	SB	960	944	100%	-16	1	-2%

Table 11-8 Calibration screenlines – Cars – IP

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
IP							
1	NB	2076	2075	67%	-1	0	0%
1	SB	2203	2207	67%	4	0	0%
2	NB	1389	1387	100%	-2	0	0%
2	SB	1407	1426	100%	18	0	1%
3	NB	1183	1182	100%	-2	0	0%
3	SB	1252	1255	100%	3	0	0%
4	NB	870	880	100%	10	0	1%
4	SB	864	879	100%	15	1	2%
5	NB	1795	1795	60%	0	0	0%
5	SB	1744	1745	60%	2	0	0%
6	NB	1222	1222	67%	0	0	0%
6	SB	1238	1238	67%	0	0	0%
7	EB	2236	2234	100%	-2	0	0%
7	WB	2176	2176	100%	0	0	0%
8	EB	418	418	100%	0	0	0%
8	WB	386	386	100%	0	0	0%
9	NB	812	811	25%	-1	0	0%
9	SB	789	771	25%	-18	1	-2%

Table 11-9 Calibration screenlines – Cars – PM

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
PM							
1	NB	3234	3234	50%	0	0	0%
1	SB	3781	3788	50%	7	0	0%
2	NB	1971	1972	33%	2	0	0%
2	SB	1898	1893	33%	-5	0	0%
3	NB	1905	1920	100%	15	0	1%
3	SB	2406	2412	100%	6	0	0%
4	NB	1825	1824	100%	-1	0	0%
4	SB	1608	1617	100%	8	0	1%
5	NB	2881	2876	80%	-5	0	0%
5	SB	2817	2807	80%	-10	0	0%
6	NB	1525	1544	100%	19	0	1%
6	SB	1441	1435	100%	-6	0	0%
7	EB	3649	3655	100%	6	0	0%
7	WB	3039	3039	100%	0	0	0%
8	EB	772	766	100%	-6	0	-1%
8	WB	529	530	100%	1	0	0%
9	NB	1089	1083	75%	-5	0	0%
9	SB	1104	1105	75%	1	0	0%

The results above show that most of the calibration screenlines meet the 5% difference criterion for all model peaks. There are only two screenlines, both relating to the AM peak, which do not quite meet this criterion:

- Screenline 2 (cars) in southbound direction – the percentage difference is 5.4%, which is very close to the pass criteria and the actual difference is only around 100 vehicles.
- Screenline 8 (total vehicles) in eastbound direction - the percentage difference is 5.9%, which is close to the pass criteria and the actual difference is only 40 vehicles.

In accordance with TAG unit M3-1, an analysis of the calibration screenlines has also been undertaken without high flow routes included. The results are very similar to the results including high flow routes.

11.5 Validation of individual site locations

The validation results for individual counts are summarised in Table 11-10. Of the 91 counts used to validate the model, 28 of these were used on screenlines and the remaining 63 counts used as independent link counts. The validation results are also shown geographically in Plate 11-2 to Plate 11-4.

Table 11-10 Validation link flow comparison with observed flows

Criteria	AM		IP		PM	
	Compliant	Compliant %	Compliant	Compliant %	Compliant	Compliant %
All Vehicles						
Number of links meeting Acceptability criteria (hourly flow)	79	87%	86	95%	80	88%
Number of links meeting Acceptability criteria (GEH)	69	76%	77	85%	71	78%
Number of links meeting Acceptability criteria (GEH OR Hourly flows)	80	88%	86	95%	81	89%
Cars						
Number of links meeting Acceptability criteria (hourly flow)	80	88%	84	92%	81	89%
Number of links meeting Acceptability criteria (GEH)	68	75%	79	87%	72	79%
Number of links meeting Acceptability criteria (GEH OR Hourly flows)	80	88%	88	97%	81	89%

Plate 11-2 Validation individual link counts AM

Plate 11-3 Validation individual link counts IP

Plate 11-4 Validation individual link counts PM

The above results show that the traffic model fully meets the 85% criteria for all link flows for all time periods.

For all time periods, most of the counts which are close to the scheme and therefore of particular importance do meet the validation flow criteria. The ones that fail are discussed below.

The B1022 Maldon Road in Tiptree fails in each time period in at least one direction and has lower traffic in the model compared to the observed data. The A12 junction 26 count on Halstead Road fails in both the AM and PM peak models, with lower traffic in the model than the observed count. However, there are a large number of calibration counts along the A12 mainline and slip roads around J26, which do match well with the model flows.

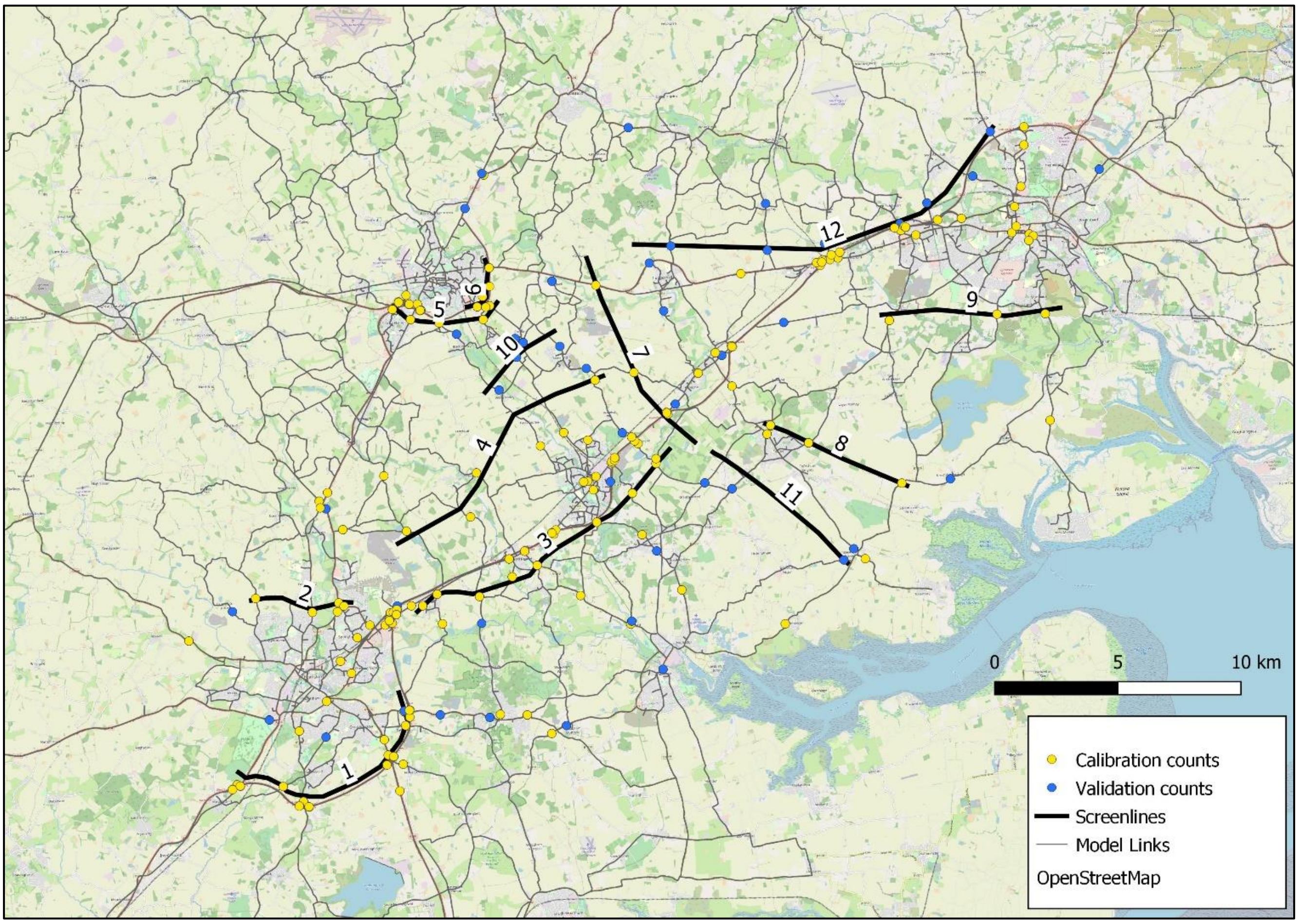
It should be noted that the observed data used at these sites are one-day counts. Despite the higher risk that one-day counts may not represent typical traffic conditions, they were still used if they were the best available data. This approach was agreed following the cancellation of the planned March 2020 data collection.

11.6 Validation screenlines

Validation screenlines are shown geographically in Plate 11-5.

- Screenline 10 lies in the White Notley area between Braintree and Witham
- Screenline 11 lies to the south of Tiptree.
- Screenline 12 lies in the Colchester area; west of A12 and north of A120.

Plate 11-5 Location of calibration and validation screenlines and counts



The performance of the model along the validation screenlines is summarised in Table 11-11 and Table 11-12 for total vehicles and cars.

Table 11-11 Validation screenlines – all vehicles

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
AM							
10	NB	1294	1420	100%	126	3	10%
10	SB	1447	1442	50%	-5	0	0%
11	EB	579	478	67%	-101	4	-17%
11	WB	1290	996	67%	-294	9	-23%
12	NB	1947	2062	57%	115	3	6%
12	SB	2656	2546	86%	-110	2	-4%
IP							
10	NB	761	904	100%	143	5	19%
10	SB	757	837	100%	79	3	10%
11	EB	548	460	100%	-87	4	-16%
11	WB	505	387	67%	-118	6	-23%
12	NB	1639	1698	71%	59	1	4%
12	SB	1637	1541	86%	-96	2	-6%
PM							
10	NB	1380	1444	100%	64	2	5%
10	SB	1375	1284	100%	-91	3	-7%
11	EB	1044	1004	100%	-40	1	-4%
11	WB	616	462	67%	-154	7	-25%
12	NB	2501	2434	71%	-67	1	-3%
12	SB	2019	2135	86%	116	3	6%

Table 11-12 Validation screenlines – cars

Screenline Name	Direction	Observed Flow	Modelled Flow	% of Links Compliant	Actual Difference	GEH	% Diff
AM							
10	NB	1173	1287	75%	114	3	10%
10	SB	1320	1356	75%	36	1	3%
11	EB	470	386	100%	-84	4	-18%
11	WB	1069	869	100%	-200	6	-19%
12	NB	1572	1757	57%	184	5	12%
12	SB	2318	2088	57%	-230	5	-10%
IP							
10	NB	665	816	100%	151	6	23%
10	SB	654	752	100%	97	4	15%
11	EB	443	370	100%	-73	4	-16%
11	WB	410	319	100%	-91	5	-22%
12	NB	1364	1387	71%	23	1	2%
12	SB	1357	1238	71%	-119	3	-9%
PM							
10	NB	1313	1367	100%	55	1	4%
10	SB	1284	1197	100%	-87	2	-7%
11	EB	962	917	67%	-44	1	-5%
11	WB	570	399	67%	-171	8	-30%
12	NB	2290	2148	57%	-142	3	-6%
12	SB	1796	1881	57%	85	2	5%

It can be seen that whilst some of the validation screenlines don't pass the 5% criteria, there are a far greater number that pass or almost pass an alternative criterion of GEH of less than 4. The GEH statistic is often a better indicator when comparing lower flow levels as is the case here where these screenlines can be comprised of a small number of links and the links themselves can have low flows. Given the rural nature of the area, most of these validation screenlines have very low flow, often with less than 1,000 vehicles across the entire screenline.

In Table 11-11, although screenline 10 does not pass the TAG percentage criteria, they pass the GEH criteria in all peaks except in interpeak southbound, which has a GEH 4.9. Also, all links within Screenline 10 pass the TAG criteria individually except for in the AM peak where two count sites marginally fail to meet the threshold. Screenline 10 lies in between other calibration screenlines (4 and 5/6), which ensure the main movements in and out of major towns (Witham and Braintree) is correct. There are lots of very small settlements around screenline 10, and it is likely that the model is missing some of the local trips between these. These local trips do not affect the A12 scheme.

