South Essex Model

Public Transport and Variable Demand Model Development Report

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1 Introduction

1.1 Model Overview

As specialist consultant to Ringway Jacobs, the framework provider to Essex County Council (ECC), Jacobs UK Limited have been commissioned to develop the required strategic modelling necessary to understand how people currently travel strategically within the South Essex region and how this might change with future growth and as specific major schemes are implemented. The model should also be appropriate for the following tasks:

- Help to develop South Essex regionwide transport strategies.
- Help to assess the impact of highway schemes (and where appropriate, public transport schemes).
- Help to assess the combined impact of Local Plans on the primary roads.
- Provide evidence for early appraisal and sifting of strategic major scheme options.
- Provide inputs into corridor microsimulation models in the PTV VISSIM software platform.
- To be used for the appraisal of potential highway schemes along the A127 corridor.

The model has been delivered in stages with the highway assignment component delivered first, based on the locally enhanced version of the Essex Countywide highway assignment model. A new highway model known as Enhanced Essex Countywide Strategic Model (EECSM) focusing on the South Essex region has now been developed and validated to a base year of 2019. That work has been completed in 2020 and a local model validation report (LMVR) for the highway model has been submitted to ECC.

This model development work described here refers to the remaining components identified as necessary to form a multi-modal modelling framework for South Essex, which will now include Public Transport (PT) model and a Variable Demand Model (VDM). With the completion of these components the modelling framework for South Essex is now complete and in this report the name South Essex Model (SEM) will be used interchangeably with EECSM with the latter is used to describe solely the highway component of the model described in the LMVR referred to above. With the completion of the overall SEM framework, EECSM will now also be called South Essex Highway Assignment Model (HAM) or simply SEM highway component.

1.2 Purpose of this Report

This Base Model Local Model Validation Report (LMVR) summarises the work carried out in the development of the EECSM highway model. The key design considerations and features of the model are discussed there, but are also repeated in this report, which sets out the model featires relevant to PT and VDM. This report sets out sources used in PT and VDM models development, the checks that have been undertaken on the demand and supply components of the model, and the resulting calibration and validation of the models.

This report demonstrates that the model produces an accurate representation of Public Transport in the study area, making it suitable for the evaluation of improvements and land use changes in future year scenarios. In order to demonstrate the suitability of the model, its level of accuracy has been quantified and described with reference to TAG guidance.

The purpose of this report is therefore to:

- Describe the development of the base year PT model for South Essex.

- Detail the accuracy with which the PT model reproduces an observed situation, in a limited number of cases where independent data was available.
- Summarise the accuracy of the base from which the forecasts are to be prepared.
- Describe the structure and capabilities of the Variable Demand Model.
- Describes the adjustment made to the 24hr (daily) matrices to incorpoarate the changes made in the highway model calibration for each time period (separately) AM peak, Interpeak and PM peak) and this facilitate the implementaiton of VDM.
- Describe the model's fitness for purpose.

1.3 Report Structure

The remainder of this report is set out as follows:

- **Chapter 2 -** Details the uses of the model and key design considerations.
- **Chapter 3 -** Identifies the standards to which the model was built.
- **Chapter 4 -** Describes the key features of the PT model.
- **Chapter 5 -** Details the data used for PT model calibration and validation.
- **Chapter 6 -** Describes the processes used in developing the PT network.
- **Chapter 7 -** Describes the processes used in developing the PT trip matrices.
- **Chapter 8 -** Provides information on the calibration and validation of the trip matrices.
- **Chapter 9 -** Details the calibration and validation of the PT assignment.
- **Chapter 10 –** Describes the VDM structure and adjustments to the 24 P/A matrices.
- **Chapter 11 –** Describes the calibration of the VDM and realism testing.
- **Chapter 12 -** Provides a summary of the model and its development.

2 Purpose of the Model and Key Model Design Considerations

2.1 Proposed Use of the Model

The propose of SEM is set out in the highway LMVR and summarised below:

- Evidence for Local Plan development and hearings.
- Testing the impact of housing and employment growth and major transport schemes on the network, and to identify options for mitigation.
- Evidence for Business Cases, specifically for the appraisal of schemes in the A127 corridor.
- Provide evidence to support responses to Government department or company consultations.
- Support planning processes on key schemes.
- Understand suitable phasing of maintenance and utilities work to manage congestion impacts.
- Optimisation of the performance of the existing transport network using technology.
- Accessibility planning for key land uses.

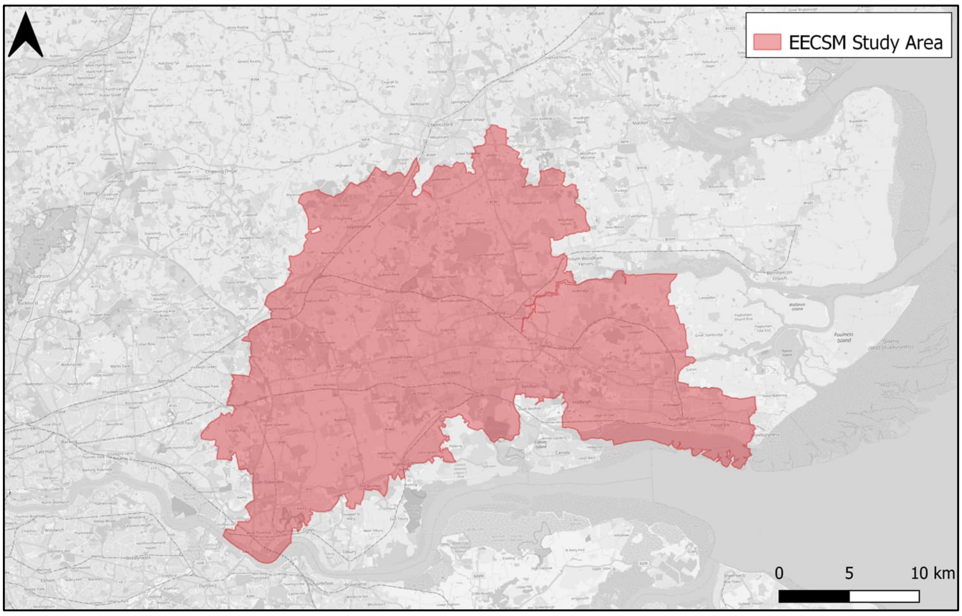
In addition, following the addition of the PT model described here, the framework will be capable of testing strategic public transport impriovements such as increases in bus service provision (journey times and frequencies). The model will also be capable of testing the interacitons between highway schemes and public transport (for instance re-allocaiton of highway capacity to public transport, but priority schemes or schemes that change journey times in public transport corridors. The latter is supported by the model funcitonality to pass highway speeds onto the bus service run times.

2.2 Key Model Design Considerations

2.3 Introduction

Tto test the strategic impacts of potential transport schemes in the area of interest, the model extends to an area that is sufficient to assess strategic movements and key route choices as well as local movements within the study area. The zone system, study area and area of influence (AoI) was determined in the highway LMVR and the study area is shown in Figure 2-1 below.

Figure 2-1: Study Area



2.3.1 Software

The South Essex Public Transport Model has been developed in INRO's EMME 4.4.4.2 software package and the network has been updated and made consistent with the highway assignment model network. The Variable Demand Model (VDM) has also been coded in EMME software in-line with the principles set out in TAG Unit M2-1 "Variable Demand Modelling" and embedded in DfT's DIADEM software. This approach was chosen to enable more flexible interactions with the public transport assignment model (limited in DIADEM) and enable future extensions of the demand modelling functionality.

2.3.2 Study Area

2.3.3 Modelled Responses

Both highway and public transport assignment models provide a detailed route choice modelling capability in the Fully Modelled Area. The choice between the bus and rail services is handled in the demand model, which improves the allocation of bus and rail demand to their respective modes.

VDM follows the model structure recommended in TAG. It models mode choice between car and public transport and trip distribution (more sensitive of the responses). In-line with best practice and consistently with the structure of Essex CW, the demand model is in the incremental form and operates at the 24-hour PA level, which ensures consistency of trip distribution and mode choice responses across the modelled time periods.

The main mode choice model (PT vs car) includes information about car availability. The model includes sub-mode choice (bus vs rail) at the bottom of the choice model hierarchy. Trip generation is based on TEMPro inputs and local uncertainty log for car and bus, with rail-specific growth forecasts based on PDFH. The trip end growth inputs are prepared externally and applied to the base year matrix through with trip end factors and furnessing to estimate the reference case forecast matrix used in the incremental pivot-point procedures of VDM. Further detail is set out in the Technical Note: South Essex Transport Model - Forecasting Process.

Goods vehicle trips are assumed not to change destination in response to travel costs as these responses are influenced by other factors that are beyond the scope of a typical transport model. However, their choice of route is modelled in the highway assignment model.

The highway model passes the information about the outturn highway speeds into the public transport assignment model, which adjusts timetabled bus speeds to reflect local congestion. Slow modes (cycle and walk) do not lend themselves to detailed modelling in strategic models and in case of SEM are expected to be handled in bespoke tools, which will draw on data from SEM.

Overall, SEM demand model functionality is intended to:

- Allow modelling of the impact of strategic highway interventions in the Area of Detail Modelling, including route choice, destination and mode choice.
- Allow modelling of the impact of strategic bus interventions in the Area of Detail Modelling, including route choice, destination and mode choice.
- Ensure that areas outside the Area of Detailed Modelling, which are potential alternative destinations, are properly represented.
- Ensure that the full lengths of trips are represented for the purpose of deriving realistic travel costs required for the demand modelling.

3 Public Transport Model Standards

3.1 General requirements

Department for Transport's (DfT) Transport Analysis Guidance (TAG) Unit M3.2 Chapter 7 suggests that the validation of a public transport passenger assignment model should involve three kinds of check:

- Validation of the trip demand matrix.
- Network and service validation.
- Assignment validation.

Validation of the trip matrix should involve comparisons of assigned and counted passengers across screenlines and cordons (as opposed to individual services). At this level of aggregation, TAG recommends that the differences between assigned and counted flows should, in 95% of the cases, be less than 15%.

Validation of the network should involve checks on the accuracy of the coded geometry and transit service speeds in the model (i.e. for in-vehicle, access and interchange times where relevant) and frequency checks. It is also desirable to demonstrate the accuracy of the coding of the public transport routes as this defines the accuracy of the modelled generalised cost of travel by public transport. Validation of the assignment should involve comparing modelled and observed:

- Passenger flows across screenlines and cordons.
- Passengers boarding and alighting in relevant urban centres.