Screenline 11, which lies south of Tiptree consists of three counts. It is a very low flow screenline, with less than 1,000 vehicles in all but one time period / direction, and less than 500 vehicles in half of them. All links within Screenline 11 pass the

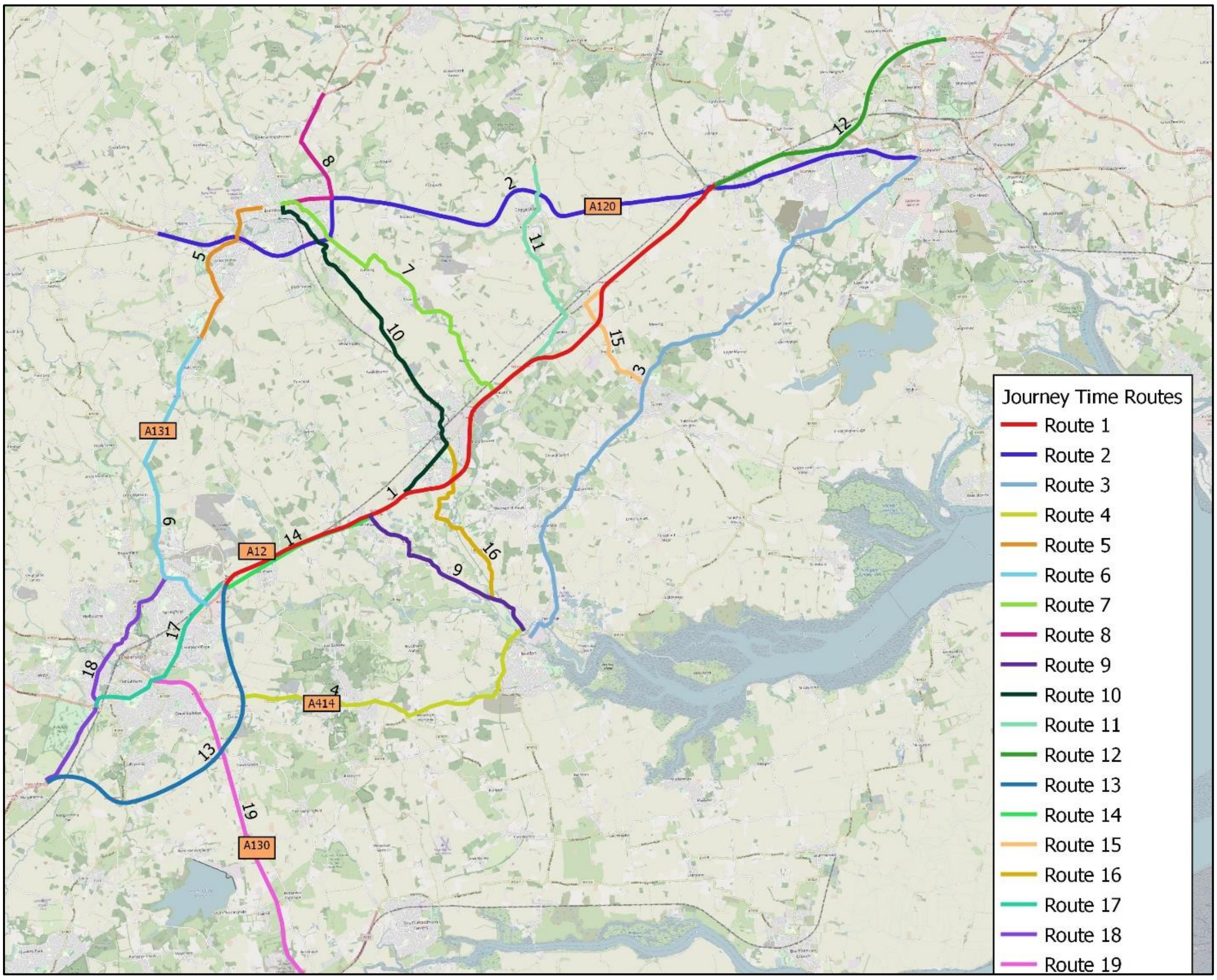
TAG criteria individually except for one count site on B1022 Maldon Road. Model flows on Maldon Road are lower than the observed traffic. It should be noted that the observed data used at this site is one-day count. Despite the higher risk that one-day counts may not represent typical traffic conditions, they were still used if they were the best available data. This approach was agreed following the cancellation of the planned March 2020 data collection.

Screenline 12, which lies west of Colchester is a long screenline which covers movements in/out of Colchester from the north, beyond the section of A12 being widened. The screenline performs well with regards to GEH and almost passes the percentage criteria for IP and PM peak. Although the validation in terms of percentage flow is poorer in the AM, there are several independent calibration counts along A12 mainline and slip roads in this area which ensures that the traffic on those roads is correct and therefore the result is considered acceptable.

11.7 Journey time validation

Modelled journey time routes have been validated against observed journey time routes, calculated using DfT GPS data obtained from Teletrac Navman. The location of these routes is provided in Plate 11-6.

Plate 11-6 Simulation area journey time routes



Criteria to demonstrate satisfactory validation of modelled journey times are detailed in TAG M3.1 Table 3. This states that modelled journey times should be within 15% of the mean observed journey time (or within 1 minute, if higher). The TAG acceptability guideline states that these criteria should be attained on more than 85% of routes. Table 11-13 to Table 11-15 summarise the performance of the journey time routes for each time period.

Table 11-13 Comparison of modelled journey time against the observed - AM

Route ID	Total Observed JT [mm:ss]	Total Modelled JT [mm:ss]	Difference (sec)	% Difference	TAG Compliant
Route 1 NB	15:33	17:47	134	14%	Pass
Route 1 SB	19:47	19:19	-28	-2%	Pass
Route 2 EB	34:58	37:09	131	6%	Pass
Route 2 WB	38:43	40:17	94	4%	Pass
Route 3 NB	32:13	32:09	-4	0%	Pass
Route 3 SB	31:20	32:11	51	3%	Pass
Route 4 EB	14:13	13:59	-14	-2%	Pass
Route 4 WB	15:37	17:46	129	14%	Pass
Route 5 NB	08:35	08:23	-12	-2%	Pass
Route 5 SB	06:54	07:35	41	10%	Pass
Route 6 NB	13:09	13:15	6	1%	Pass
Route 6 SB	14:18	14:46	28	3%	Pass
Route 7 NB	18:17	16:49	-88	-8%	Pass
Route 7 SB	15:56	15:54	-2	0%	Pass
Route 8 NB	07:25	07:45	20	5%	Pass
Route 8 SB	10:11	10:58	47	8%	Pass
Route 9 NB	08:58	09:44	46	9%	Pass
Route 9 SB	08:20	08:10	-10	-2%	Pass
Route 10 NB	21:11	22:36	85	7%	Pass
Route 10 SB	22:05	23:07	62	5%	Pass
Route 11 NB	12:26	12:09	-17	-2%	Pass
Route 11 SB	13:45	14:39	54	6%	Pass
Route 12 NB	06:39	07:02	23	6%	Pass
Route 12 SB	07:57	08:10	13	3%	Pass
Route 13 NB	09:55	10:09	14	2%	Pass
Route 13 SB	09:26	11:07	101	18%	Fail
Route 14 NB	06:11	06:24	13	4%	Pass
Route 14 SB	06:37	07:52	75	19%	Fail
Route 15 NB	07:03	06:23	-40	-10%	Pass
Route 15 SB	05:10	06:00	50	16%	Pass
Route 16 NB	09:29	09:26	-3	0%	Pass
Route 16 SB	08:25	08:32	7	1%	Pass
Route 17 EB	12:27	15:46	199	27%	Fail
Route 17 WB	11:00	12:24	84	13%	Pass
Route 18 NB	15:47	18:05	138	15%	Pass
Route 18 SB	13:34	17:32	238	29%	Fail
Route 19 NB	13:18	12:22	-56	-7%	Pass
Route 19 SB	08:27	08:56	29	6%	Pass

Table 11-14 Comparison of modelled journey time against the observed – IP

Route ID	Total Observed JT [mm:ss]	Total Modelled JT [mm:ss]	Difference (sec)	% Difference	TAG Compliant
Route 1 NB	15:37	16:16	39	4%	Pass
Route 1 SB	15:14	15:27	13	1%	Pass
Route 2 EB	32:37	34:19	102	5%	Pass
Route 2 WB	31:44	33:30	106	6%	Pass
Route 3 NB	30:49	30:08	-41	-2%	Pass
Route 3 SB	30:14	29:25	-49	-3%	Pass
Route 4 EB	14:12	13:38	-34	-4%	Pass
Route 4 WB	14:35	13:43	-52	-6%	Pass
Route 5 NB	07:43	07:19	-24	-5%	Pass
Route 5 SB	06:47	07:04	17	4%	Pass
Route 6 NB	11:26	12:29	63	9%	Pass
Route 6 SB	11:53	12:15	22	3%	Pass
Route 7 NB	15:30	15:32	2	0%	Pass
Route 7 SB	15:09	15:01	-8	-1%	Pass
Route 8 NB	07:27	07:27	0	0%	Pass
Route 8 SB	08:17	08:38	21	4%	Pass
Route 9 NB	08:15	07:39	-36	-7%	Pass
Route 9 SB	08:09	07:55	-14	-3%	Pass
Route 10 NB	20:18	20:26	8	1%	Pass
Route 10 SB	20:33	20:59	26	2%	Pass
Route 11 NB	12:10	11:51	-19	-3%	Pass
Route 11 SB	12:18	12:34	16	2%	Pass
Route 12 NB	06:32	06:31	-1	0%	Pass
Route 12 SB	06:35	06:33	-2	0%	Pass
Route 13 NB	08:58	09:13	15	3%	Pass
Route 13 SB	08:38	08:43	5	1%	Pass
Route 14 NB	06:06	06:12	6	2%	Pass
Route 14 SB	05:56	06:16	20	6%	Pass
Route 15 NB	05:27	05:52	25	8%	Pass
Route 15 SB	05:16	05:56	40	13%	Pass
Route 16 NB	10:03	08:45	-78	-13%	Pass
Route 16 SB	08:22	08:18	-4	-1%	Pass
Route 17 EB	09:35	09:57	22	4%	Pass
Route 17 WB	08:53	10:31	98	18%	Fail
Route 18 NB	12:09	13:15	66	9%	Pass
Route 18 SB	12:16	13:26	70	10%	Pass
Route 19 NB	09:09	09:52	43	8%	Pass
Route 19 SB	08:23	08:44	21	4%	Pass

Table 11-15 Comparison of modelled journey time against the observed - PM

Route ID	Total Observed JT [mm:ss]	Total Modelled JT [mm:ss]	Difference (sec)	% Difference	TAG Compliant
Route 1 NB	21:57	23:41	104	8%	Pass
Route 1 SB	15:33	16:21	48	5%	Pass
Route 2 EB	46:00	39:42	-378	-14%	Pass
Route 2 WB	32:21	35:58	217	11%	Pass
Route 3 NB	32:37	33:17	40	2%	Pass
Route 3 SB	30:24	30:36	12	1%	Pass
Route 4 EB	16:54	17:22	28	3%	Pass
Route 4 WB	14:42	13:48	-54	-6%	Pass
Route 5 NB	12:17	09:33	-164	-22%	Fail
Route 5 SB	07:09	07:24	15	4%	Pass
Route 6 NB	12:45	15:19	154	20%	Fail
Route 6 SB	12:46	13:21	35	5%	Pass
Route 7 NB	16:34	17:14	40	4%	Pass
Route 7 SB	17:07	15:51	-76	-7%	Pass
Route 8 NB	09:29	08:13	-76	-13%	Pass
Route 8 SB	09:55	11:06	71	12%	Pass
Route 9 NB	08:11	08:05	-6	-1%	Pass
Route 9 SB	08:32	09:21	49	10%	Pass
Route 10 NB	23:29	23:28	-1	0%	Pass
Route 10 SB	21:34	22:14	40	3%	Pass
Route 11 NB	12:23	12:42	19	3%	Pass
Route 11 SB	12:52	13:20	28	4%	Pass
Route 12 NB	07:47	07:20	-27	-6%	Pass
Route 12 SB	06:46	06:56	10	3%	Pass
Route 13 NB	10:34	10:38	4	1%	Pass
Route 13 SB	09:21	09:17	-4	-1%	Pass
Route 14 NB	07:34	07:38	4	1%	Pass
Route 14 SB	05:57	06:42	45	13%	Pass
Route 15 NB	07:40	05:57	-103	-22%	Fail
Route 15 SB	05:39	06:48	69	20%	Fail
Route 16 NB	10:27	08:59	-88	-14%	Pass
Route 16 SB	08:57	09:04	7	1%	Pass
Route 17 EB	13:59	11:55	-124	-15%	Pass
Route 17 WB	11:32	10:44	-48	-7%	Pass
Route 18 NB	17:32	14:56	-156	-15%	Pass
Route 18 SB	17:21	14:53	-148	-14%	Pass
Route 19 NB	13:49	09:48	-241	-29%	Fail
Route 19 SB	08:39	09:05	26	5%	Pass

The journey time validation results show that by time period, 89% pass in the AM peak, 97% pass in the IP and 87% pass in the PM peak. Of particular importance for this study is the A12 route J19 – J25 which validates to the observed journey time data for all time periods and in both directions.

In AM peak there are four journey time routes that do not pass the TAG criteria. They are:

- Route 13 southbound – A12 Junction 19 to 15: The model journey times are slower than the observed times. The overall journey time difference does not pass TAG criteria, however, all sub-sections along this route do pass the threshold. Network coding especially at merges were checked along with traffic counts available along this corridor. This journey time route passes in both IP and PM peak.
- Route 14 southbound – Hatfield Peverel to B1137 Boreham: The model journey times are slower than the observed times with difference slightly over the threshold of 60 secs. The overall journey time difference does not pass TAG criteria, however, all sub-sections along this route do pass TAG criteria.
- Route 17 eastbound – Chelmsford to A12 Junction 19: All journey time sub-sections pass except the section between Miami roundabout and Army and Navy roundabout. The model time is slower for this section with large delays at the Army and Navy roundabout along Van Diemans Rd approach. It should be noted that the eastbound model flows for this section match well with the observed counts. As Chelmsford city centre is not the focus of the study, it is not modelled to the same level of detail and therefore the model does not always accurately model delays at congested city centre junctions.
- Route 18 southbound – Chelmsford to A12 Junction 15: All journey time sub-sections pass except the section between A1060 Parkway junction to Britvic roundabout. The model time is slower for this section with delay at the Britvic roundabout southbound approach. Junction coding, saturation flows and gap were checked to ensure the model coding is correct across all time periods.

In IP peak, only route does not pass the TAG criteria.

- Route 17 westbound – A12 Junction 19 to Chelmsford. The model journey times are slower than the observed times and overall journey time difference does not pass the TAG criteria. However, all sections along this route pass the TAG criteria individually.

In PM peak there are five journey time routes that do not pass the TAG recommended criteria. They are:

- Route 5 northbound – A131 Great Leighs to Braintree: All journey time sections pass except the section between A120/A131 Junction to Rayne Road roundabout. The model journey times are faster than the observed times. This section is located in the Braintree town centre and the localised delays are not fully captured in the SATURN model. However this would not impact the A12 scheme.
- Route 6 northbound – Chelmsford to Great Leighs: All journey time sections pass except the section between Sheepcotes roundabout to Main Road roundabout. The model time is slower than the observed times for this section. The model shows some delay near the Main Road roundabout and

network checks such as junction coding, saturation flows and gap were done to ensure the network coding is correct. The model flows match well with the observed traffic flows for all time periods.

- Route 15 northbound – Tiptree to B1023 Feering: Model times are quicker than the observed. In the PM peak, the model does not capture sufficient delay at the junction B1023 Inworth Road and Feering Hill. However, this section passes in both the other peaks. The high level of observed delay in PM peak was difficult to replicate in SATURN model.
- Route 15 southbound – B1023 Feering to Tiptree: The model times are generally slower for the overall journey route, but the sub-sections pass individually. The model flows match well with the observed traffic flows for this section for all time periods.
- Route 19 northbound – A130 to Army and Navy roundabout: All sections pass except the approach to the Army and Navy roundabout. The observed delay along Essex Yeomanry Way is not fully represented in the model but this does not impact the A12 scheme.

The modelled and observed journey times have been output by section for each route.

11.8 A12 results

A12 flow summary

The A12 mainline flows are presented in Plate 11-7 and Plate 11-8.

Plate 11-7 A12 mainline flows northbound – all vehicles

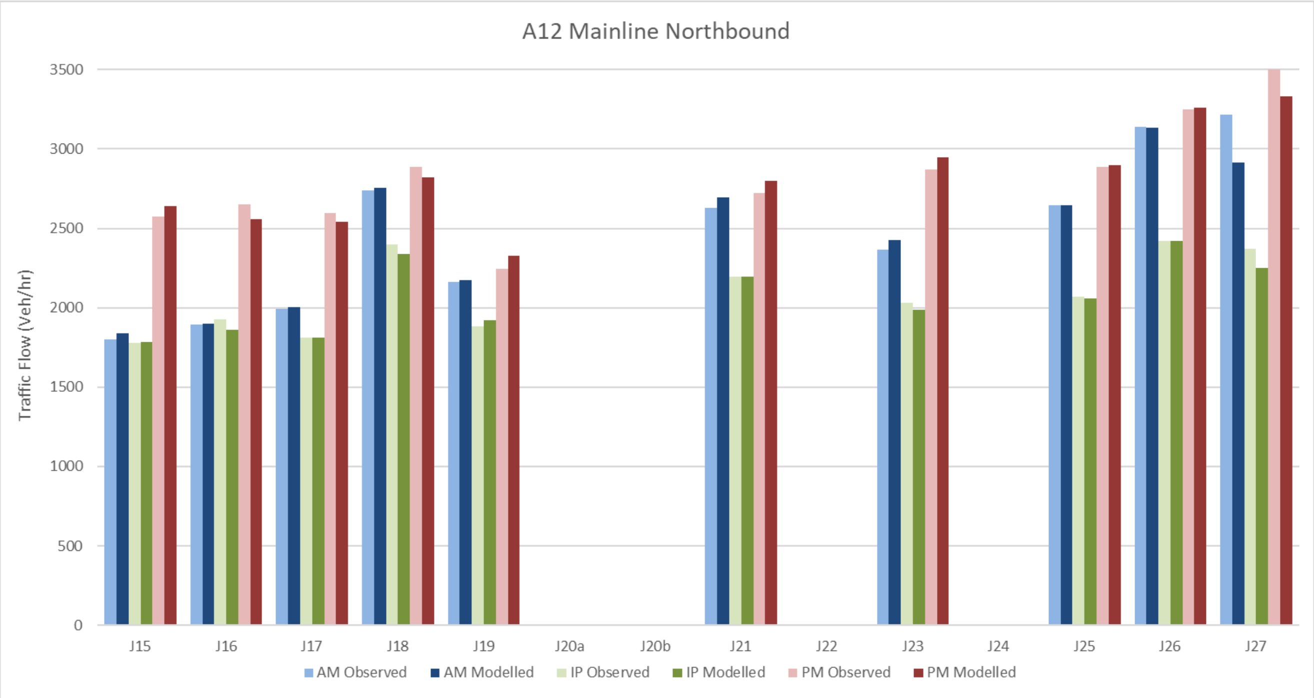
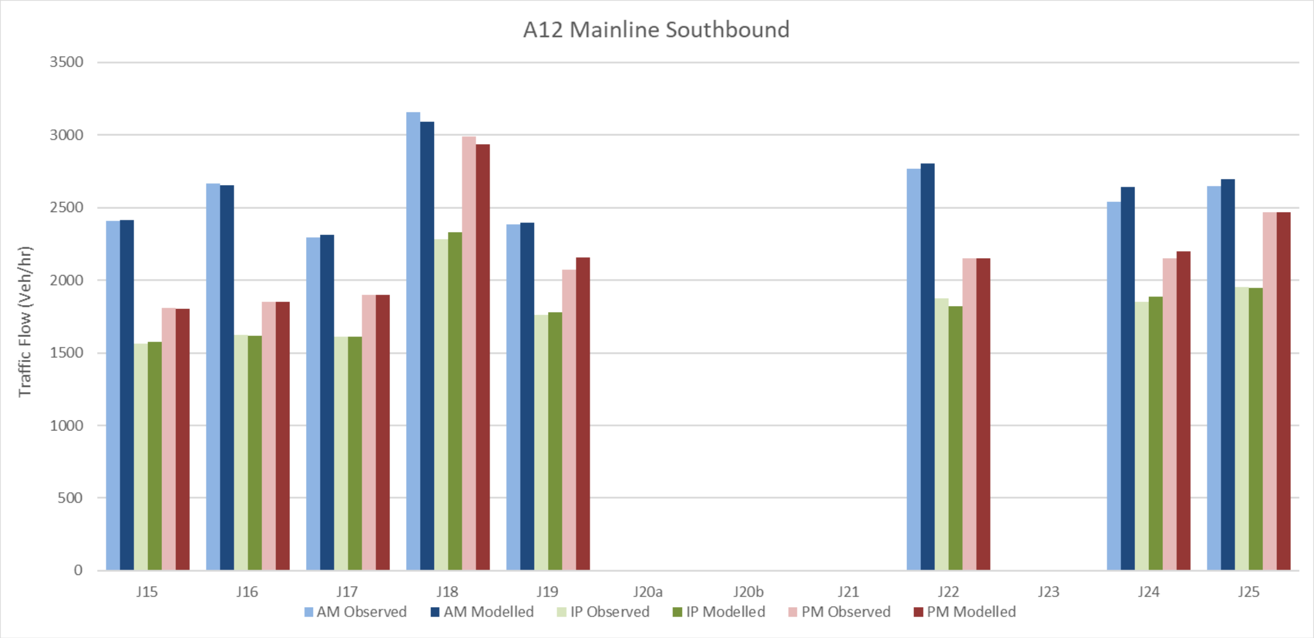


Plate 11-8 A12 mainline flows southbound – all vehicles



All mainline A12 mainline flows meet the TAG link flow criteria, as outlined in Section 3. This provides confidence that the modelled flows match the observed flows along the scheme route.

A12 journey time summary

The journey time route along the A12 has also been analysed by section. The A12 northbound journey time information is presented in Table 11-16 to Table 11-18 and Plate 11-9 to Plate 11-11. The southbound journey time information is presented in Table 11-19 to Table 11-21 and in Plate 11-12 to Plate 11-14.

Table 11-16 A12 journey time route summary – northbound – AM Peak

Location	AM				
	Observed JT [mm:ss]	Modelled JT [mm:ss]	Difference (sec)	% Diff	TAG Compliant
A12 J19	00:44	00:44	0	0%	Pass
A12 J19 to J20A	02:23	02:52	29	21%	Pass
A12 J20A to J20B	00:57	01:01	4	7%	Pass
A12 J20B to J21	00:49	01:13	24	49%	Pass
J21 to J22	02:38	02:49	11	7%	Pass
A12 J22 to Rivenhall End	00:42	00:49	7	16%	Pass
Rivenhall End to A12 J23	00:58	00:59	1	2%	Pass
A12 J23 to J24	02:49	03:06	17	10%	Pass
A12 J24 to Easthrope Road	01:06	01:17	11	16%	Pass
Easthorpe Road to A12 J25	01:54	02:24	30	26%	Pass
A12 J25	00:33	00:33	0	-1%	Pass
Total	15:33	17:47	**134**	**14%**	**Pass**

Table 11-17 A12 journey time route summary – northbound – IP Peak

Location	IP				
	Observed JT [mm:ss]	Modelled JT [mm:ss]	Difference (sec)	% Diff	TAG Compliant
A12 J19	00:43	00:44	1	2%	Pass
A12 J19 to J20A	02:24	02:41	17	12%	Pass
A12 J20A to J20B	00:58	00:58	0	1%	Pass
A12 J20B to J21	00:50	00:53	3	7%	Pass
J21 to J22	02:39	02:40	1	1%	Pass
A12 J22 to Rivenhall End	00:43	00:46	3	6%	Pass
Rivenhall End to A12 J23	00:58	00:56	-2	-4%	Pass
A12 J23 to J24	02:50	02:53	3	2%	Pass
A12 J24 to Easthrope Road	01:06	01:08	2	3%	Pass
Easthorpe Road to A12 J25	01:53	02:05	12	10%	Pass
A12 J25	00:33	00:32	-1	-3%	Pass
Total	15:37	16:16	**39**	**4%**	Pass

Table 11-18 A12 journey time route summary – northbound – PM Peak

Location	PM				
	Observed JT [mm:ss]	Modelled JT [mm:ss]	Difference (sec)	% Diff	TAG Compliant
A12 J19	00:50	00:45	-5	-10%	Pass
A12 J19 to J20A	04:30	05:17	47	17%	Pass
A12 J20A to J20B	01:32	01:07	-25	-27%	Pass
A12 J20B to J21	01:05	01:38	33	52%	Pass
J21 to J22	04:45	03:50	-55	-19%	Pass
A12 J22 to Rivenhall End	01:11	01:26	15	20%	Pass
Rivenhall End to A12 J23	01:04	01:14	10	15%	Pass
A12 J23 to J24	03:00	03:29	29	16%	Pass
A12 J24 to Easthrope Road	01:18	01:37	19	24%	Pass
Easthorpe Road to A12 J25	02:07	02:44	37	29%	Pass
A12 J25	00:34	00:34	0	-1%	Pass
Total	21:57	23:41	**104**	**8%**	Pass