TAG recommends that across modelled screenlines, flows should, in total, be within 15% of the observed values. For individual counts, modelled flows should be within 25% of the counts, except where observed hourly flows are particularly low (less than 150 passengers per hour).

Wherever possible, a check should also be made between the annual patronage derived from the model and annual patronage derived by the operator. Precise comparisons may be difficult but may be sufficiently accurate to provide a cross-check on the general scale of patronage, bearing in mind that operator patronage is likely to be boardings and not trips.

3.1 Requirements for the South Essex Model

The level of public transport model validation that can be achieved is limited by the availability of relevant observed data. Comprehensive bus patronage data by service, in particular, is often not accessible for use in transport model development. In these cases, network and service validation can still be undertaken but validation of the trip matrix and assignment is often reduced to high-level benchmarking of flows against secondary data sources, aggregate data source which can be sourced online (publicly available) and local network knowledge and experience. This approach has been followed in SEM.

3.2 Public Transport Assignment Model Convergence Criteria and Standards

Convergence measurements are not applicable to the public transport assignment model as passenger crowding is not modelled in the Public Transport Model.

4 Key Features of the Public Transport Model

4.1 Summary

The key characteristics of the South Essex Public Transport Model are described in Table 4-1.

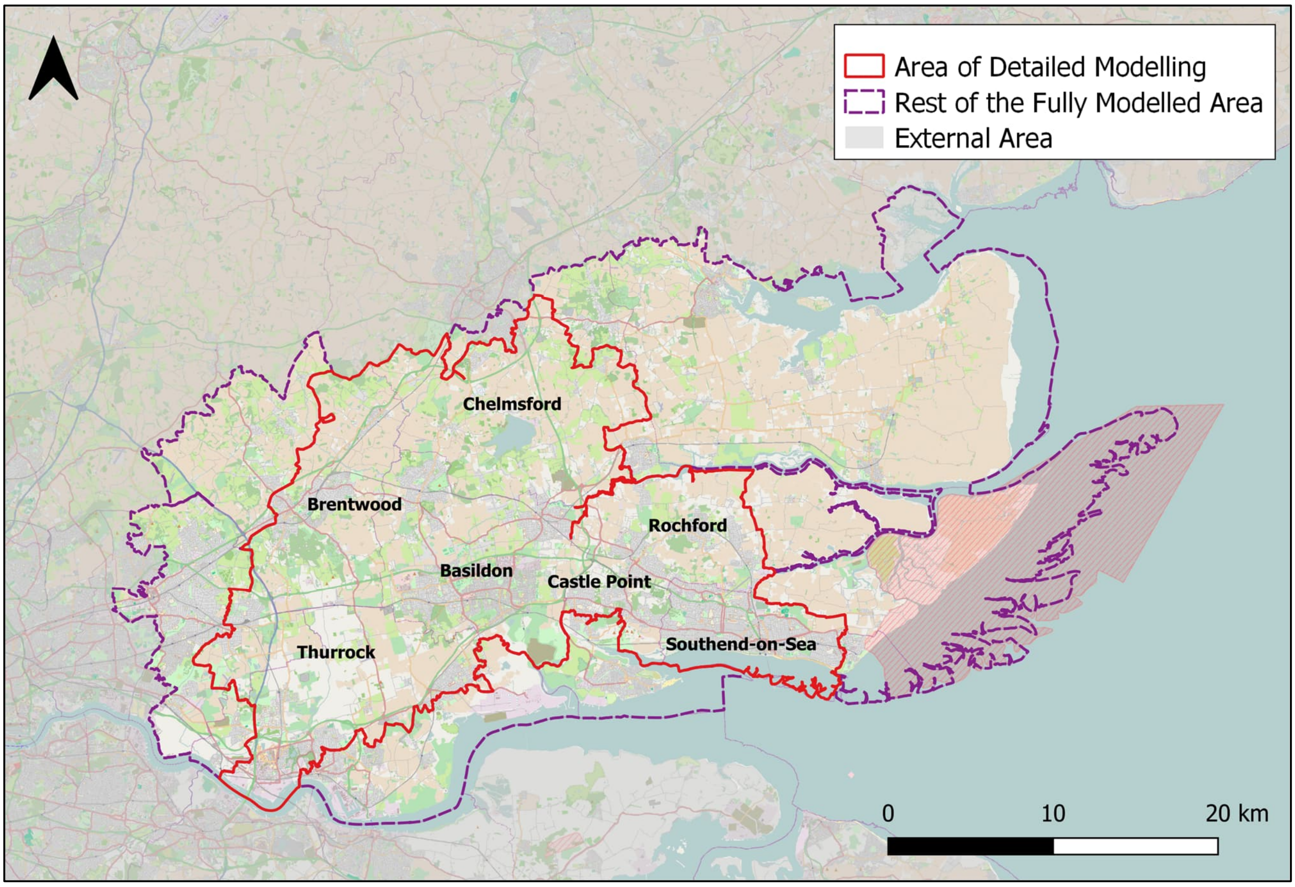
Table 4-1: Key Model Features

Characteristic	Model Coverage
Model structure	Average hour PT assignment model. 24-hour PA incremental pivot-point VDM.
Software platform	PT model: EMME version 4.4.4.2. VDM: EMME with Excel VBA front-end
PT Assignment method	Multiclass Frequency-based Optimal Strategies algorithm, without crowding
Time Periods	PT Model: AM peak, inter-peak and PM peak average hour. VDM: 24-hour.
Trip matrix segments	7 journey purposes in VDM (see Chapter 10), combined into all-purpose matrix
Base Year	Neutral month 2019
Calibration / Validation	To follow TAG, where data availability permits.

4.2 Fully Modelled Area and External Area

The Fully Modelled Area (FMA) and External Area has been defined during the development of the highway EESCM. The same definition has been adopted in the PT and VDM models. Figure 4-1 below replicates these areas for the convenience of the reader.

Figure 4-1: Definition of Modelled Areas in SEM



SEM is focussed on the South Essex region (which coincides with the Area of Detailed Modelling). The immediate surrounding area comprising the Rest of the Fully Modelled Area are still covered to a reasonable level of detail by the PT network and is fully responsive in VDM. The remainder of the study area consists of an external area, which covers only skeletal public transport network (rail) and is non-responsive in VDM. The model structure is reflected in the accompanying model zoning system, detailed in Section 4.3 and in the network structure, detailed in Section 4.5.

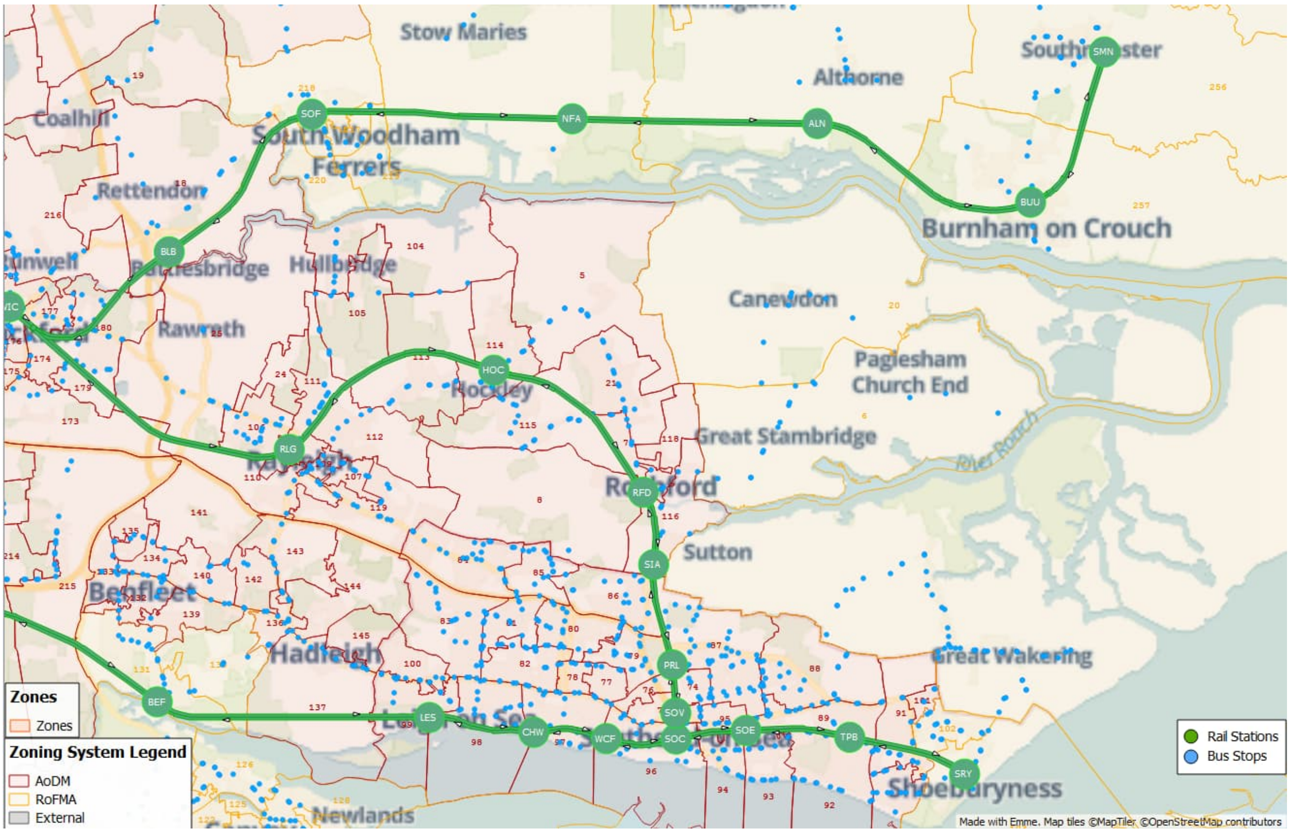
4.3 Zoning System

4.3.1 Public Transport Model: Zoning System Review

The SEM zoning system used in the Highway Assignment Model implemented in VISUM software (referred to as EECSM in other reports) was reviewed to assess of it is detailed enough in comparison with the density of PT network access points (rail stations and bus stops) within the FMA. All rail stations in FMA served by Greater Anglia and C2C trains, were compared with the EECSM zoning system (Figure 4-2). The comparison shows good zone detail since each of the rail stations falls into a single zone boundary apart from Westcliff and Southend Central rail stations, which share the same zone. Special attention was paid to Westcliff and Southend Central during model calibration to ensure that this exception does not affect the quality of the modelling.

The bus network checks focused in urban areas where bus stops are more densely spaced, such as Southend-on-Sea, Basildon, Brentwood, Billericay and Stanford-le-Hope. In addition to these locations, zones along A127 were reviewed and considered acceptable.

Figure 4-2 – ECCSM Zoning System vs Public Transport Network (Rail and Bus).



Zones located to the east of South Essex, Maldon and Rochford districts, showed to be larger when compared with AoDM zones, but were judged to offer sufficient granularity as they are located in rural areas with lower population density and sparse development.

It was concluded that the EECSM zoning system used in the Highways Assignment Model is appropriate and capable of supporting major PT schemes and a strategic demand model and was therefore adopted in for the purposes of SEM. It is worth noting that in the forecasting mode future housing and employment development sites will be modelled with dedicated development zones. The zone system is shown in Figure 4-3.

Figure 4-3: SEM Zone System

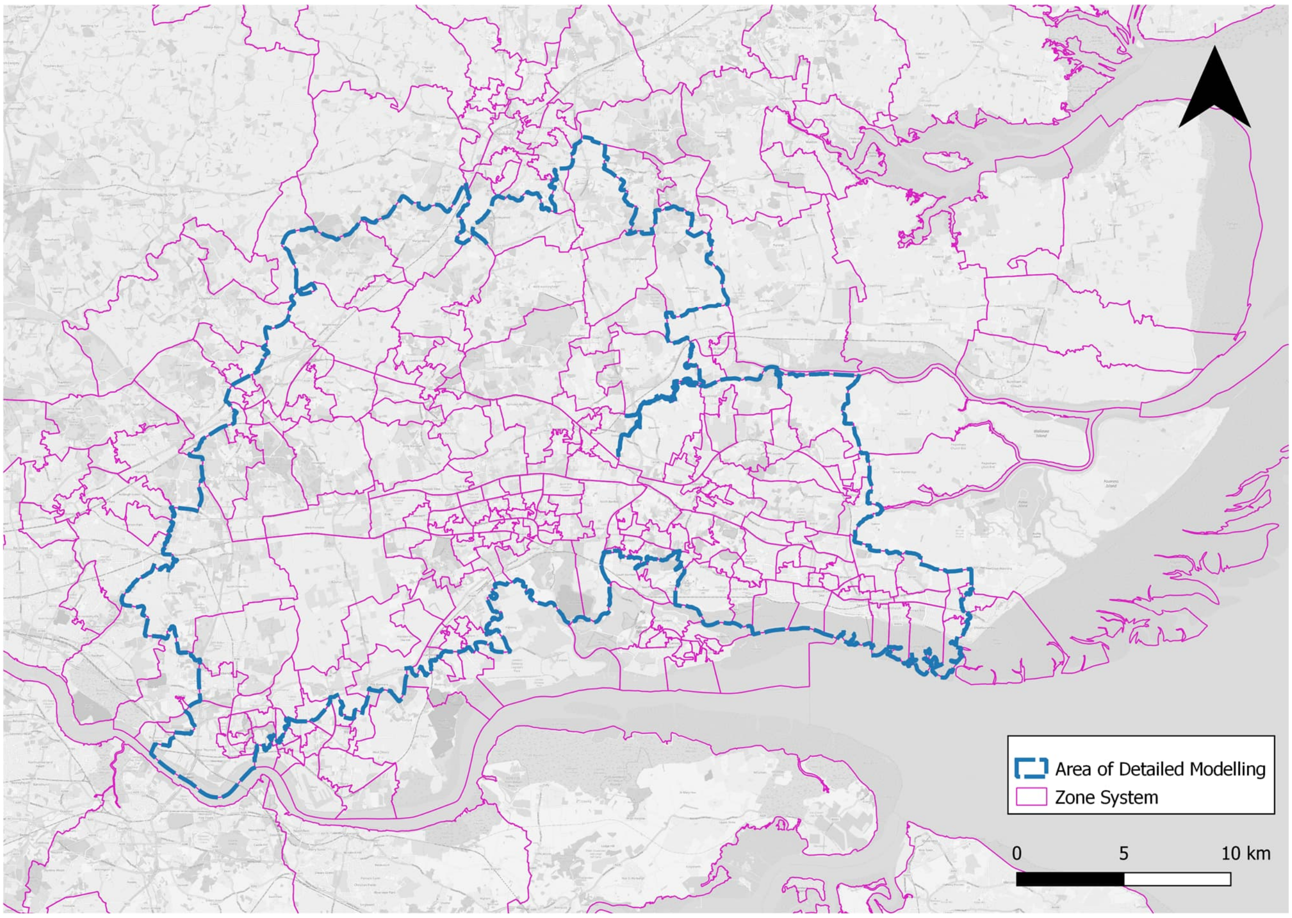
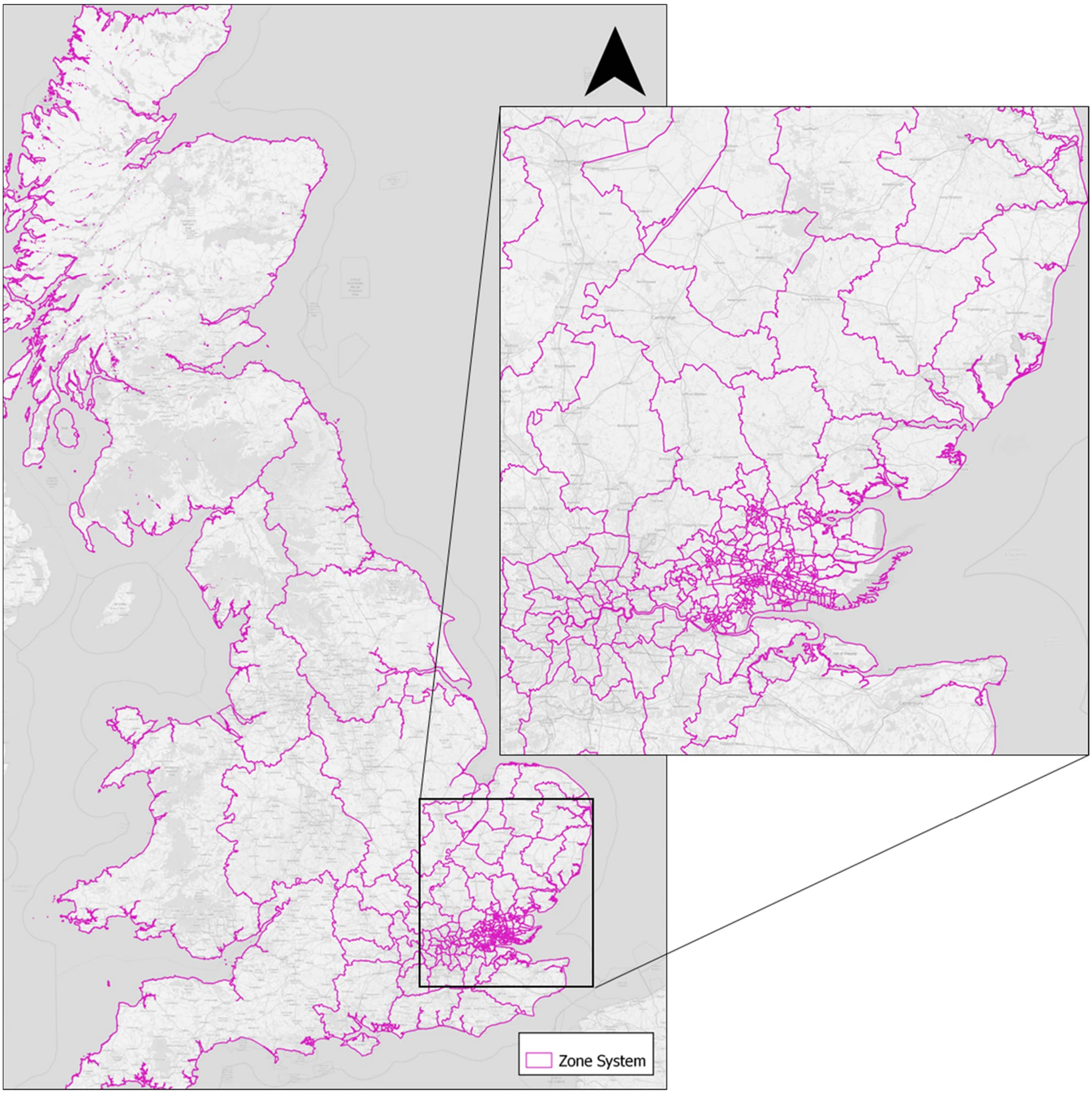


Figure 4-4 below shows the zone system across the full model. There are 332 zones in the network. The zone system within the model is hierarchical with higher levels of detail within the South Essex region, decreasing in detail as the distance from the study area increases.

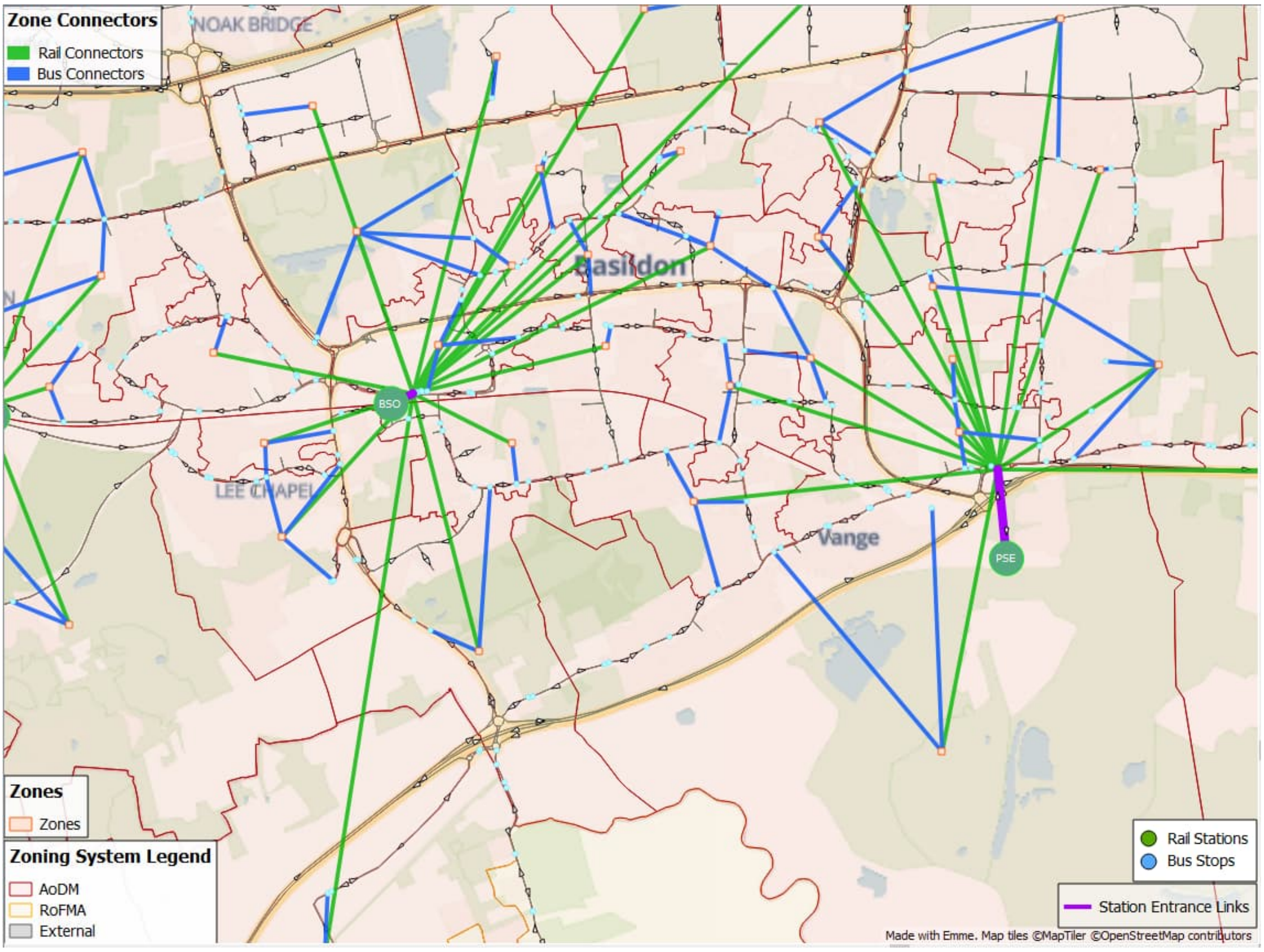
Figure 4-4: EECSM Zone System, Full Model