Plate 11-9 A12 J19 to J25 journey time northbound AM

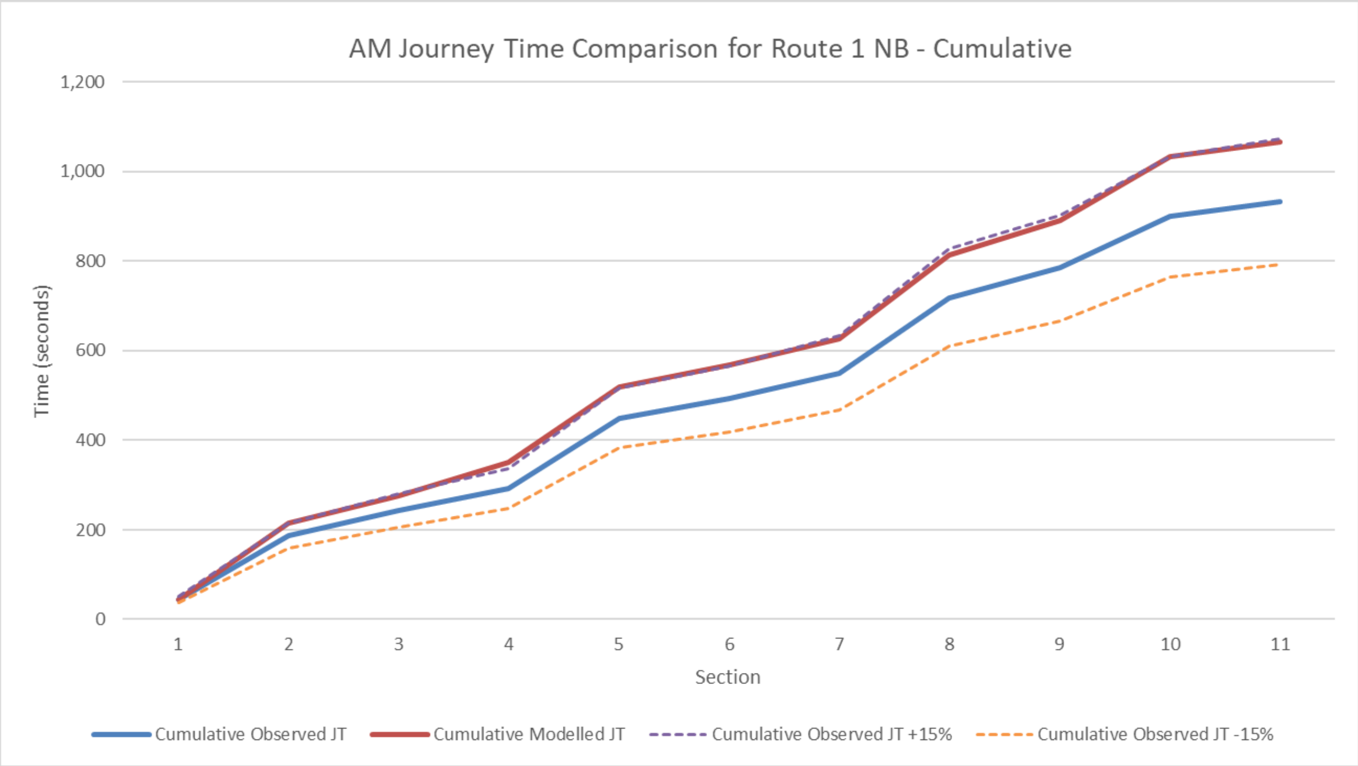


Plate 11-10 A12 J19 to J25 journey time northbound IP

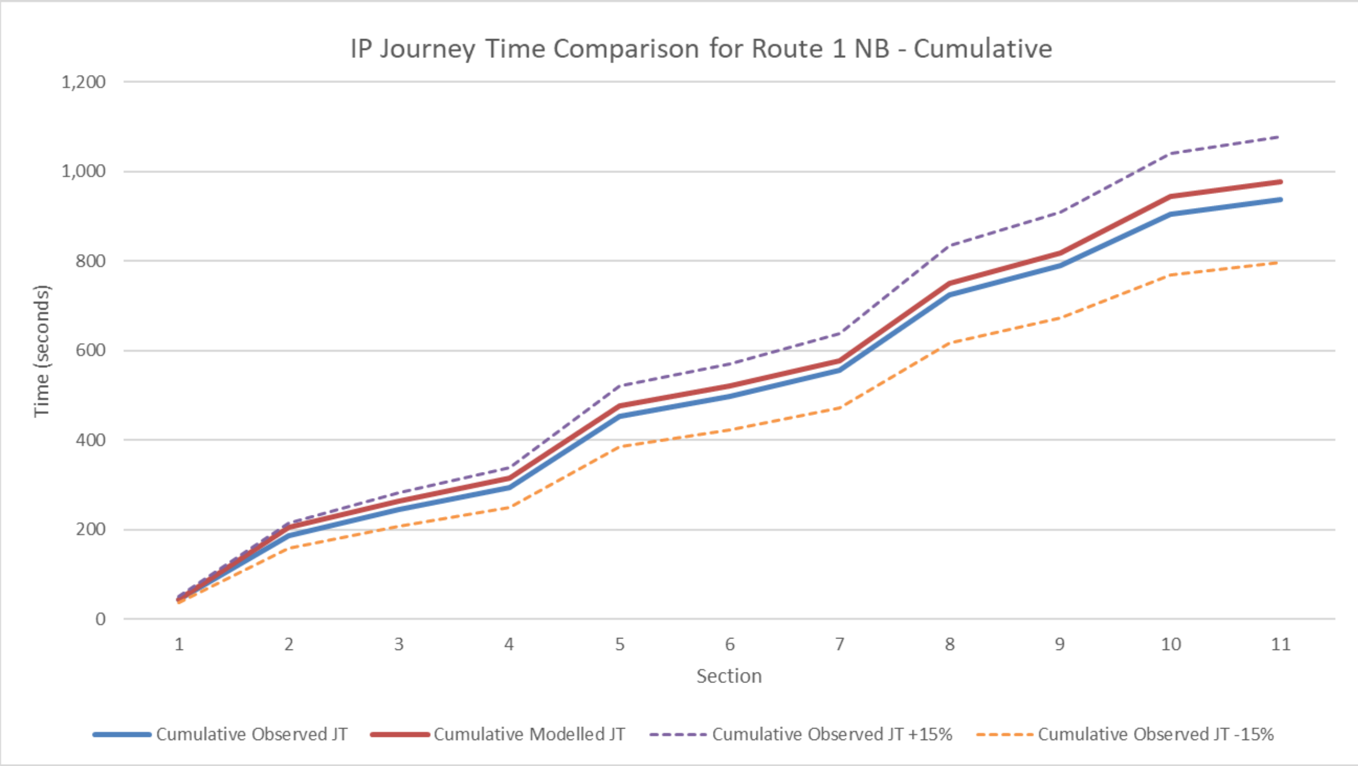


Plate 11-11 A12 J19 to J25 journey time northbound PM

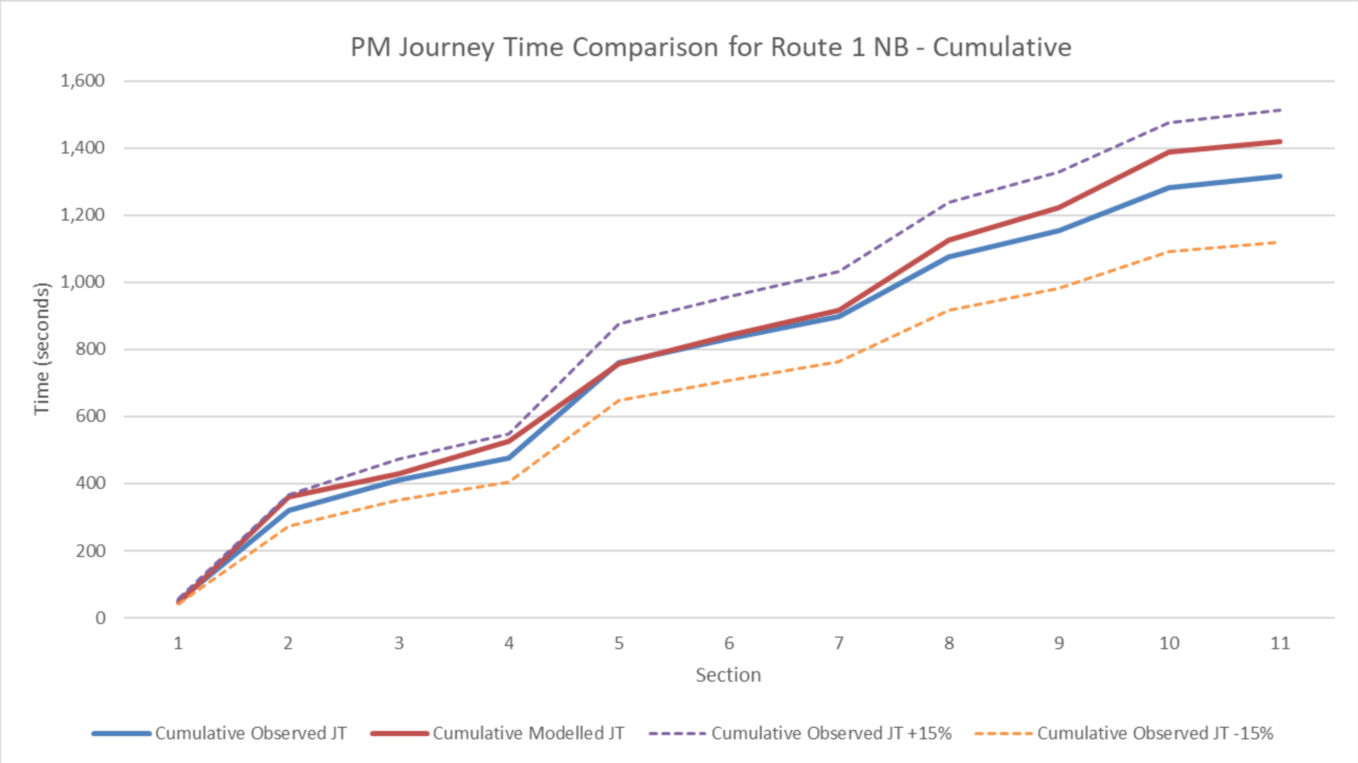


Table 11-19 A12 journey time route summary – southbound – AM Peak

Location	AM				
	Observed JT [mm:ss]	Modelled JT [mm:ss]	Difference (sec)	% Diff	TAG Compliant
A12 J25	01:05	00:52	-13	-20%	Pass
A12 J25 to Easthorpe Road	02:53	02:49	-4	-2%	Pass
Easthorpe Road to A12 J24	00:53	01:04	11	21%	Pass
A12 J24 to J23	04:08	03:21	-47	-19%	Pass
J23 to Rivenhall End	01:24	01:19	-5	-6%	Pass
Rivenhall End to A12 J22	00:48	01:12	24	51%	Pass
A12 J22 to J21	03:35	03:17	-18	-9%	Pass
A12 J21 to J20B	00:41	00:38	-3	-6%	Pass
A12 J20B-J20A	01:18	01:21	3	4%	Pass
A12 J20A-J19	02:32	02:48	16	10%	Pass
A12 J19	00:31	00:38	7	22%	Pass
Total	19:47	19:19	**-28**	**-2%**	**Pass**

Table 11-20 A12 journey time route summary – southbound – IP Peak

Location	IP				
	Observed JT [mm:ss]	Modelled JT [mm:ss]	Difference (sec)	% Diff	TAG Compliant
A12 J25	00:43	00:46	3	8%	Pass
A12 J25 to Easthorpe Road	02:04	02:12	8	7%	Pass
Easthorpe Road to A12 J24	00:43	00:45	2	5%	Pass
A12 J24 to J23	02:47	02:50	3	2%	Pass
J23 to Rivenhall End	00:57	00:56	-1	-2%	Pass
Rivenhall End to A12 J22	00:38	00:36	-2	-6%	Pass
A12 J22 to J21	02:59	02:53	-6	-3%	Pass
A12 J21 to J20B	00:31	00:31	0	-1%	Pass
A12 J20B-J20A	01:04	01:10	6	10%	Pass
A12 J20A-J19	02:22	02:16	-6	-4%	Pass
A12 J19	00:26	00:32	6	22%	Pass
Total	15:14	15:27	13	1%	Pass

Table 11-21 A12 journey time route summary – southbound – PM Peak

Location	PM				
	Observed JT [mm:ss]	Modelled JT [mm:ss]	Difference (sec)	% Diff	TAG Compliant
A12 J25	00:42	00:49	7	15%	Pass
A12 J25 to Easthorpe Road	02:05	02:24	19	15%	Pass
Easthorpe Road to A12 J24	00:43	00:50	7	15%	Pass
A12 J24 to J23	02:47	02:55	8	5%	Pass
J23 to Rivenhall End	00:57	01:00	3	4%	Pass
Rivenhall End to A12 J22	00:38	00:37	-1	-2%	Pass
A12 J22 to J21	02:59	03:03	4	2%	Pass
A12 J21 to J20B	00:32	00:32	0	2%	Pass
A12 J20B-J20A	01:05	01:14	9	14%	Pass
A12 J20A-J19	02:29	02:22	-7	-5%	Pass
A12 J19	00:35	00:35	0	1%	Pass
Total	15:33	16:21	48	5%	Pass