4.3.2 Public Transport Centroid Connectors

The centroid connectors define how trips to and from zones are allocated to the PT network from the zone centroid (centre of gravity of the zone). The PT zone connectors depend on the geographical location of the zone and the mode they connect to (Figure 4-5).

Figure 4-5 Public Transport Connectors Modelled in the South Essex Area.



Different connectors types have been created for bus and rail. The need for this, arises from differences in the hierarchy of these modes. Rail serves longer-distance strategic journeys and the rail network is accessed by multiple other modes (including car), whilst bus serves local trips and tends to be the primary mode (bus is typically accessed only by walking). This is reflected in the to the South Essex PT model assignment strategy. This approach helps avoid rail or bus demand miss allocation, mainly rail demand leakage to the bus as well as allows reflecting that access to rail is also made by modes other than bus (for instance car).

Therefore, the PT model assigns the rail and bus demand as individual user classes each bus and rail networks separately. This also means that the assigned rail demand cannot use bus network, neither the assigned bus demand cannot use the rail network. Bus and rail connectors definitions are described in the sections below, 4.3.2.1 and 4.3.2.2 respectively.

4.3.2.1 Bus Connectors

Within FMA, where the bus network is detailed, centroids are connected directly to the bus stops coded in the PT network. These are connected to two or three bus stops located within the same zone by connectors that have the same link definitions, walking speed and length. This approach helps avoid a situation where the bus connectors influence the route decision and at the same time improves the responsiveness of the model to bus system improvements. Bus connectors definitions coded in SEM PT model are presented in Table 4-2.

Table 4-2 - Bus link connectors definition

Areas	Walk speed [km/h]	Length [km]	Connect to bus stop
AoDM	5	0.25	yes
RoFMA	5	0.5	yes
External within Essex	5	0.5	yes
External outside of Essex	5	0.5	no*

4.3.2.2 Rail Connectors

Rail centroid connectors link to the rail station entrance node, using two different connector types:

- Mode 'g' for zones within AoDM which are within 750m crow fly distance to the rail station.
- Mode 'G' for zones within AoDM that are more than 750m from the rail station.
- External zones connectors were coded as mode 'g' connected directly to station node and different length than in the AoDM.

Rail connectors definitions are described in Table 4-3.

Table 4-3 - Rail mode g link connectors

Areas	Walk speed [km/h]	Length [km]	to Station Entrance Node	Directly to Station Node
AoDM	5	0.75	yes*	no
RoFMA	5	1	yes*	no
External within Essex	5	1.25	yes*	no
External outside of Essex	5	1.5	no	yes

Connectors with mode 'G' have been coded with variable access speed depending on distance (distance from the zone centroid to the station entrance node). This approach allows the model to reflect that for longer distances the access mode tends to be car, whereas, for shorter distances connectors a greater proportion of access trips made by bus or cycling (with lower speed) is likely.

To define the type of centroid connector, path analysis has been Uniteperformed in EMME for all zones within FMA to identify the closest distance between the zone centroid node and the closest access station entrance node. The path analysis is preformed allowing mode walk, bus or car.

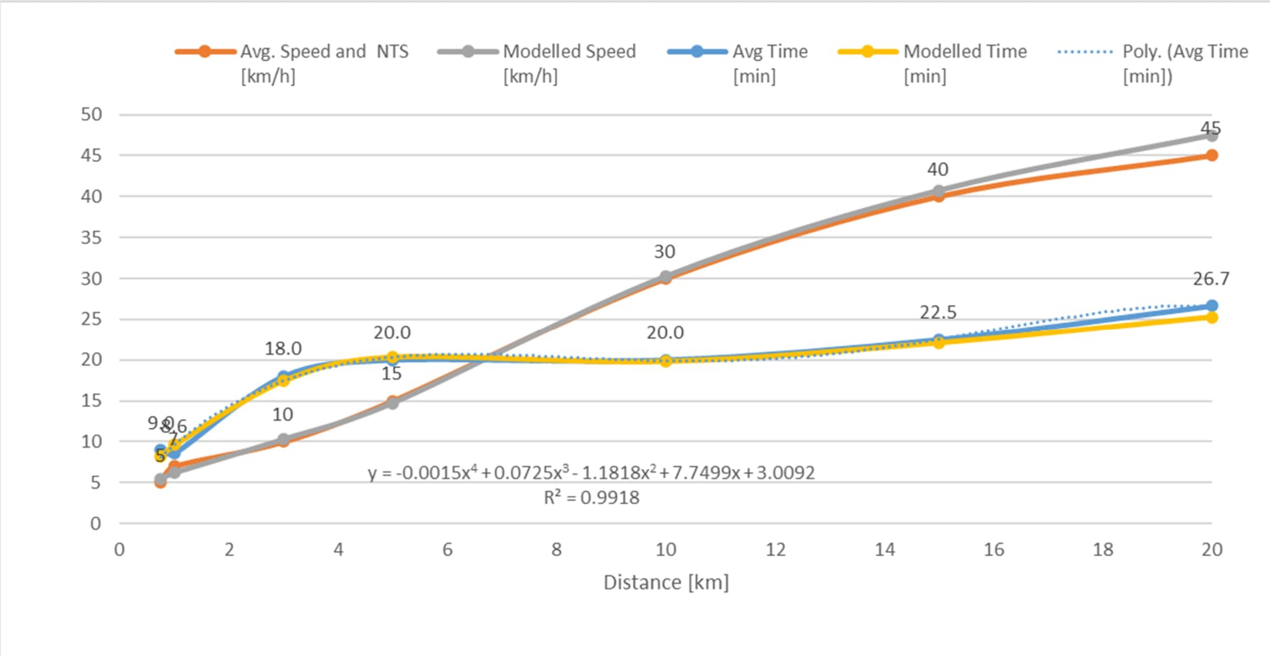
Bus and car average trip distance and speed are informed by the National Travel Survey, Table NTS0303, to formulate the rail link connector distance-based speed function.

Table 4-4 – Average distance and time informed by NTS.

Distance [km]	Avg. Speed based on the NTS* [km/h]	Avg Time [min.]	Avg Time distance based
0.75	5	9.0	8.19
1	7	8.6	9.65
3	10	18.0	17.46
5*	**15***	20.0	20.34
10	30	20.0	19.83
15*	**40***	22.5	22.10

Table 4-4 shows the distance and average speed according to the NTS. Speeds for a distance of 5 km (15km/h) and for a distance of 15km (40km/h) (highlighted in bold) have beed used as the main distances the define the shape of the speed function. The other speeds presented in the table were reasonably approximated by a funciton depicted in (Figure 4-6). The final average time distance function was assessed in terms of R^2 performance shown in the figure.

Figure 4-6 - Observed NTS Distanced Time and Speed vs Modelled Time and Speed



4.4 Public Transport Network Structure

The public transport network consists of two layers:

- The bus network, which has a one-to-one correspondence with the highway network. Bus services are routed directly on the highway links to facilitate the transfer of highway speeds into the bus assignment model during the operation of the model.
- The rail network, which covers the entire UK rail network coded directly from timetable data. High level of detail away from FMA is still available as it is obtained automatically from electronic timetables even if it is not used in the model.

The full detail of public transport network development is provided in Chapter 6.

4.5 Time Periods

The highway model has been built to represent three time periods:

- AM peak hour (07:30-08:30).
- PM peak hour (17:00-18:00).
- Average hour in the interpeak (10:00-16:00).

The peak hours represent the times at which observed traffic volumes were the highest in each peak period, and an average hour for the interpeak model.

The same time periods are modelled in public transport assignment, with the exception that the in the AM peak and PM peak, average hour demand is assigned to the network. This is because crowding is not modelled in the public transport assignment and the level of demand assigned to the network does not influence generalised cost. However, as there is a link between highway speeds and public transport speeds, the generalised costs obtained from the PT assignment are consistent with highway costs. Modelled time periods are summarised in Table 4-5.

Table 4-5 - Definition of Modelled Time Periods

Period	Highway	Public Transport
AM peak period	Peak hour	Peak hour generalised cost reflective of peak hour bus journey times consistent with highway (average hour PT demand).
Inter-peak period	Average hour	Average hour
PM peak period	Peak hour	Peak hour generalised cost reflective of peak hour bus journey times consistent with highway (average hour PT demand).

4.6 Key features of the PT and Variable Demand Model

4.6.1 Variable Demand Model

The Variable Demand Model (VDM) predicts mode choice and trip distribution of trips for the 24hr period for trips with one or both trip-ends within South Essex study area separately for the following journey purposes. The full specification of the VDM is described in Chapter 10.

The following journey purpose segmentation is used in VDM:

- Home-Based Work (HBW) – travelling from home to work (and any return journeys) – a typical commuting journey (not in employers' time).
- Home-Based Employer's Business (HBEB) – travelling from home to a destination where you are in employers' time and any return journeys.
- Home-Based Other (HBO) – travelling from home to a non-work-related location (other than shopping or education) and any return journeys.
- Home-Based Shopping (HBShop) – travelling from home to a non-work, shopping-related location and any return journeys.
- Home-Based Education (HBEdu) – travelling from home to an education destination (primary/secondary schools) and any return journeys.
- Non-Home-Based Employer's Business (NHBEB) – travelling during employers' time, such as from a place of work to a business meeting.
- Non-Home-Based Other (NHBO) – travel between two non-home-based locations (for example, from work to shops).

Car availability classes have also been used for each journey purpose:

- No Car Available.
- Car Available.

4.6.2 Public Transport Assignment Model

The public transport model separately assigns two different modes:

- Rail (only rail is permitted).
- Bus (only bus is permitted).

As the rail assignment model does not include monetary costs and value of time is not used in the assignment generalised cost (fares are included in the generalised cost in the demand model), their journey purpose segments are combined for input into the assignment.

4.7 Assignment Methodology

4.7.1 Public Transport Assignment

The public transport assignment is implemented in EMME software. It is a multi-class frequency-based assignment (with a variant based on frequency and time for selected longer-distance services). Frequency-based assignment is suited to modelling public transport route choice in urban areas, has much lower data input requirements and is more suited to forecasting where the details of the timetable cannot be known. On selected London-bound services, both frequency and journey time are taken into account during the allocation of demand to individual services.

Crowding is not modelled in the public transport model assignment and the assignment procedure is effectively uncongested (a single iteration is modelled). The measurement of convergence is therefore not required.

4.8 Generalised Cost Formulations and Parameter Values

4.8.1 Public Transport Assignment

The generalised cost for public transport trips consists of different components:

$$PTGeneralisedCost_{minutes} = 2 * Walktime + 2.5 * WaitTime + 1 * Invehicle\,Time + BoadingPenalty$$

Each component can be given its own weight or coefficient in order to convert them to common units and to ensure that the relative importance of each component for passengers is reflected. The components are:

- In-vehicle time.
- Wait time (time spent waiting for services).
- Walk time (time spent walking on-street, PT and zone access and egress).
- Boarding penalty (penalty associate with inconvenience of interchanging.

The components are weighted in line with the recommendations in TAG. The weights are summarised in Table 4-6 below.

Table 4-6 – Public Transport Generalised Cost Weights

Generalised Cost Component	Coefficient (weighting)
In-vehicle time	1.0
Walk time	2.0
Wait time	2.5
Boarding Penalty	1.0

As mentioned earlier, fares are not part of the public transport assignment generalised cost. However, bus and rail fares are included in VDM, based on the in-vehicle distance and the number of boardings obtained for the respective user classes from the assignment.

The boarding penalty was defined at the node level and set to 5 minutes for all transit modes available, to reflect the inconvenience of transfer and minimise excessive transfers in places with a high transit frequency such as major roads or transit corridors.

5 Calibration and Validation Data

5.1 Public Transport Data

5.1.1 Existing Public Transport Data

This section discusses the observed data used in the calibration of the public transport assignment model, which was readily available from ECC or earlier commissions. These are:

- Office of Rail and Road (ORR) Station Usage data.
- http://trains.im/ web site used for rail journey time validation.
- ECC Web-based maps[1] used for bus route geometry validation.
- 2019 BUS ATCO–CIF timetable files used for bus journey time validation.
- ECC high-level bus use statistics (Basildon town centre).

The first and last of these sources relate to rail and bus passenger data and are described below.

5.1.2 Existing Rail Passenger Data

The only publicly available source of rail passenger demand data are the station usage statistics published by ORR. This publication is based on the rail industry LENNON database of ticket sales and provides annual figures station entries and exist by ticket type for each station in Great Britain. The data is available for March-to-March financial years and the 2018/19 dataset was available to the study team.

The data is available at an annual level and a conversion to daily data is necessary. The annual rail data divides into 13 four-week 'rail periods' otherwise known as 'rail months'. A set of factors to convert average period data to average weekday data was previously prepared for use in ECC's NERT model based on the ticket data (by ticket type) for all stations in the study area provided by Greater Anglia Trains for the neutral month of November 2014. This data was used to derive month-to-weekday factors for full, reduced and season ticket data summarised in Table 5-1 below.

Table 5-1 - Conversion factors used to establish daily rail users

Conversion Factors	Value
Season Ticket Monthly-to-Daily Factor	20.6
Other Ticket Monthly-to-Daily Factor	24

Table 5-2 below shows the 2018/19 annual usage data obtained from the Office of Rail and Road as well as the figures converted to 2019 average weekday. The data shows that the rail stations with large passenger volumes in the FMA are Upminster, Shenfield, Grays, Benfleet, Southend Central and Basildon with daily passengers ranging from 12,000 to 8,000 and Southend Victoria shows approximately 5,700 daily passengers.

[1] http://www.essexbus.info/map.html

Table 5-2 - 2019 Office of Rail and Road: Rail Station usage data.

Station Description	2019 Annual Station Usage				2019 Average Weekday		
	Other Tickets		Season Tickets		Daily Total		
	Entries	Exits	Entries	Exits	Entries	Exits	Total
Romford	3,315,366	3,315,366	1,275,122	1,275,122	15,388	15,388	20,149
Upminster	2,307,371	2,307,371	647,570	647,570	9,814	9,814	12,232
Shenfield	1,297,023	1,297,023	777,721	777,721	7,061	7,061	9,965
Grays	1,445,290	1,445,290	637,426	637,426	7,013	7,013	9,393
Benfleet	978,463	978,463	853,920	853,920	6,325	6,325	9,513
Southend Central	831,200	831,200	891,846	891,846	5,994	5,994	9,325
Basildon	935,829	935,829	698,020	698,020	5,606	5,606	8,212
Brentwood	1,091,840	1,091,840	513,418	513,418	5,417	5,417	7,334
Billericay	608,615	608,615	913,057	913,057	5,360	5,360	8,770
Harold Wood	1,065,615	1,065,615	478,869	478,869	5,204	5,204	6,992
Chafford Hundred Lakeside	1,153,116	1,153,116	302,863	302,863	4,827	4,827	5,958
Gidea Park	1,029,163	1,029,163	387,823	387,823	4,747	4,747	6,195
Laindon	682,049	682,049	498,060	498,060	4,046	4,046	5,906
Leigh-On-Sea	733,663	733,663	444,162	444,162	4,010	4,010	5,669
Wickford	452,894	452,894	677,711	677,711	3,982	3,982	6,513
Southend Victoria	513,659	513,659	551,136	551,136	3,704	3,704	5,762
Southend East	471,608	471,608	506,017	506,017	3,401	3,401	5,291
Chalkwell	496,590	496,590	460,185	460,185	3,310	3,310	5,028
Rayleigh	356,714	356,714	559,647	559,647	3,233	3,233	5,323
Rainham (Essex)	641,955	641,955	232,447	232,447	2,926	2,926	3,794
Pitsea	439,085	439,085	219,078	219,078	2,225	2,225	3,043
Tilbury Town	376,846	376,846	249,980	249,980	2,141	2,141	3,075
Westcliff	422,734	422,734	205,974	205,974	2,124	2,124	2,893
Stanford-Le-Hope	328,645	328,645	236,583	236,583	1,937	1,937	2,820
Ockendon	438,594	438,594	141,583	141,583	1,934	1,934	2,463
Ingatestone	183,088	183,088	278,437	278,437	1,627	1,627	2,666
Thorpe Bay	280,159	280,159	164,600	164,600	1,513	1,513	2,127
Shoeburyness	213,504	213,504	162,162	162,162	1,290	1,290	1,895
Hockley	189,425	189,425	172,719	172,719	1,252	1,252	1,897
Purfleet	275341	275,341	68,022	68,022	1,137	1,137	1,391
Rochford	148,422	148,422	159,369	159,369	1,071	1,071	1,666
Southend Airport	273,329	273,329	32,299	32,299	997	997	1,117
South Woodham Ferrers	89,405	89,405	167,209	167,209	911	911	1,535
East Tilbury	151,330	151,330	77,728	77,728	775	775	1,066
West Horndon	125,009	125,009	91,938	91,938	744	744	1,087
Emerson Park	125,905	125,905	48,911	48,911	586	586	769
Burnham-On-Crouch	58,446	58,446	62,235	62,235	420	420	652
Prittlewell	61,936	61,936	48,377	48,377	379	379	560
Southminster	26,241	26,241	38,092	38,092	226	226	369
North Fambridge	15,863	15,863	25,656	25,656	147	147	242
Althorne (Essex)	8,944	8,944	12,964	12,964	77	77	125
Battlesbridge	5,521	5,521	2,702	2,702	28	28	38

In addition, the study team had access to readily processed station-to-station 2017 passenger flow data obtained through the Greater Anglia and C2C Train Operating Company for the validation of the Essex Countywide rail demand matrices. The readily re-processed data from the Essex Countywide Model was used in the local calibration of the South Essex Public Transport Model rail demand matrix (Chapter 8) but is not presented here due to commercial confidentiality.

5.1.3 Essex County Council Bus Data

The only bus data available is the number of annual bus boardings and alightings obtained from local bus operators in 2017. The counts were all-week annual total and were converted to average weekday with the assumed annualisation factors presented in Table 5-3.

Table 5-3 - Essex County Wide bus data – Basildon Town Centre.

Description	Annualisation Factor	Total Passengers
Basildon Town Centre annual boarders & aligthers	1	5,422,664
Basildon Town Centre weekly boarders & aligthers	52	104,282
Basildon Town Centre weekly boarders	2	52,141
Basildon Town Centre daily boarders	6*	8,690

The data described in Table 5-3 represents Basildon Town Centre. For modelling purposes, the town centre cordon was defined as the perimeter of Southernhay and Broadmayne Avenue (Figure 5-1), covering five main bus stops in Basildon Town Centre. This data was used in the high-level validation of the Basildon town centre bus arrivals in EMME South Essex Public Transport Model. Table 5-4, describes the selected Basildon town centre bus stop locations.