Plate 11-12 A12 J19 to J25 journey time southbound AM

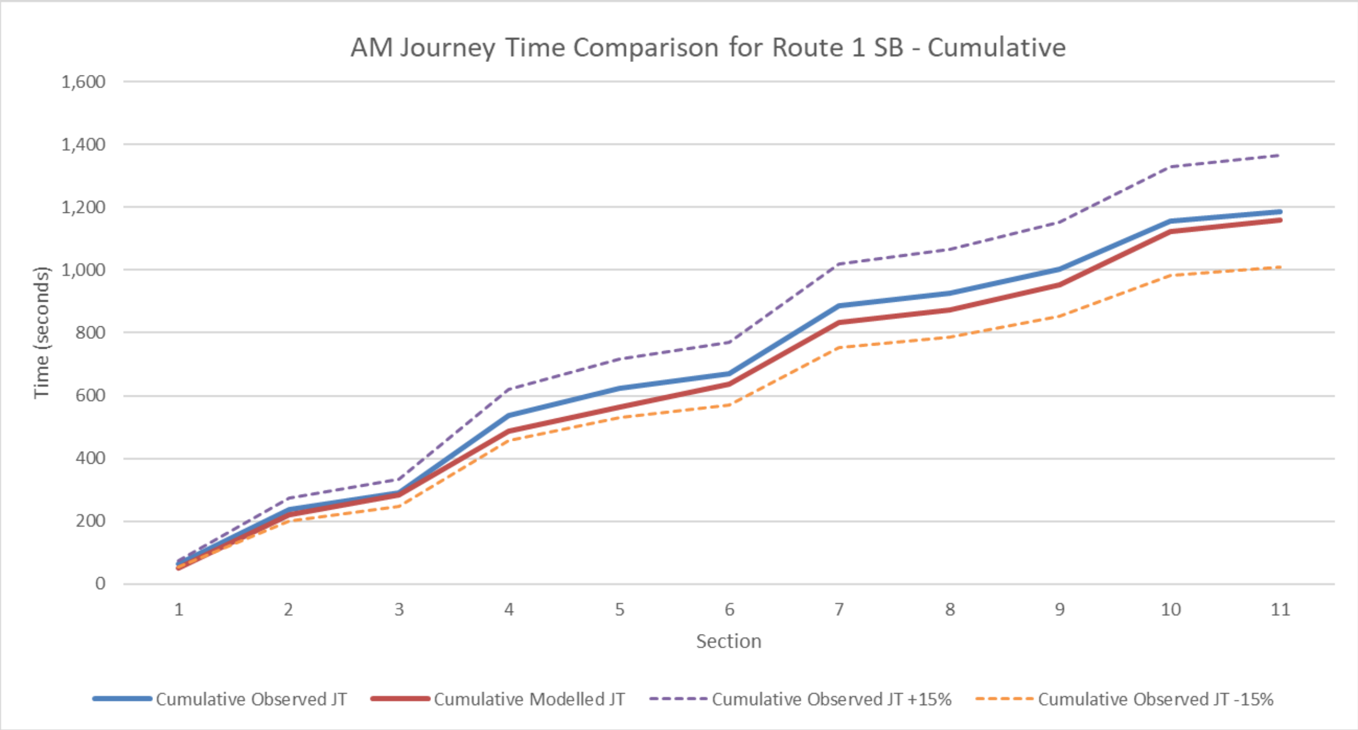


Plate 11-13 A12 J19 to J25 journey time southbound IP

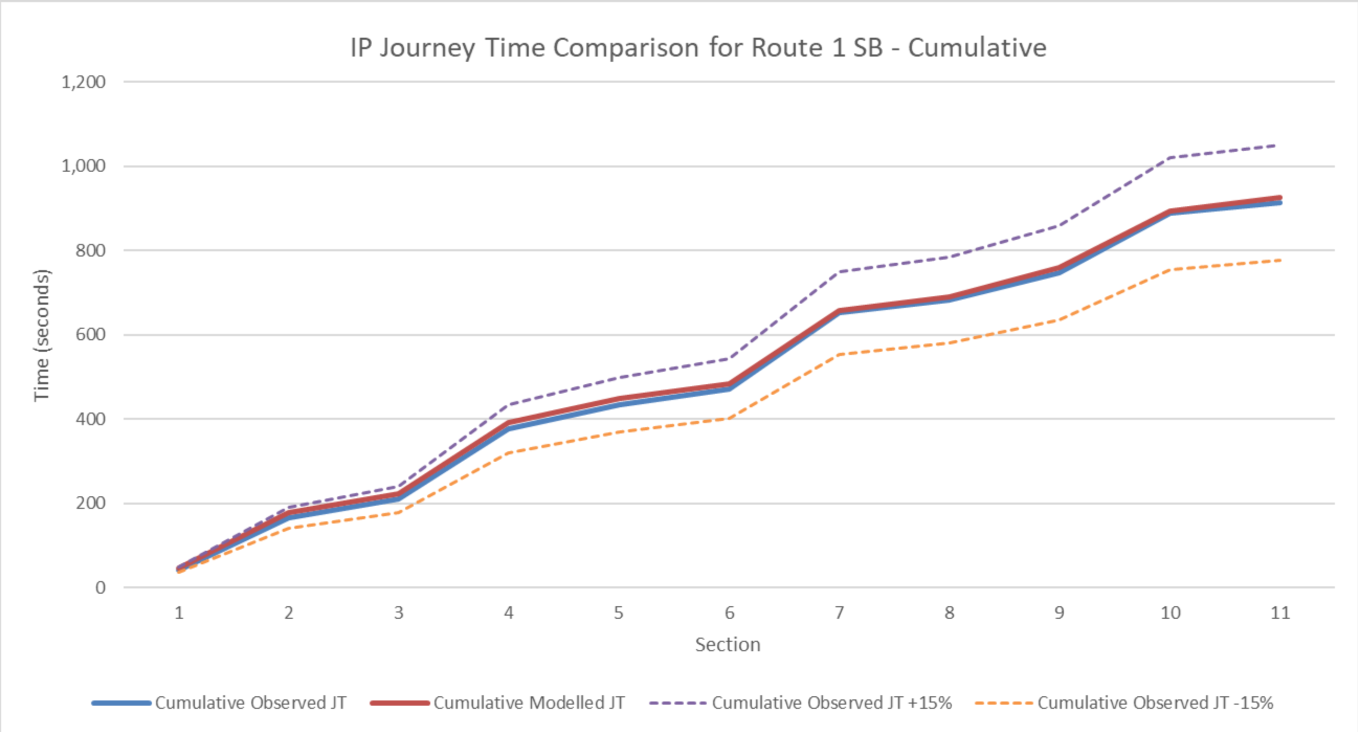
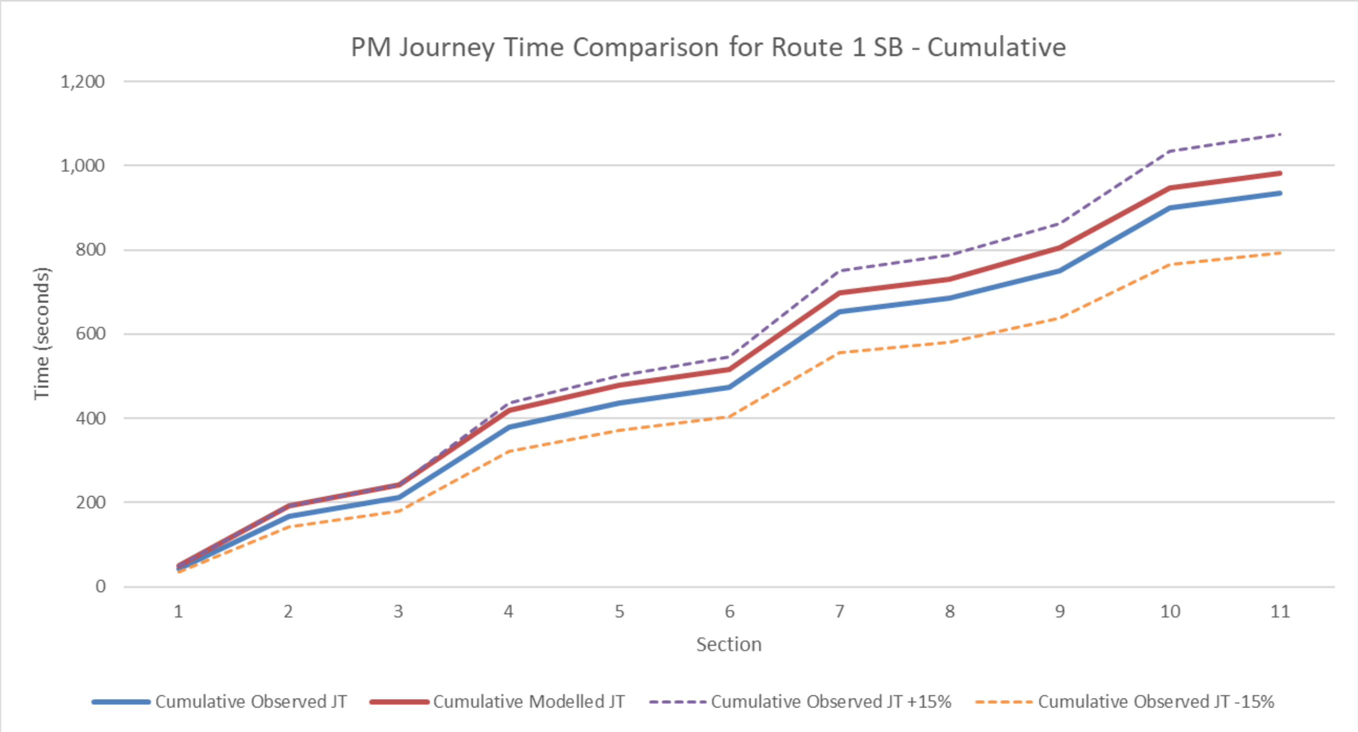


Plate 11-14 A12 J19 to J25 journey time southbound PM



The results show that the model achieves a good fit between modelled journey time and observed journey time for the A12 J19 to J25.

12. Variable Demand Model Building and Validation

12.1 Introduction

The premise of variable demand modelling (VDM) is that any change in travel cost, through traffic intervention or changes in travel demand is liable to either induce or suppress traffic. Any proposed improvements will likely make journeys quicker and cheaper for existing users by relieving congestion in the network and as such users will not only re-route from less appealing roads but may also change their destination of travel where previously inaccessible locations now become available, or shift travel from public transport to car and generate new trips that previously did not travel.

The purpose of VDM is to predict and quantify these changes. VDM establishes, in the absence of the scheme or strategy, the extent of travel suppression in the "without-scheme" case, and the relative additional traffic induced in the "with-scheme” case.

This chapter summarises the previous VDM modelling undertaken as part of PCF Stage 2 and details the VDM carried out as part of the A12 PCF Stage 3 model update.

12.2 PCF Stage 2 VDM

A modal shift significance test undertaken at PCF Stage 2 in line with TAG Unit M2 section 2.3.8 confirmed that a multi-modal VDM was required. However, there was no obvious evidence to show that the public transport (PT) times would change significantly after the scheme implementation. There was therefore no need to set up a complete PT assignment model. Due to the length and journey purposes associated with the improvements, rail was identified as the main competing public transport mode and was included in VDM.

The A12 PCF Stage 2 model VDM was developed as a production-attraction (PA) model within the DIADEM 6.3.3 software platform. The full detail of the model architecture and methodology was provided in the Local Model Validation Report, and can be summarised as follows:

- The variable demand model is incremental and hierarchical in line with TAG guidance
- All car-based journey purposes are subject to variable demand. Goods vehicles do not form part of the VDM and remain fixed in line with TAG M2 section 1.1.5 guidance

- The choice mechanisms used for this scheme assessment are:
  - destination of any given trip (trip distribution)
  - mode of transport taken (mode choice)
  - generation or loss of trip (trip frequency)
- Cost damping was not included.
- Time of Day choice was not modelled.
- Mode choice focused on rail and car modes and omitted active modes.
- The rail demand was derived using the mobile phone data and infilled for the short distance trips using Census JTW.
- Only the PT demand generated by car owning persons was included. Car ownership proportions were obtained from NTEM and applied at origin level.

For the PCF Stage 3 modelling it was agreed to retain the majority of the VDM scope as previously used at Stage 2. It was not deemed practical to re-assess the need for VDM and for mode choice component as part of PCF Stage 3 given that there was no material change either to the scheme or to the evidence that was used to inform those decisions.

Therefore, a Variable Demand Model was developed as part of PCF Stage 3 model update which included a mode choice model primarily for the choice between car and rail in the study area.

12.3 PCF Stage 3 VDM structure

The Variable Demand model is run as an incremental Origin-Destination based model using the same purpose definitions as the assignment model and using the DIADEM 7.0 software platform. The spatial coverage of the Variable Demand model is the same as the Highway model and they use the same zone system and generalised cost parameters.

The traffic model has been developed for three time periods;

- Weekday AM peak hour = 07:30 – 08:30.
- Weekday Inter-Peak (IP) hour = average hour between 1000 and 1600
- Weekday PM peak hour = 17:00 – 18:00

This is in line with guidance, with states that actual peak hour models are to be preferred in most circumstances.

The model area has been divided into two areas: the internal area and the external area. The internal area is the area where trip movements could potentially be impacted on by the scheme, in this area the network is generally fully defined and the model validated. The external area is the area outside this.

In the demand model calibration exercise all calculations are based on the following movements:

- internal to internal
- internal to external
- external to internal

The following movements are treated as fixed, and are excluded from the demand model calculations:

- external to external trips

Freight is also excluded from variable demand calculations.

12.4 Demand model user classes

Highway demand

In the highway assignment model, the assignment user classes are consistent with those in the demand model (there is a 1:1 correspondence). Road traffic has been sub-divided into eight user classes covering all journey purpose and vehicle combinations.

For some journey purposes fixed and variable demand user classes have been separately identified, where “fixed demand” relates to origin-destination movements that will not be subject to variable demand modelling, and “variable demand” relates to origin-destination movements that will be subject to variable demand modelling. Separate assignment parameters have been produced for each of the user classes to reflect traffic behaviour accurately in the assignment process.

Table 12-1 Demand model user classes

Assignment User Class	Demand Segment	Vehicle Type	Demand Model Segment
User Class 1	1	Car	VDM - Distribution
	6		Fixed
User Class 2	2	Car	VDM – Distribution
	7		Fixed
User Class 3	3	Car	VDM – Distribution & Frequency
	8		Fixed
User Class 4	4	LGV	Fixed
User Class 5	5	HGV	Fixed

Guidance recommends that LGV and HGV vehicle types are treated as fixed. Variable demand modelling is therefore only applied to car user classes.

Public transport demand

OD rail demand and cost matrices were readily available covering south-east England from the M3/M27 SMART motorway scheme model. Rail demand was consistent with SERTM (based on PLANET data) and SERTM zoning (largely corresponding to MSOA areas).

The base year for SERTM was 2015, and therefore instead of taking 2015 PT matrices and cost for A12 models where the base year model corresponds to 2019, it was decided that SERTM PT matrices and cost for the year 2021 will be taken for the A12 base year VDM runs.

Rail demand was provided per time period, while time and fare costs were provided as a weekday average hour.

Demand and costs were spatially adjusted to fit the A12 zone system using the method described in 6.2.1.

The same fixed versus variable demand structure was applied to the public transport demand for user classes 1 to 3 as that used for highway demand detailed in Table 12-1.

12.5 Doubly or singly constrained

Within the A12 VDM modelling:

- Commute trips are doubly constrained in all time periods, reflecting the confidence in the measures of attraction (employment) for commuting trips;
- Employers Business trips are doubly constrained in all time periods; and
- Other trips are singly constrained (Origin) in all time periods.

12.6 Demand model responses

Table 12-*2* below, indicates the DIADEM responses which have been modelled for the A12 scheme.

Table 12-2 Scope of VDM for A12

Modelled	Not Modelled
Trip Frequency	Mode Choice (Active modes, bus)
Mode Choice (Car / Rail)	Time of day choice
Trip Distribution	Micro time choice
Cost Damping	

12.7 Discussion on P/A and O/D model

TAG Unit M2 (paragraphs 2.5.2-2.5.3) state that Production-Attraction (PA) matrices should be used in variable demand modelling, even if no explicit trip distribution modelling is performed, unless there is a strong evidence why it shouldn't be.

One of the core advantages of PA modelling is to ensure consistency of response among time periods and specifically in the context of the mode choice. For example, the same number of home-based trips going outbound should return home during the same day and the mode choice is made based on the cost of the tour to prevent trips from changing modes due to the cost change through the day.