Figure 5-1 – Basildon town centre bus stops

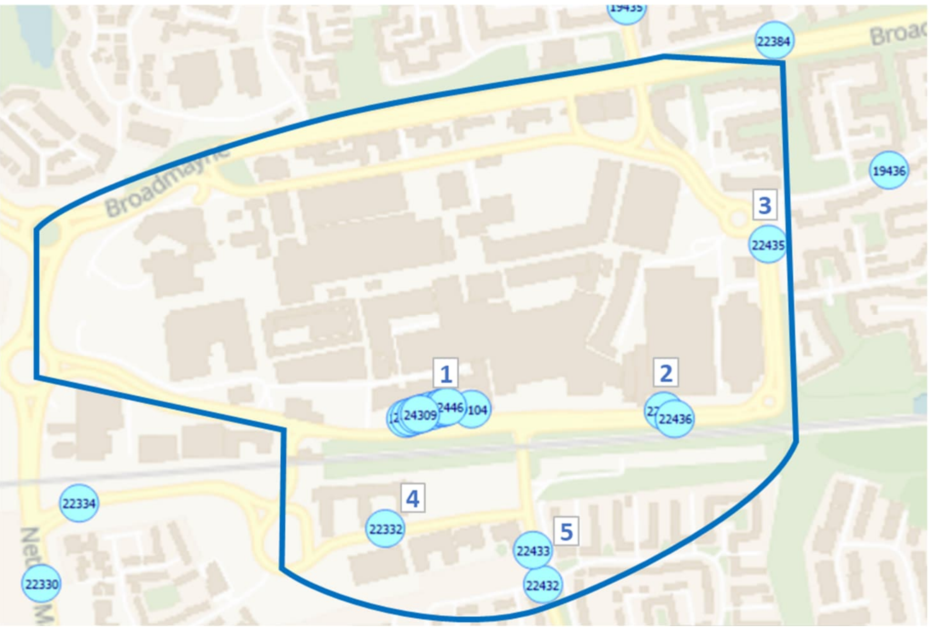


Table 5-4 – Basildon town centre main bus stops.

N.	Bus Stop Locations
1	Basildon Town, Bus Station, Southernhay
2	Basildon Town, Asda Eastgate, Southernhay
3	Basildon Town, Long Riding, Southernhay
4	Basildon, Cherrydown E
5	Basildon, Waldegrave, Clay Hill Rd

6 Public Transport Network Development

6.1 Network Basis

The public transport model was constructed using EMME software version 4.4.4.2. The South Essex public transport network includes two components:

- The rail network, which covers Great Britain and is connected to the bus network in Essex.
- The bus network is consistent with the VISUM highway model for buses and coaches.

6.2 Rail Network

The Rail network, services frequencies, stop-to-stop journey times and stopping pattern was coded in accordance with the spring 2019 National Rail CIF files. The rail services that run across Essex are the Greater Anglia Trains (on Great Eastern Main Line) and C2C on Essex Thameside. Although the entire national timetable is coded in the model the greatest level of detail is coded on routes of these two operators shown in Figure 6-1 below.

Figure 6-1 - Greater Anglia and C2C Trains - Network Coverage.

Although the greatest level of detail has been coded on the Greater Anglia and c2c networks (every station and branch line is represent), only the section of the network is FMA is directly relevant to South Essex Public Transport Model. Connecting public transport services in London such as London Underground and Overground, Docklands Light Rail (DLR) and Tramlink services are also represented to allow onward interchanges to the rest of the network and the coding of these services has been sourced from Essex CW.

6.3 Bus Network

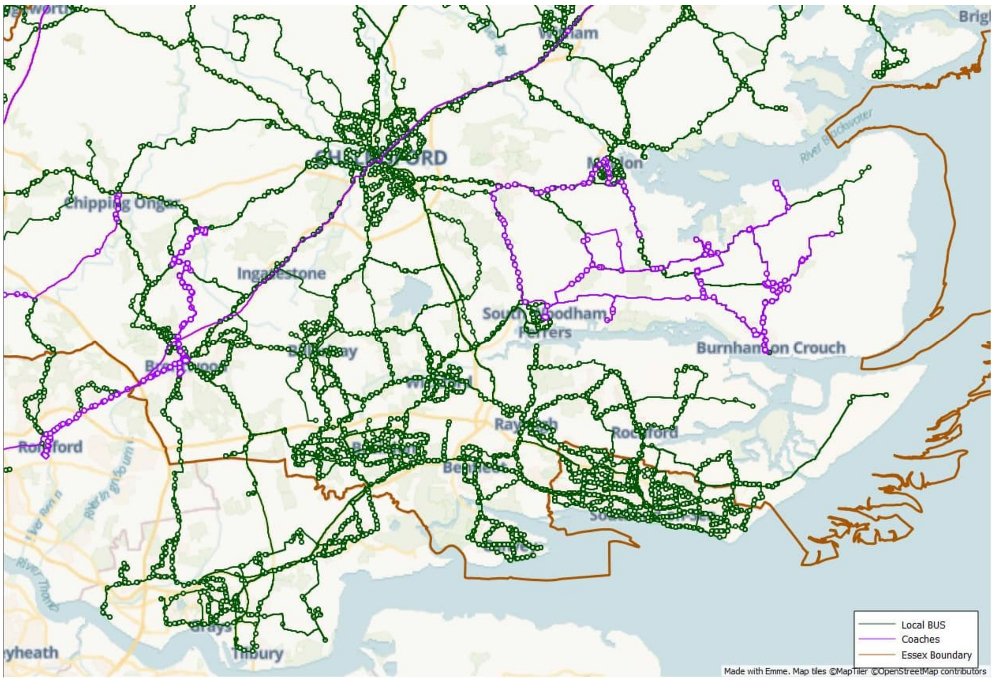
6.3.1 Timetable Coding

The modelled bus network across Essex is represented at high level and has been based on ATCO-CIF timetable files available from the Essex Open Data[2] website maintained by Essex County Council (ECC). The ATCO-CIF files are updated regularly by the council and the version available at the time was Essex Bus Network (CIF), dated 24 February 2020. This version was used as an approximation of the 2019 timetable given that the bus timetables do not differ significantly year-on-year. The ATCO files include geographic information about bus stops in Essex, the name and code of each bus stop served by the bus line route, the frequency of each line, time between stops, and the days when the service operates. The file includes information for all bus services in Essex and for coaches that run through Essex.

An automated process has been developed to convert the CIF data into a format suitable for EMME. The process operates in two main steps: time period classification and bus route pattern optimization. In the first step the time period to which the bus service belongs is defined by the time of its arrival or passing through South Essex AoDM. The remaining bus routes that do not cross any part of the South Essex AoDM network area were allocated to time period according to the route origin departure time specified in the CIF timetables.

The second step identifies similar bus services of a given bus operating company and merges them into routes that run along the same path, with the same stopping pattern. For each service on the route, times between stops have been averaged and average frequencies for the route calculated. The coding has been updated for all bus services operating in Essex with the network coverage illustrated in Figure 6-2, which shows the bus network coverage in South Essex area.

Figure 6-2 - Modelled Bus Network – South Essex



[2] https://data.essex.gov.uk/dataset?topic=transport-and-infrastructure

6.3.2 Approach to Modelling Bus Speeds

In-vehicle times for the bus routes have been coded at two levels. Within the AoDM, in-vehicle times have been linked to congested highway journey times resulting from the traffic model assignment. In the rest of the model, in-vehicle times were based on the times extracted from the bus operating timetables. The incorporation of highway congested journey time into in-vehicle times is essential for a realistic representation of bus times the congested areas. The details of the functionality and its calibration are discussed in Chapter 8.

6.4 Walk Links

Walk links have been reviewed in key City and Town Centres, especially within the AoDM area. Where the original highway network links are one-way street, checks were made to ensure walk in the opposite direction is possible. This is particularly important in central areas where the pedestrian network is key to the routing of the access and egress to the zone. In addition, walk links are coded to connect stations with the on-street walk network to allow a full range of interchange possibilities between public transport services.

6.5 Modes, Vehicle Types and Transit Services

Each transit and walk mode permitted in EMME South Essex Public Transport Model has been given a unique mode identification. In case of walk or other auxiliary modes, this definition includes assumptions about average speeds that these links represent (Table 6-1).

Table 6-1 - Public Transport Model Modes.

Mode	Description	Type	Speed (km/h)
b	Bus	Transit	timetable
c	Coach	Transit	timetable
d	DLR	Rail	timetable
l	Light Rail: Tram link and RHDR	Rail	timetable
t	National Rail	Rail	timetable
u	London Underground	Rail	timetable
f	Zone Connector Bus	Walk	5
g	Zone Connector Rail 1	Walk	5
G	Zone Connector Rail 2	Walk	*on distance
s	Station Entrance to Platform	Walk	5
w	Walk	Walk	5
x	Cross Platform Interchange	Walk	5

Vehicle types were informed by the Essex ATCO CiF timetables. Table 6-2 below describes the coded vehicle types in the south Essex public transport model and their respective seated and total vehicle capacities.

Table 6-2 - Public Transport Model Vehicle Types.

Mode	Description	Vehicle Type	Seat capacity	Total Capacity
Coach	Coach	12	64	100
Bus	Double Deck (DD)	13	60	80
Bus	Single Deck (SD)	14	20	40
Bus	SD-CITARO	15	26	86
Bus	SD-SOLO	16	36	58
Bus	SD-B7RLE	17	28	51
Bus	SD-VERSA	18	44	62
Bus	SD-DAF CAD	19	30	50

Vehicle capacities for Coach, Bus Double Deck and Bus Single Deck vehicle types are aligned with the rail plan model, whereas other vehicle types such as CITARO, SOLO, B7RLE, VERSA, and DAF CAD were informed by the vehicle manufacturers technical data and Wikipedia website.

The non-walk modes have an appropriate vehicle type created to enable the representation of transit lines. However, it should be noted that SEM does not model crowding and the vehicle types are notional element of the model. The list of transit services coded in SEM is presented in Appendix B.

7 Trip Matrix Development

7.1 Overview

The trip matrices for car and rail have been derived using the 2017 Essex Countywide Model as the starting point. As the base year for SEM is 2019, the Countywide matrices were uplifted based on background growth rates from the DfT's Trip End Modelling Programme (TEMPro) and known housing and employment development completions between 2017 and 2019. In addition, the matrices were converted from the Countywide zone system to the SEM zone system.