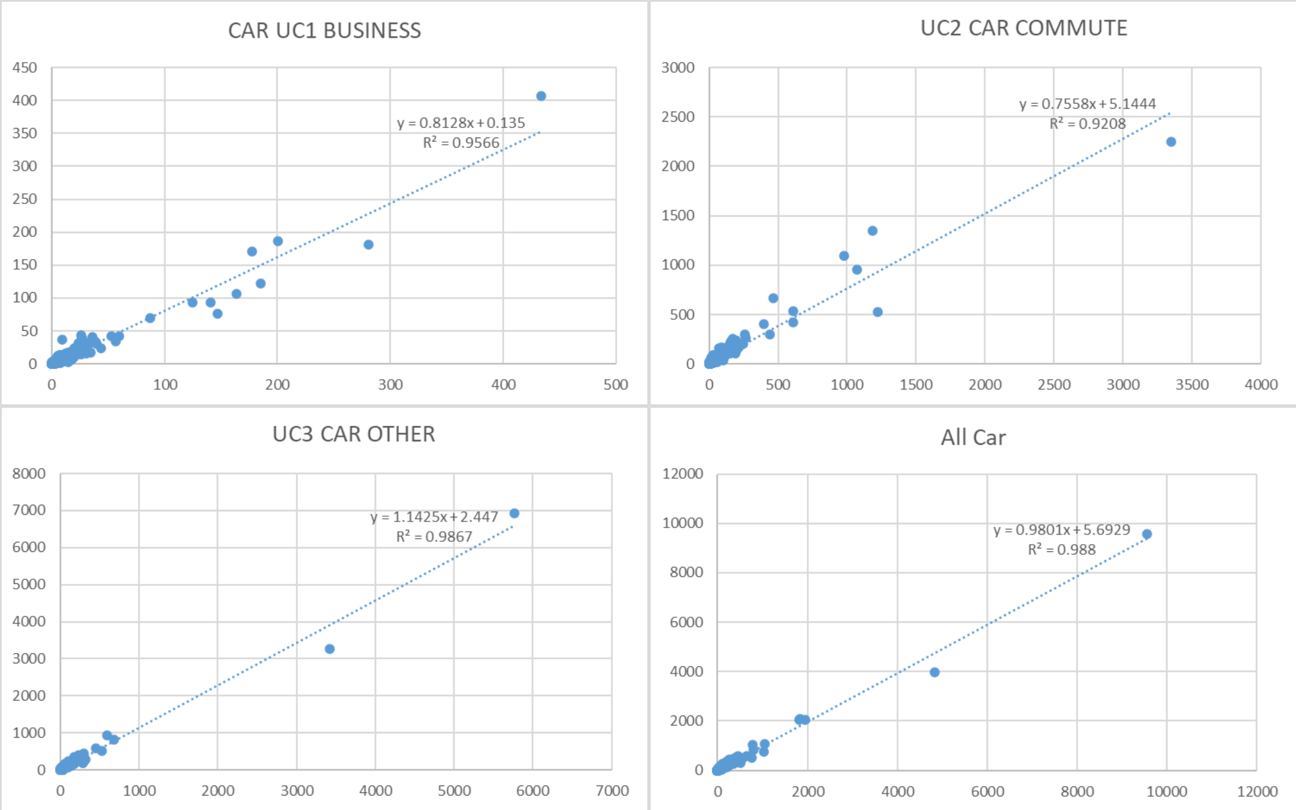
The analysis of travel time along the A12 corridor (where the scheme is likely to generate most benefits) suggests that without the scheme the congestion and delays will be substantial in the southbound direction in AM and in the northbound direction in PM.

This is logical as in the morning there is a significant demand towards London and Chelmsford as the key employment centres and in the evening the same people are returning home in the reverse direction. This means that any future decrease in travel cost by car will affect the same people in both directions and therefore O/D based VDM is likely to result in the same mode shift as the PA modelling.

Therefore, the advantage of PA based VDM over OD is significantly reduced, and only relates to destination choice impacts. It is acknowledged that in the scenario where a non-uniform growth is forecast at either the production (residential growth) end or the attraction end forecasts using OD matrices will be less accurate. However, the majority of the future demand will be base year trips and all major developments will be explicitly modelled in the forecast scenario. TEMPRO growth factors will only be used to derive the background growth and it is likely to be a very small proportion of future demand. Given the above and the fact that travel time savings are similar in AM and PM the benefits of PA VDM are even more modest.

To further reinforce this position, we undertook symmetry checks across modelled peaks at a sector-to-sector level to confirm that there is no major asymmetry in demand between AM and PM. Sector-sector regression analysis was performed, comparing transposed AM demand against PM demand.

Plate 12-1 Sector regression analysis demonstrating AM and PM symmetry



The results show strong correlation between AM and PM with gradients close to 1, R^2 close to 1 and intercept values near zero.

This demonstrates the suitability of an OD based VDM, provided the elasticity responses are balanced across all time periods, because this represents balance between majority outbound trips in AM and majority return trips in PM, similar to the linked outbound and return trips within PA modelling.

12.8 Demand model calibration – realism testing

The VDM guidance prescribes that where variable demand is assessed, realism tests should be carried out on the base year model to ensure that it behaves realistically to changes in travel costs and time, and the overall model response conforms to general guidelines.

The DIADEM model is an iterative process which starts with a set of base demand car/rail matrices and costs. Through the process the highway demand matrices and travel costs are allowed to change at each iteration until convergence is reached.

When used in forecasting mode the future year demands are calculated using the calibrated base year costs and demands as a pivot point.

DIADEM requires that model parameters are defined for each of the selected responses. For logit-based models the spread (dispersion) parameter Lambdas (λ) must be defined for the choice at the bottom of the hierarchy and for choices above the bottom the scaling parameter Thetas (θ) is required.

TAG Unit M2 requirements

TAG Unit M2 provides guidance on the calibration of demand models. It recommends a number of realism tests that should be carried out and provides a range of appropriate parameter values and expected responses from the model. It recommends that the following should be carried out:

- Car fuel cost elasticities;
- Car journey time elasticities; and
- Public transport fare elasticities.

For the purposes of modelling the A12 scheme only calibration based on car fuel elasticities and car journey time elasticities have been considered. In the absence of a PT model, the PT fare elasticity calibration is not included.

Fuel cost elasticities – guidelines

TAG Unit M2 recommends that demand model calibration is undertaken so that model achieves the following:

- The annual average fuel cost elasticity should lie in the range -0.25 to -0.35
- The pattern of annual average elasticities:
  - Employers Business near -0.1;
  - Discretionary trips near to -0.4;
  - Commuting and Education somewhere near the average
- Pattern of all-purpose elasticities should show peak period elasticities which are lower than inter peak which are lower than off peak.

Calculations are matrix based, and network based using car vehicle kilometre changes calculated from car trip matrices and skimmed distance matrices. Calculations are based on demand segments and model areas with variable demand, i.e. excludes ‘external to external’ trips, intrazonal demand and freight.

TAG Unit M2 also provides the recommended range for parameter values. These are shown in Table 12-3.

Table 12-3 TAG Unit M2 Lambda targets

Purpose	TAG Targets		
	Minimum	Median	Maximum
Car			
Commute	0.054	0.065	0.113
Employer Business	0.038	0.067	0.106
Other	0.074	0.090	0.160
Public Transport			
Commute	0.023	0.033	0.043
Employer Business	0.030	0.036	0.044
Other	0.033	0.036	0.062

Combined with the TAG Unit M2 requirement the distribution parameters should ideally lie within 25% of the median Lambda values. For the purposes of the A12 model, the HB purposes have been used as the median Lambda values for employer business and the other trip purpose.

Additionally, TAG Unit M2 paragraph 6.4.14 expects that:

- the annual average fuel cost elasticity should lie on the right side of -0.3, taking account of the levels of income and average trip lengths prevailing in the modelled area.

The characteristics of the study area were compared against the national characteristics to determine which side of -0.3 the annual average fuel cost elasticity should lie. The result of this comparison is presented in Table 12-4.

Table 12-4 - Fuel cost elasticity – right side test

Conditions for elasticity weaker than -0.30	Condition met?
Trip lengths shorter than average	East of England (NTS 2018/19) = 8.7 miles England (NTS 2018/19) = 7.5 miles **No** - Longer than NTS for majority of trips (across all purposes)
Car mode share higher than average	East of England (Census 2011) car availability = 81%, car use for travel to work = 45% England & Wales (Census 2011) car availability = 74%, car use for travel to work = 41% **Yes** - Greater than national
EB proportion higher than average	East of England (TEMPRO 7.2) = 4.4% GB (TEMPRO 7.2) = 5.9% **No** - Lower than national
Higher disposable household income levels	East of England (ONS 2018) = £22,205 England (ONS 2018) = £21,609 **Yes** - Greater than national

Given that half of the conditions are met, it is reasonable to conclude that elasticity should lie between -0.25 and -0.3, as the income is higher than the national average (less affected by increases to fuel costs).

12.9 Process for realism testing

The realism testing approach uses a two-staged calibration method:

- Changing model generalised cost coefficients (the distance coefficient) in the validated base model to reflect a 20% fuel increase. This has a different impact for different trip purposes. (TAG Unit M2 recommends a 10%-20% fuel increase). The 20% increase has been used to reduce the impact that model noise has on the calculations; and
- Modifying the model parameters to achieve the overall target fuel cost elasticity in the range -0.25 to -0.3. The individual purposes are calibrated to different values as suggested in TAG Unit M2.

Stage 1 - Calculating generalised cost parameters to reflect fuel cost increase

A new SATURN Vehicle Operating Cost parameter PPK (Pence per Kilometre) has been calculated from the validated model PPK for each user class. Table 12-5 shows the PPK values used in the validated base assignment model and the PPK values that reflect a 20% fuel cost increase. As part of the realism tests, the fuel cost element of the model generalised cost coefficient (the distance coefficient) was increased by 20%.

Table 12-5 Fuel elasticities Generalised Cost co-efficient

Vehicle Type	Trip Purpose	Time Period	Vehicle operating cost / PPK (p/km)	
			Validated Base Year	20% Fuel Cost Increase
Car	Employer Business	AM	12.27	13.25
Car	Commute	AM	6.01	7.21
Car	Other	AM	6.01	7.21
Car	Employer Business	IP	12.27	13.25
Car	Commute	IP	6.01	7.21
Car	Other	IP	6.01	7.21
Car	Employer Business	PM	12.27	13.25
Car	Commute	PM	6.01	7.21
Car	Other	PM	6.01	7.21

Stage 2 - Calculating Model Parameters

The second stage of the calibration process is to calculate the demand model parameters required to achieve the overall target fuel cost elasticity of in the range -0.25 to -0.3. The median values of Lambdas **(λ)** and Thetas **(θ)** parameters given as in the latest TAG Unit M2 guidance are used as the starting point and then these are systematically modified until a satisfactory elasticity for the base year is achieved. The model is run after each adjustment and the elasticity calculated using the arc-elasticity formulation, which for a 20% fuel increase, is given by:

$$Fuel\ Cost\ Elasticity = \frac{In\left(\frac{Veh\_km^1}{Veh\_km^0}\right)}{In(1.20)}$$

Where the superscript 0 indicates the value from the base year model and 1 indicates the results from the model run with the increased distance coefficient. Similarly, the car journey time elasticity is calculated based on the equation below:

$$Car\ Journey\ Time\ Elasticity = \ Elasticity^{Fuel\ Cost}\frac{aT}{bK}$$

Where a is the cost per hour, b is cost per km, K is vehicle kilometres and T is total vehicle hours.

Cost Damping

To further improve and adjust the outturn realism test results to ensure that the change in travel costs and time are realistic, cost damping has been utilised.

There is evidence that long distance trips are less sensitive to changes in costs than short distance trips and TAG Unit M2 recommends that cost damping functions are included in the variable demand process. The idea behind cost damping is to adjust the costs for longer trips so that their sensitivity to individual cost components (such as fuel cost or travel time) is reduced.

TAG Unit M2 provides the following advice on cost damping:

Para 3.3.2 states *"not all models will need to use cost damping but, if it is employed, then functions of one of the forms specified below should generally be used. The choice of the following cost damping mechanisms is a matter for the analyst. If analysts wish to use other forms of cost damping, they should consult the Department before doing so."*

Additionally, para 3.3.3 states "It is not necessary for analysts to conduct tests using each of the forms specified below and to prove that one is better than the others. This is because the form of cost damping and the cost damping parameter values will interact with other aspects of the model, such as the demand model parameter values and values of time. While the cost damping parameter values, demand model parameter values and values of time should all be kept within certain limits specified below and in Section 6, it is the performance of the combination of all these aspects of the model in yielding satisfactory realism test results that is important."

The use of cost damping was deemed necessary as initial realism tests using median value parameters and varying them within the permitted 25% ranges did not give acceptable elasticities for ‘other’ trip purposes. This is further discussed in the following section.

DIADEM offers a range of different methods of applying cost damping. The approach used for this study is the first option, damping by a Function of Distance.

The damped cost is given by the formula:

$$G' = (d/k)^{-\alpha}.(t + c/VOT),$$

Where:

t = time (minutes)

c = cost (pence)

VOT = value of time (pence per minute)

d' = trip length; and

α and k = parameters that need to be calibrated.

TAG acknowledges that whilst there is no firm guidance provided on setting the parameters for cost damping, TAG Unit M2, paragraph 3.3.10 provides the following commonly used parameters which were adopted.

Table 12-6 Cost Damping TAG Unit M2 Parameters

Parameter	Description	Commonly used value
α	must be positive and less than 1 and should be determined by experimentation in the course of adjusting a model so that it meets the requirements of realism tests	0.5
k	must also be positive and in the same units as d’	30 km
d’	calculated by skimming distances	30 km

12.10 Realism testing results

This section presents outturn results from the following analysis:

- Car fuel cost elasticities;
- Network based elasticities;
- Journey time elasticities; and
- DIADEM Convergence.

Car fuel cost elasticities

Calibration of the destination model parameters was conducted in line with guidance from TAG Unit M2 para 6.6.5 using median values taken from Table 5.1 of the same document. A sequence of model runs was conducted, as described below, in order to achieve calibration. Some run numbers are excluded, these relate to individual sensitivity tests on cost response that did not influence the parameters used for final calibration.

Run 00 used the median parameter settings from TAG Unit M2 Table 5.1 for all time periods. The results indicate that in all time periods for commute purposes the response is not sensitive enough, while employer business and other elasticity response is too strong.

Run 01 aims to increase the distribution parameters by +25% above median values commute purposes, while reducing to -25% below the median for employer business and other. The elasticity responses improved for all purposes, but largely remained too sensitive for other purpose and weak for commute trip purpose.

Run 00 and Run 01 showed that changes to lambda values alone would not be sufficient to reduce the other purpose response to close to -0.4. So, distance-based cost damping was introduced for other purposes for further runs, based on the commonly used values quoted in TAG Unit M2 paragraph 3.3.10, namely **k** and **d'** set to 30km and alpha to 0.5.

In Run 02, median lambda values were applied together with cost damping for other purposes to isolate the impact of cost damping. The results show that cost damping alone had a significant impact on reducing the other elasticity response to -0.43 though this can then be further improved.

Run 03 then combines cost damping with ±25% of median values as used in Run 01 with cost damping for other purposes. This resulted in very close matches to target elasticities when combining to 12 hours. However, commute still remained too weak.

Run 04 was then run with maximum lambda and theta value for commute as quoted in TAG Unit M2 and -12.5% below the median for Other trip purpose. This produced acceptable employer business and other purpose responses in all time periods and all car users 12-hour response. Commute response is a little low overall but consistent across time periods. Given a symmetric response in AM and PM is highly preferrable to replicate the tie between outbound and return in PA-based VDM. Given that all possible combinations of parameters were tested to keep parameter values within TAG guidelines, the values were deemed to be calibrated.

The input parameters and the results of the sequence of runs are presented in Table 12-7 and Table 12-8 respectively.

The outturn fuel cost elasticities from the realism testing of the final run are presented in Table 12-9.

Table 12-7Car fuel cost elasticities – Parameters

Run	Highway Distribution (Lambda)			PT Distribution (Lambda)			Mode Parameter (Theta)			Cost Damping	Frequency
ID	Commute	EB	Other	Commute	EB	Other	Commute	EB	Other	Other	Other
Run00	Median -0.065	Median -0.067	Median -0.09	Median -0.033	Median -0.036	Median -0.036	Median 0.68	Median 0.45	Median 0.53	-	0.08
Run01	25% -0.081	-25% -0.050	-25% -0.068	25% -0.041	25% -0.027	-25% -0.027	25% 0.850	-25% 0.338	-25% 0.398	-	0.08
Run02	Median -0.065	Median -0.067	Median -0.09	Median -0.033	Median -0.036	Median -0.036	Median 0.68	Median 0.45	Median 0.53	d’=k=30000m, alpha =0.5	0.08
Run03	25% -0.081	-25% -0.050	-25% -0.068	25% -0.041	25% -0.027	-25% -0.027	25% 0.850	-25% 0.338	-25% 0.398	d’=k=30000m, alpha =0.5	0.08
Run04	MAX -0.113	-25% -0.05	-12.5% -0.079	MAX -0.043	-25% -0.027	-12.5% -0.032	MAX 0.83	-25% 0.338	-12.5% 0.464	d’=k=30000m, alpha =0.5	0.08

Table 12-8 Car fuel cost elasticities – 12hr Results (including weekends)

Run ID	12hr (including weekends)			
	Commute	EB	Other	Overall
Target Elasticity	-0.25 to -0.3	near -0.1	near -0.4	-0.25 to -0.3
Run 00	-0.07	-0.32	-0.75	-0.46
Run 01	-0.10	-0.09	-0.60	-0.37
Run 02	-0.07	-0.32	-0.43	-0.30
Run 03	-0.10	-0.10	-0.33	-0.22
Run 04	-0.14	-0.09	-0.39	-0.27

Table 12-9 Car fuel cost elasticities – Final Results

Time Period	Matrix Based			
	Commute	Employer Business	Other	Overall
Target	-0.25 to -0.3	Near -0.1	Near -0.4	-0.25 to -0.3
AM	-0.17	-0.12	-0.40	-0.26
IP	-0.12	-0.09	-0.38	-0.29
PM	-0.11	-0.07	-0.41	-0.25
Elasticity Results_12 Hour (excl. weekends)	-0.139	-0.097	-0.392	-0.265
Elasticity Results_12 Hour (incl. weekends)	-0.136	-0.095	-0.388	-0.270

Table 12-9 indicates final demand model calibration results, based on the changes outlined above. The resulting elasticities (based on all non-fixed trips which are subject to variable demand) have:

- All-purpose all-day elasticities on the right side of -0.3 (result -0.26, is in range of -0.25 to -0.3, see Table 12-4*).*
- Commute elasticity below the all-purpose values, but consistent across time periods (important when running OD rather than PA VDM as discussed in Section 12.7). The Stage 2 VDM commute elasticity was similar at -0.16 and was considered appropriate.
- Employers business elasticities have a response close to the TAG recommended -0.1.
- Other purpose elasticities have a response close to the TAG recommended -0.4.
- IP elasticity for all-purposes is higher than AM and PM. This fits with the expectation that other purpose trips form a higher proportion of IP demand.

Network based elasticities

Network based elasticities were calculated and are presented in Table 12-10 below. This indicates that commute and employer business elasticities are consistent with the matrix-based values in Table 12-9*,* while other elasticities are lower.

This is expected given that the other trips response is more heavily influenced by longer distance trips which extend into the buffer area and are not fully represented by the simulation area network values in Table 12-10.

This response is also anticipated within TAG unit M2 6.4.13 which states *"This calculation is likely to underestimate the fuel cost elasticity if the change in car-kms includes fixed elements, such as external to external trips"*.

The overall network-based elasticity response of -0.13 is similar to the Stage 2 modelling result of -0.18, which was deemed appropriate in discussion with TPG.

Table 12-10 Network Based Elasticities – Results

Time Period	Network Based			
	Commute	Employer Business	Other	Overall
Target	-0.25 to -0.30	Near -0.1	Near -0.4	-0.25 to -0.35
AM	-0.15	-0.10	-0.13	-0.14
IP	-0.15	-0.09	-0.13	-0.13
PM	-0.13	-0.08	-0.11	-0.11
Elasticity Results_12 Hour (excl. weekends)	-0.14	-0.09	-0.12	-0.13
Elasticity Results_12 Hour (incl. weekends)	-0.15	-0.09	-0.12	-0.13

Journey time elasticity

Car journey time elasticities were calculated using the fuel cost elasticities and cost damping, using the equation below:

$$E^{time} = E^{fuel}\frac{p^{time}}{p^{fuel}}$$

Where $\boldsymbol{p}^{time}$ is cost of travel as a proportion of generalised cost; and

$\boldsymbol{p}^{fuel}$ is the cost of fuel as a proportion of total generalised cost.

Furthermore, if the total vehicle kilometres (K) and total vehicle hours (T) are known then the following relationship can be derived:

$$\frac{p^{time}}{p^{fuel}} = \frac{aT}{bK}$$

where ***a*** is the cost per hour; and ***b*** is the cost per km.

Consequently, using the above relationship, the car elasticities of vehicle kms with respect to journey time elasticities have been derived and the results are presented within Table 12-11 below.

Table 12-11 Car Journey time elasticities - Results

Time Period	Purpose	Matrix base	Network based
AM	Commute	-0.67	-0.67
	EB	-0.31	-0.26
	Other	-1.11	-0.40
IP	Commute	-0.41	-0.57
	EB	-0.21	-0.23
	Other	-1.00	-0.36
PM	Commute	-0.41	-0.51
	EB	-0.18	-0.21
	Other	-1.17	-0.32

Results demonstrate that the car journey time elasticities are below the TAG recommended threshold of -2.0 and are therefore TAG compliant and acceptable to be used as part of forecasting for the A12 model.

DIADEM convergence

Based on the lambda parameters derived in the realism tests, the forecast models have been run through DIADEM. In assessing the outputs of the model runs, the main parameter of importance is the 'relative gap', which is the measure of convergence between demand and supply. Current TAG guidance recommends a relative gap of at least 0.2%.

The Diadem base year realism testing models all converged to less than 0.2% within 10 iterations, which suggests the demand - supply convergence of the variable demand traffic model is acceptable. It has therefore been shown that the traffic model is stable and has converged to an acceptable standard.

12.11 Conclusion

The variable demand model for the A12 model has been calibrated using the DIADEM software in accordance with the methodology and recommendations set out in TAG unit M2.

Realism tests have readily converged giving a relative gap of 0.2% (in line with TAG Unit M2).

The results presented in the preceding sections demonstrate that:

- The demand model structure and response hierarchy have been set up correctly and comply with TAG Unit M2 requirements;

- The calculations and the methodology used for fuel cost elasticities are compliant to TAG Unit M2 guidance;
- The overall outturn elasticity results fall within the TAG Unit M2 expectations and requirements; and
- The distribution parameters that are adopted in the model are TAG Unit M2 compliant and within recommendations.

Overall, the demand model responses to change are realistic and within the requirements of TAG Unit M2. Thus, these calculated parameters will be considered suitable for variable demand modelling for future year forecasting and to appraise the proposed A12 scheme.

13. Summary and conclusions

This report outlines the development of the A12 PCF Stage 3 DCO traffic model. A summary is given below on the model development, standards achieved, and fitness for purpose of the model.

13.1 Summary of model development

This section summarises the key points of the model development.

Overall model infrastructure:

- **Highway Model**: a highway assignment model was developed in SATURN (V11.4.07H).
- **Study Area**: the model covers all of the UK including England, Scotland and Wales as per SERTM. The simulation area is defined by the district boundaries for Braintree, Colchester, Chelmsford, Uttlesford, Tendring and Maldon.
- **Time Periods**: the time periods covered by the model represent AM peak hour (07:30 – 08:30), average Inter–Peak hour (10:00 – 16:00) and PM peak hour (17:00 – 18:00).
- **Base Year**: the model has been validated to a base year of an average weekday 2019.
- **User Classes**: the five User Classes modelled are Cars Employer Business, Cars Commute, Cars Other, Light Goods Vehicles (LGVs) and Heavy Goods Vehicles (HGVs).

Network development:

- **Network components**: In the network, junctions are represented by nodes, whilst links represent the roads in between the junctions. The modelled network also includes zones and connectors that attach zones to the network.
- **Network coverage**: The model covers all of the UK including England, Scotland and Wales.
- **Link and Junction coding**: Speed flow curves and free flow speed parameters were added to links with junctions coded in detail in the simulation area.
- **Modelling standards**: Model parameters, assumptions, speed flow curves and the methodology used to code turn saturation flows have been standardised where possible to keep the coding consistent.
- **Network checks**: Sufficient network checks have been performed to ensure the model is robust.
- **Zoning system**: Zones represent the starting or finishing points of journeys. A hierarchy of zones is used, with a large number of small zones in the urban

areas and the area of concern, a moderate number of moderate–sized zones further away, and a small number of large zones on the periphery.

- **Assignment procedures**: The assignment procedure used within SATURN is the default one, Wardrop's Equilibrium.
- **Generalised cost parameters**: Generalised cost parameters are calculated using May 2021 version of the TAG Data Book (v1.15).
- **Convergence criteria**: The convergence criteria adopted are robust and meet the TAG requirements.

Trip Matrix Development:

- The base year demand matrices are based on SERTM prior matrices from March 2015;
- These were disaggregated and uplifted to represent 2019.
- Matrix Estimation was undertaken using a combination of screenlines and individual counts.

The assignment of matrices to the network gave good calibration results at screenline and link level. The level of validation achieved falls just short of the criteria set out in TAG.

All A12 flows from J15 to J27 are within GEH 5 or 15% difference across links in all time periods.

Journey times for routes along the A12 corridor and other identified key routes meet TAG criteria.

13.2 Summary of standards achieved

The standards to which the model aimed to conform to are set out in Chapter 3. Table 13-1 summarises how the model has actually performed against those standards:

Table 13-1 Model Performance Standards

Model aspect	Criterion	Acceptability Guideline	Actual model performance
Matrix estimation	Matrix zonal cell values	Slope within 0.98 and 1.02 Intercept near zero R2 in excess of 0.95	Satisfies criterion in all time periods
	Matrix zone trip ends	Slope within 0.99 and 1.01 Intercept near zero R2 in excess of 0.98	Largely satisfies criterion in all time periods
	Trip length distributions	Means within 5% Standard deviations within 5%	Satisfies criterion in all time periods
	Sector to sector level matrices	Differences within 5%	Fails criterion in all time periods. Discussion and justification for this has been provided in the report.
Assignment convergence	Delta and %GAP	Less than 0.1%	Satisfied for all time periods
Link calibration	Individual flows within 100 veh/hr of counts for flows less than 700 veh/hr	> 85% of cases	Criteria is satisfied in all time periods for Flows meeting GEH or link flow criteria. AM peak: criteria met for car flows on 91% of links, and for total vehicles on 89% of links. IP: criteria met for car flows on 94% of links and for total vehicles on 93% of links PM peak: criteria met for car flows on 90% of links and for total vehicles on 89% of links.
	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	

Model aspect	Criterion	Acceptability Guideline	Actual model performance
Link validation	Same as for link calibration, but for independent counts		Criteria is satisfied in all time periods for Flows meeting GEH or link flow criteria. AM peak: criteria met for car flows on 88% on links, and total vehicles on 88% of links Interpeak: criteria met for car flows on 97% of links and total vehicles on 95% of links. PM peak: criteria met for car flows on 89% of links and for total vehicles on 89% of links.
Journey times	Modelled times along routes should be within 15% of surveyed time, or 1 minute if higher	> 85% of all routes	Criteria met for 89% of journey time routes in the AM, 97% in the IP and 87% in the PM time period.
VDM Realism Test	Overall, the demand model responses to change are realistic and within the requirements of TAG Unit M2.		

Table 13-1 demonstrates that the vast majority of the model standards set out in Chapter 3 are met.

13.3 Assessment of fitness for purpose

The model performs well against the model standards previously set out and this should serve to give confidence and provide reassurance that the model is representative of observed conditions.

The Stage 3 traffic model is capable of producing accurate estimates of existing traffic conditions within the study area, in particular along and around the A12 corridor.

Given that the model has been demonstrated to have been constructed in a manner consistent with guidance, it is expected that a high degree of confidence may be placed in the model for the purposes of scheme assessment, including economic and environmental appraisal.

Appendix A. A12 Coding Manual

Description	Free-flow Speed kph	Speed at Capacity kph	Capacity	n	Index
Simulation and Buffer Network					
Rural 3 lane Motorway	116	45	7560	3.81	1
Rural 2 lane Motorway	112	67	4660	2.90	2
Previously: Rural 2 lane Motorway	112	45	4860	3.85	-
Rural 3 lane Slip Road	88	45	6540	3.63	3
Rural 2 lane Slip Road	88	45	4360	3.63	4
Rural 1 lane Slip Road	88	45	2180	3.63	5
Rural Dual 3 lane A Road	88	45	6540	3.63	6
Rural Dual 2 lane A Road	88	45	4360	3.63	7
Rural Dual 3 lane A Road (Trunk)	109	45	6780	3.66	8
Rural Dual 2 lane A Road (Trunk)	109	45	4520	3.66	9
Rural 3 lane Single Carriageway A Road (Good condition)	91	45	5580	2.24	10
Rural 3 lane Single Carriageway A Road (Average condition)	84	45	4980	2.13	11
Rural 2 lane Single Carriageway A Road (Good condition)	87	45	3280	2.16	12
Rural 3 lane Single Carriageway A Road (Poor condition)	87	45	4920	2.16	13
Rural 2 lane Single Carriageway A Road (Average condition, 50mph)	78	45	2760	2.07	14
Rural 2 lane Single Carriageway B Road (Good condition, 50mph)	78	45	2760	2.07	15
Rural 2 lane Single Carriageway C Road (Good condition, 50mph)	78	45	2760	2.07	16
Rural 2 lane Single Carriageway A Road (Poor condition, 40mph)	67	45	2020	1.79	17
Rural 2 lane Single Carriageway B Road (Average condition, 40mph)	67	45	2020	1.79	18
Rural 2 lane Single Carriageway C Road (Good condition, 40mph)	67	45	2020	1.79	19
Rural Single Carriageway A Road (Good condition)	87	45	1640	2.16	20
Rural 2 lane Single Carriageway A Road (Poor condition)	87	45	3280	2.16	21
Rural Single Carriageway A Road (Average condition, 50mph)	78	45	1380	2.07	22
Rural Single Carriageway B Road (Good condition, 50mph)	78	45	1380	2.07	23
Rural Single Carriageway C Road (Good condition, 50mph)	78	45	1380	2.07	24
Rural Single Carriageway A Road (Poor condition, 40mph)	67	45	1010	1.79	25

Rural Single Carriageway B Road (Average condition, 40mph)	67	45	1010	1.79	26
Rural Single Carriageway C Road (Good condition, 40mph)	67	45	1010	1.79	27
Rural Single Carriageway C Road (Bad condition)	50	25	800	1.5	28
Village 2 lane Single Carriageway A Road (40mph, Light Development)	66	30	2600	3	29
Village 2 lane Single Carriageway A Road (40mph, Typical Development)	57	30	2000	3.39	30
Village 2 lane Single Carriageway A Road (30mph, High Development)	47	30	1760	2.45	31
Village Single Carriageway A Road (40mph, Light Development)	66	30	1300	3	32
Village Single Carriageway A Road (40mph, Typical Development)	57	30	1150	3.39	33
Village Single Carriageway A Road (30mph, High Development)	47	30	880	2.45	34
Village 2 lane Single Carriageway B Road (40mph, Light Development)	66	30	2600	3	35
Village 2 lane Single Carriageway B Road (40mph, Typical Development)	57	30	2000	3.39	36
Village 2 lane Single Carriageway B Road (30mph, High Development)	47	30	1760	2.45	37
Village Single Carriageway B Road (40mph, Light Development)	66	30	1300	3	38
Village Single Carriageway B Road (40mph, Typical Development)	57	30	1000	3.39	39
Village Single Carriageway B Road (30mph, High Development)	47	30	880	2.45	40
Village 2 lane Single Carriageway C Road (40mph, Light Development)	66	30	2600	3	41
Village 2 lane Single Carriageway C Road (40mph, Typical Development)	57	30	2000	3.39	42
Village 2 lane Single Carriageway C Road (30mph, High Development)	47	30	1760	2.45	43
Village Single Carriageway C Road (40mph, Light Development)	66	30	1300	3	44
Village Single Carriageway C Road (40mph, Typical Development)	57	30	1000	3.39	45
Village Single Carriageway C Road (30mph, High Development)	47	30	880	2.45	46
Rural Single Carriageway B Road (Good condition)	50	40	900	1.75	134
Rural Single Carriageway A Road (Good condition)	50	30	800	1.75	135
Village Single Carriageway (reduced capacity	47	30	150	2.45	136
Simulation Network Only					
Suburban 2 lane Dual A Road (Good condition, 50mph)	78	35	3640	2.94	47
Suburban 2 lane Dual A Road (Average condition, 40mph)	73	35	3520	3.18	48
Suburban 2 lane Dual A Road (Poor condition, 40mph)	68	35	3450	3.47	49
Suburban 2 lane Dual B Road (condition, 40mph)	68	35	3450	3.47	50
Suburban 2 lane Single Carriageway A Road (Good condition, 50mph)	65	25	3600	2.71	51
Suburban Single Carriageway A Road (Good condition, 50mph)	65	25	1800	2.71	52

Suburban 2 lane Single Carriageway A Road (Average condition, 40mph)	60	20	3500	2.01	53
Suburban Single Carriageway A Road (Average condition, 40mph)	60	20	1750	2.01	54
Suburban 2 lane Single Carriageway B Road (Good condition, 40mph)	60	20	3500	2.01	55
Suburban Single Carriageway B Road (Good condition, 40mph)	60	20	1750	2.01	56
Suburban 2 lane Single Carriageway C Road (Good condition, 40mph)	60	20	3500	2.01	57
Suburban Single Carriageway C Road (Good condition, 40mph)	60	20	1750	2.01	58
Suburban 2 lane Single Carriageway A Road (Poor condition, 30-40mph)	55	20	3200	1.65	59
Suburban Single Carriageway A Road (Poor condition, 30-40mph)	55	20	1600	1.65	60
Suburban 2 lane Single Carriageway B Road (Average condition, 30-40mph)	55	20	3200	1.65	61
Suburban Single Carriageway B Road (Average condition, 30-40mph)	55	20	1600	1.65	62
Suburban 2 lane Single Carriageway C Road (Average condition, 30-40mph)	55	20	3200	1.65	63
Suburban Single Carriageway C Road (Average condition, 30-40mph)	55	20	1600	1.65	64
Suburban 2 lane Single Carriageway A Road (Residential Development)	45	21	2400	1.38	65
Suburban Single Carriageway A Road (Residential Development)	45	21	1200	1.38	66
Suburban 2 lane Single Carriageway B Road (Residential Development)	45	21	2400	1.38	67
Suburban Single Carriageway B Road (Residential Development)	45	21	1200	1.38	68
Suburban 2 lane Single Carriageway C Road (Residential Development)	45	21	2400	1.38	69
Suburban Single Carriageway C Road (Residential Development)	45	21	1000	1.38	70
Urban 2 lane Single Carriageway A Road (Average condition, 30mph, Central Development)	62	25	3600	2.75	71
Urban Single Carriageway A Road (Average condition, 30mph, Central Development)	62	25	1800	2.75	72
Urban 2 lane Single Carriageway B Road (Good condition, 30mph, Central Development)	62	25	3600	2.75	73
Urban Single Carriageway B Road (Good condition, 30mph, Central Development)	62	25	1800	2.75	74
Urban 2 lane Single Carriageway A Road (Poor condition, 30mph, Central Development)	55	20	3400	2.65	75
Urban Single Carriageway A Road (Poor condition, 30mph, Central Development)	55	20	1700	2.65	76
Urban 2 lane Single Carriageway B Road (Average condition, 30mph, Central Development)	55	20	3400	2.65	77
Urban Single Carriageway B Road (Average condition, 30mph, Central Development)	55	20	1700	2.65	78
Urban 2 lane Single Carriageway C Road (Good condition, 30mph, Central Development)	55	20	3400	2.65	79

Urban Single Carriageway C Road (Good condition, 30mph, Central Development)	55	20	1700	2.65	80
Urban 2 lane Single Carriageway A Road (Poor condition, 30mph, Central Development)	47	20	3200	2.55	81
Urban Single Carriageway A Road (Poor condition, 30mph, Central Development)	47	20	1600	2.55	82
Urban 2 lane Single Carriageway B Road (Poor condition, 30mph, Central Development)	47	20	3200	2.55	83
Urban Single Carriageway B Road (Poor condition, 30mph, Central Development)	47	20	1600	2.55	84
Urban 2 lane Single Carriageway C Road (Poor condition, 30mph, Central Development)	47	20	3200	2.55	85
Urban Single Carriageway C Road (Poor condition, 30mph, Central Development)	47	20	1600	2.55	86
Centroid Single Carriageway A Road	30	30	9999	0	87
Centroid Single Carriageway B Road	30	30	9999	0	88
Centroid Single Carriageway C Road	30	30	9999	0	89
Buffer Network Only					
Rural 4 lane Motorway	116	45	10080	3.81	90
Rural 4 lane Dual A Road (Trunk)	109	45	9040	3.66	91
Suburban 4 lane Dual A Road (Good condition, 50mph)	76	35	6160	2.79	92
Suburban 4 lane Dual A Road (Average condition, 40mph)	71	35	5140	2.65	93
Suburban 4 lane Dual A Road (Poor condition, 40mph)	68	35	4120	1.94	94
Suburban 3 lane Dual A Road (Good condition, 50mph)	76	35	4620	2.79	95
Suburban 3 lane Dual A Road (Average condition, 40mph)	71	35	3855	2.65	96
Suburban 3 lane Dual A Road (Poor condition, 40mph)	68	35	3090	1.94	97
Suburban 2 lane Dual A Road (Good condition, 50mph)	76	35	3080	2.79	98
Suburban 2 lane Dual A Road (Average condition, 40mph)	71	35	2570	2.65	99
Suburban 2 lane Dual A Road (Poor condition, 40mph)	68	35	2060	1.94	100
Suburban 2 lane Dual B Road (Good condition, 50mph)	76	35	3080	2.79	101
Suburban 2 lane Dual B Road (Average condition, 40mph)	71	35	2570	2.65	102
Suburban 2 lane Dual B Road (Poor condition, 40mph)	68	35	2060	1.94	103
Suburban 2 lane Single Carriageway A Road (Good condition, 50mph)	66	25	3080	3.75	104
Suburban Single Carriageway A Road (Good condition, 50mph)	66	25	1540	3.75	105
Suburban 2 lane Single Carriageway A Road (Average condition, 40mph)	61	25	2570	3.76	106
Suburban Single Carriageway A Road (Average condition, 40mph)	61	25	1285	3.76	107
Suburban 2 lane Single Carriageway A Road (Poor condition, 40mph)	58	25	2060	2.32	108
Suburban Single Carriageway A Road (Poor condition, 40mph)	58	25	1030	2.32	109
Suburban 2 lane Single Carriageway A Road (Good condition, 30mph, Non-Central Light Development)	54	25	1960	1.67	110
Suburban Single Carriageway A Road (Good condition, 30mph, Non-Central Light Development)	54	25	980	1.67	111

Suburban 2 lane Single Carriageway A Road (Good condition, 30mph, Non-Central Medium Development)	49	25	1560	1.56	112
Suburban Single Carriageway A Road (Good condition, 30mph, Non-Central Medium Development)	49	25	780	1.56	113
Suburban 2 lane Single Carriageway A Road (Average condition, 30mph, Non-Central High Development)	45	25	1300	1.48	114
Suburban Single Carriageway A Road (Average condition, 30mph, Non-Central High Development)	45	25	650	1.48	115
Suburban 2 lane Single Carriageway B Road (Good condition, 30mph, Non-Central High Development)	45	25	1300	1.48	116
Suburban Single Carriageway B Road (Good condition, 30mph, Non-Central High Development)	45	25	650	1.48	117
Suburban 2 lane Single Carriageway A Road (Average condition, 30mph, Central Development)	37	15	1480	1.83	118
Suburban Single Carriageway A Road (Average condition, 30mph, Central Development)	37	15	740	1.83	119
Suburban 2 lane Single Carriageway B Road (Good condition, 30mph, Central Development)	37	15	1480	1.83	120
Suburban Single Carriageway B Road (Good condition, 30mph, Central Development)	37	15	740	1.83	121
Suburban 2 lane Single Carriageway A Road (Poor condition, 30mph, Central Development)	34	15	1260	1.73	122
Suburban Single Carriageway A Road (Poor condition, 30mph, Central Development)	34	15	630	1.73	123
Suburban 2 lane Single Carriageway B Road (Average condition, 30mph, Central Development)	34	15	1260	1.73	124
Suburban Single Carriageway B Road (Average condition, 30mph, Central Development)	34	15	630	1.73	125
Suburban 2 lane Single Carriageway C Road (Good condition, 30mph, Central Development)	34	15	1260	1.73	126
Suburban Single Carriageway C Road (Good condition, 30mph, Central Development)	34	15	630	1.73	127
Suburban 2 lane Single Carriageway A Road (Poor condition, 30mph, Central Development)	29	15	900	1.55	128
Suburban Single Carriageway A Road (Poor condition, 30mph, Central Development)	29	15	450	1.55	129
Suburban 2 lane Single Carriageway B Road (Poor condition, 30mph, Central Development)	29	15	900	1.55	130
Suburban Single Carriageway B Road (Poor condition, 30mph, Central Development)	29	15	450	1.55	131
Suburban 2 lane Single Carriageway C Road (Poor condition, 30mph, Central Development)	29	15	900	1.55	132
Suburban Single Carriageway C Road (Poor condition, 30mph, Central Development)	29	15	450	1.55	133