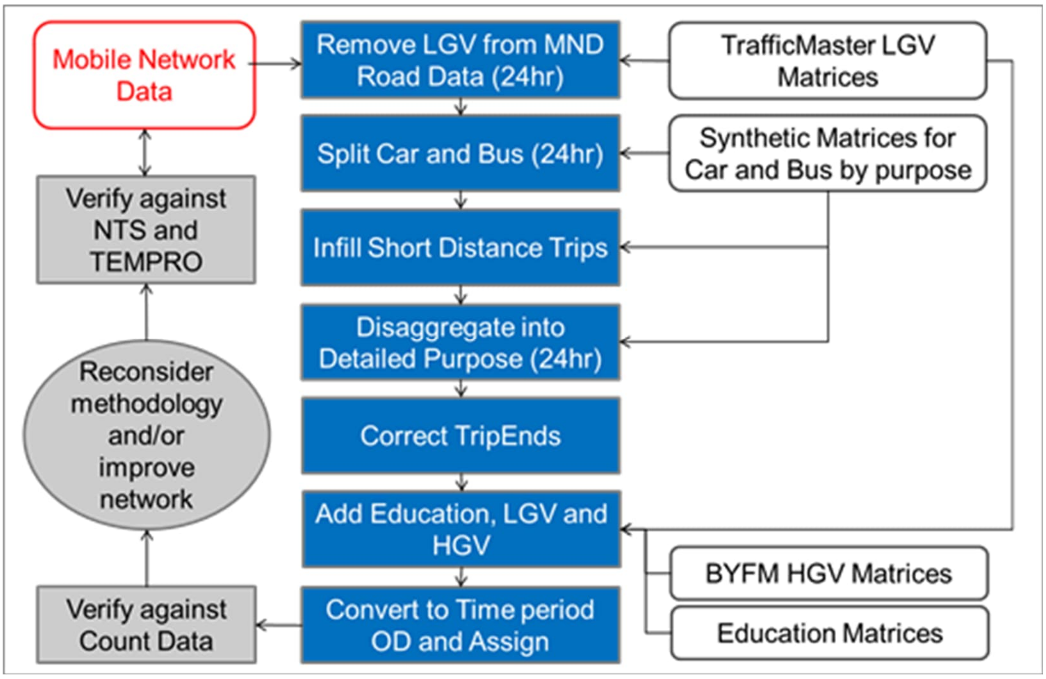
Whilst the Countywide model also included the bus matrices, these were purely synthetic and derived with the use of a relatively coarse public transport network. As SEM offers higher resolution in the local area, it was desirable to improve the bus demand matrices and update the bus gravity model. Both sets of activity are described in this chapter.

The details of the original Essex Countywide Model demand matrix development are reported in the Essex Countywide LMVR[3] and are not replicated here. However, for convenience of the reader the summary of the methodology is presented in the next section.

7.2 Essex Countywide and Use of Mobile Phone Data

The 2017 Essex Countywide Model used aggregated and anonymised Mobile Network Data (MND) provided specifically for that study by Telefonica. The development of Essex Countywide matrices was largely driven by this data, however other sources such as 2011 Census Journey to Work, National Travel Survey data, National Trip End Model, and bespoke synthetic matrices were used to augment the MND and correct for identified biases. Figure 7-1 summarises the methodology followed for developing the Essex Countywide Matrices.

Figure 7-1: Summary of Matrix Building Process for the Essex Countywide Model



[3] Essex Countywide Transport Model, Phase 2 Base Year Model Development and Validation Report, March 2019

The car trip matrices developed for the Essex Countywide Model, were developed in line with the process summarised in Figure 7-1. To provide a complete set of demand matrices for the Essex Countywide Highway Assignment Model, separate LGV and HGV matrices have been constructed:

- LGV matrices were derived from October - November 2014 and March 2015 Trafficmaster (currently referred as Teletrac) data.
- HGV matrices were derived from 2006 Base Year Freight Matrices (BYFM).

These prior matrices prepared for the 2017 Essex Countywide Model, as summarised above, formed the starting point for the development of the EECSM (SEM) model and provided the primary input into the base year model calibration and validation as well as the variable demand model development.

The details of the calibration of the EECSM Highway Assignment Model are described in the EECSM Local Model Validation Report. In this report we document updates and adjustment needed to implement the EECSM (SEM) PT and VDM models:

- The process od conversion from Essex Countywide to EECSM zoning system and data used to uplift the matrices from 2017 to 2019. This process has been documented in the EECSM Highway Assignment Model LMVR but is presented here as it also applies to the rail demand matrices.
- The re-development of the synthetic bus matrices taking into account the local network and geographical detail.
- In addition, in Chapter 10 (Variable Demand Model), we cover the adjustments that needed to be made to the 24-hour car matrices to reflect the EECSM calibration and validation adjustments implement during the Highway Assignment Model development.

7.3 Conversion from Essex Countywide zoning system

The conversion of the prior demand matrices from the Essex Countywide Model zone system to the EECSM (SEM) zone system has been informed by the 2011 Census data. For details of the EECSM (SEM) highway model, please consult the EECSM LMVR. The matrices from the Essex Countywide Model zone system were aggregated and disaggregated to match the boundaries of the EECSM (SEM) zone system. Further away from the study area, where the level of network detail in the EECSM is lower and zones larger, the Essex Countywide demand was taken directly and simply aggregated to fit the EECSM zoning system.

However, in South Essex, where the level of network detail is highest in the EECSM, there was a need to disaggregate the Essex Countywide matrices. The permanent residential population and workplace population, at Output Area (OA) level, was used to translate the demand matrices from the Essex Countywide to the EECSM zone system. This was facilitated by both zone systems being derived from OA boundaries, so there was a consistent spatial basis for the conversion.

The same principles and data sources have been used in the disaggregation of the public transport matrices and applied at 24-hour level (Table 7-1).

Table 7-1: Conversion of Production-Attraction Matrices

Purposes	24hr PA Matrices	
	Production	Attraction
Home-Based Work	Residential Population	Workplace Population
Home-Based Education	Residential Population	Workplace Population
Home-Based Employer's Business	Residential Population	Workplace Population
Home-Based Shopping	Residential Population	Workplace Population
Home-Based Other	Residential Population	Workplace Population
Non-Home-Based Other	Workplace Population	Workplace Population
Non-Home-Based Employer's Business	Workplace Population	Workplace Population

These disaggragated matrices then form an input into the VDM and PT models. The highway matrices then feed into the VDM, where an adjustment process is carried out in Section 9.12. The bus matrices will feed into the gravity model in Section 7.5 as an extra data source to help infill the synthetic matrices to create the final bus matrices. The rail matrices will feed into Section 8 - Public Transport Assignment Calibration and Validation.

7.4 Bus Matrices Development Process

7.4.1 Synthetic Matrices

7.4.1.1 Overview of the Development and Application of Synthetic Matrices

The primary data source for the EECSM demand matrices is the Essex CW model which were developed using mobile phone data (MND). The Essex CW bus demand matrices provide the strategic bus trip patterns, but refinements are required to better represent the local trip patterns in the Fully Modelled Area. The Essex CW synthetic bus matrices will be improved with TEMPro trip end data, represented at the local zoning system level and the locally refined etworks which will form new inputs into the gravity model. The bus matrices remain largely synthetic, due to the lack of the local observed bus data, but the process of their development has been supported by the information derived from the local networks such as the available bus capacities and high-level data about bus usage in the area of Basildon. These aditional insights, combined with the refinement of the local geogrpahical detail provided a significant improvement over the original Essex Countywide synthatic bus matrices.

7.4.1.2 Gravity Model Specification

EECSM bus synthetic matrix development followed a conventional approach of trip generation and trip distribution using a bespoke gravity model for bus trips. This model has been developed to operate in the Production-Attraction (P-A) form for all-day travel using journey purpose segmentation consistent with the demand model segmentation. For clarity, the journey purposes modelled with the use of the gravity models were:

- Home-Based Work (HBW)

- Home-Based Employer's Business (HBEb)
- Home-Based Other (HBO)
- Home-Based Shopping (HBShop)
- Home-Based Education (HBEdu)
- Non-Home-Based Employer's Business (NHBEb)
- Non-Home-Based Other (NHBO)

The main principle of the gravity model was to obtain a trip matrix in the EECSM zone system consistent with NTEM trip ends and the NTS trip length distributions (TLDs). This is achieved by distributing trips in the synthetic matrix based on the generalised cost of travel (which will be represented by distance for this bus matrix development), whilst fitting the synthetic TLD to the observed TLD and using trip ends as constraints. The general form of the gravity model is specified below:

$$T_{ij} = P_i A_j k_i l_j f(c_{ij})$$

where:

T_{ij} represents trips between production zone i and attraction zone j

P_i represents trip productions

A_j represents trip attractions

c_{ij} is the generalised cost (distance only) of the trip from production zone i to attraction zone j

k_i and l_j are 'balancing factors' which are calculated in matrix preparation and ensure that row and column totals of the matrix match the production and attraction targets

$f(c_{ij})$ is a deterrence function.

The deterrence function is a function of travel costs and introduces disincentive to travel with increasing cost of travel. These functions have one or more parameters to be calibrated and the number of these defines their degree of freedom with more parameters making it easier to obtain a closer fit with the observed trip length distribution. While several different deterrence functions can be used, the lognormal function is useful for modelling trip distribution as it is bounded by 0 (i.e. the number of trips cannot be negative), has a long right tail, and allows the peak to be positioned close to the y-axis (*Feldman, Forero-Martinez, & Coombe*, 2012). In our experience, the log normal distribution performs best and was applied in the development of the Colchester Transport Model (equation 1):

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

where:

c_{ij} is the cost of the trip from production zone i to attraction zone j

μ is the mean of the lognormal distribution calculated using Equation 2 below

σ is the standard deviation of the lognormal distribution calculated using Equation 3 below.

$$\mu = \ln\left(\frac{M^2}{\sqrt{M^2 + S^2}}\right) \tag{2}$$

$$\sigma = \ln\left(\frac{M^2 + S^2}{M^2}\right) \tag{3}$$

where:

- M is the mean of the midpoints of the distance bands of the observed TLD weighted by the proportion of trips in each distance band

- S is the standard deviation for the same points in M, also weighted by the proportion of trips in each distance band

7.4.1.3 Gravity Model Coverage

The intial classification of EECSM zones for the purposes of the graviy model was as follows:

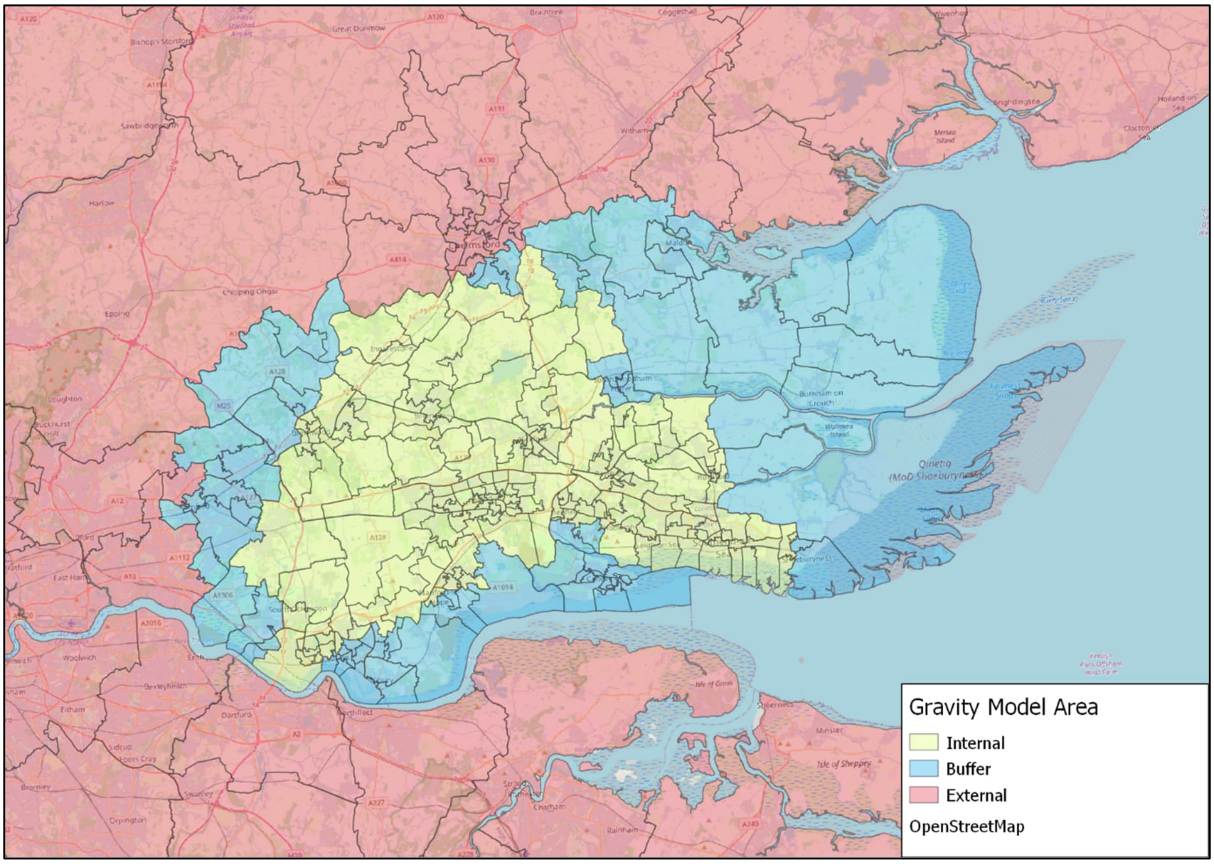
- Internal – represents the gravity model Area of Detailed Modelling (AoDM), therefore includes all NTEM production and attraction trip ends.

- Buffer – represents the Rest of Fully Modelled Area (RoFMA) zones, include a proportion of NTEM production and attractions based on the percentage of trips to/from buffer to internal. This proportion is determined from the Essex CW MND matrices.

- External - excludes any NTEM production and attraction

This initial classification was based on the modelled aread definitions used in the EECSM Highway Assignment Model and is shown in Figure 7-2.

Figure 7-2: Initial Gravity Model Zone Classification



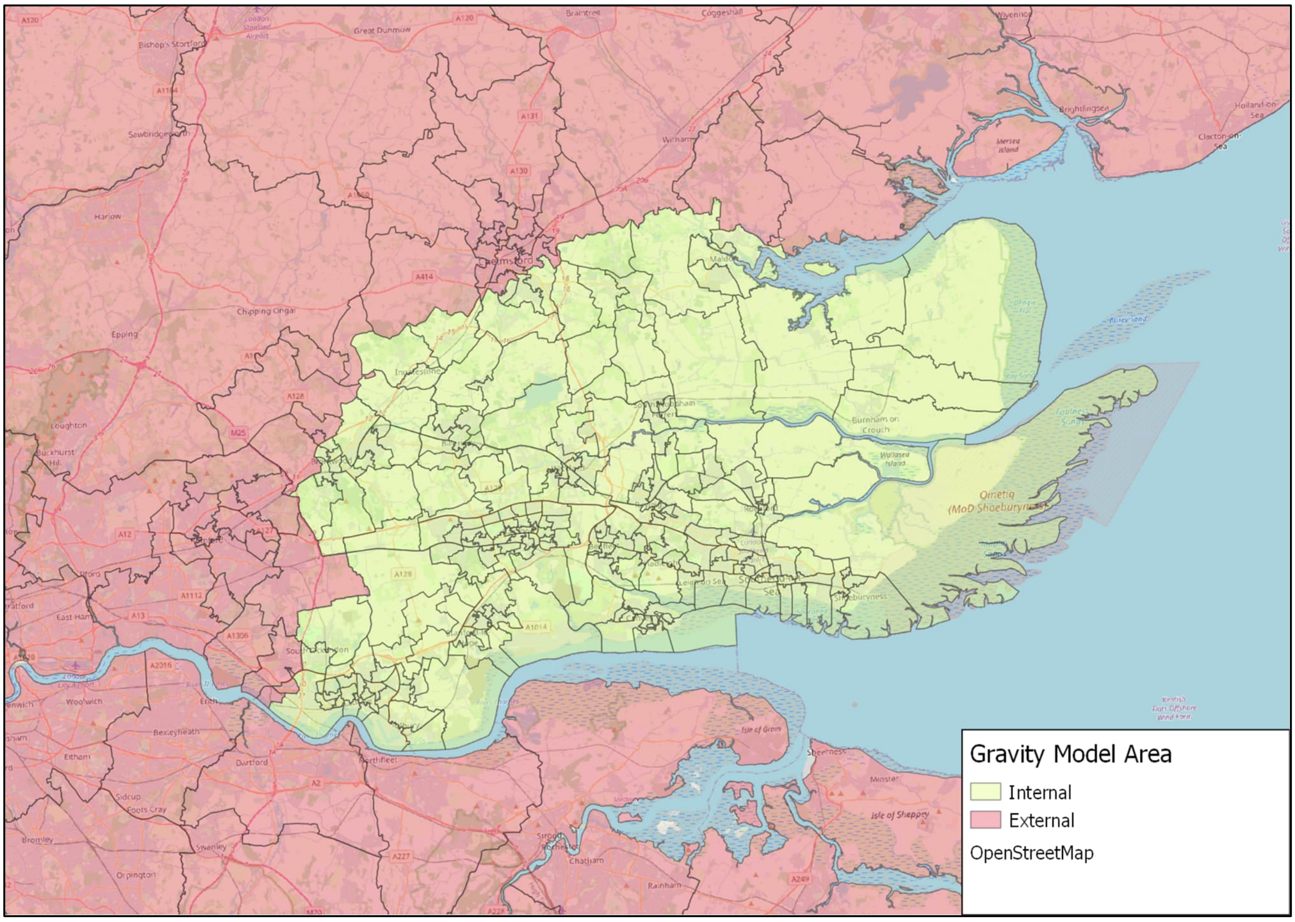
The analysis of bus loading factors (discussed in detail in Chater 9, and presented in Figure 8-7), we found that this definition of the gravity model resulted in unrealistic demand levels from the buffer zones inside the M25 (in London) towards Essex. Furthermore, the thinking behind the use of the buffer area in the initial setup of the gravity model was to make sure that the trips in those areas, particularly into the AoDM are captured fully and to a greater level of detail than in the external area. However, it has become clear that the use of the buffer area is unncessary as the most of this area (with the exception of the areas within M25) are bounded by water or AoDM and almost all trips prodcued in these areas are internal or to AoDM.

It was therefore benefitical to simplify the definition of the gravity model areas to:

- Remove the opportunities for the spuriously high level of bud demand from within M25 to Essex, but treating zones within M25 and north of A12 as external.
- Simplify the structure of the remainder of the modelled area, but treating all remainng South Essex zones bounded by water as interbnals

The revised gravity model coverag is shown in Figure 7-3.

Figure 7-3: Final Gravity Model Zone Classification



The bus gravity model developed for the internal area depicted in Figure 7-3 will be later combined with the Essex CW bus matrices, which will cover the longer-distance movements into the internal area (these form as very small proporiton of bus trips) and the movements between the external areas. The gravity model inputs, and the performance of the model, are discussed in the next sections.

7.4.1.4 Gravity Model Inputs

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

- Trip ends (both trip productions and attractions derived from NTEM), including any factors which scale trip ends to reflect proportion of trips from the external aread into the internal area of the gravity model. In the final iteration of the Gravity Model, these scaling factors were not used as buffer areas were removed from the gravity model.
- Generalised cost (distance) inputs from the public transport assignment model.
- NTS trip length distribution for the Essex County.

7.4.1.4.1 Trip Ends

Production-Attraction (PA) trip end data from NTEM for the base year (2019) was extracted from TEMPro version 7.2. TEMPro data for bus trips were extracted for an average weekday at MSOA level. These trip ends were then disaggregated to EECSM zones for input into the gravity models. For model zones larger than MSOA, data was aggregated over constituent MSOAs. For model zones smaller than MSOA, trip ends were disaggregated using the same census data as described in Section 7.3.

7.4.1.4.2 Gravity Model Cost Inputs

Cost inputs for use in the deterrence function of the gravity model were defined as distance. The cost inputs were derived using the public transport assignment model where bus cost was calculated for trips using bus only. For zone pairs in the external areas, or where there is no bus connection a very high cost value is given to reflect the absence of service whilst allowing normal operation of the gravity model function. This ensures that zones with very low or no bus connectivity do not see bus demand generated for them.

Similarly, intra-zonal matrix cells with no cost were set to be half the minimum distance to the nearest zone (similar to the approach to seeding intra-zonal costs used in variable demand modellig[4]) to avoid over-allocaiton of trips to intra-zonal cells in the gravity model.

7.4.1.4.3 Trip Length Distribution (TLD)

The TLDs used in the gravity model have been sourced from the existing work for Essex Countywide model. These were derived from the NTS database during the development of the Essex Countywide model where they were used to calibrate the parameters of the deterrence function (equations (2) and (3)).

Whilst these TLDs are representative of 2017, the distribution of trip lengths is genrally known to be stable over time and they were considered appropriate for use in the developmebt of the 2019 base year model. A smaller sample (for South Essex only) has not been pursued as samples sizes for bus trips in NTS at sub-county level tend to be insufficnet and the relatively large (sub-regional) coverag of the South Essex model means that Essex-wide data is still releveant. The performance of the gravity model calibration is presented alongside the outputs from the models (the distribution of the synthesised trips) in the next section.

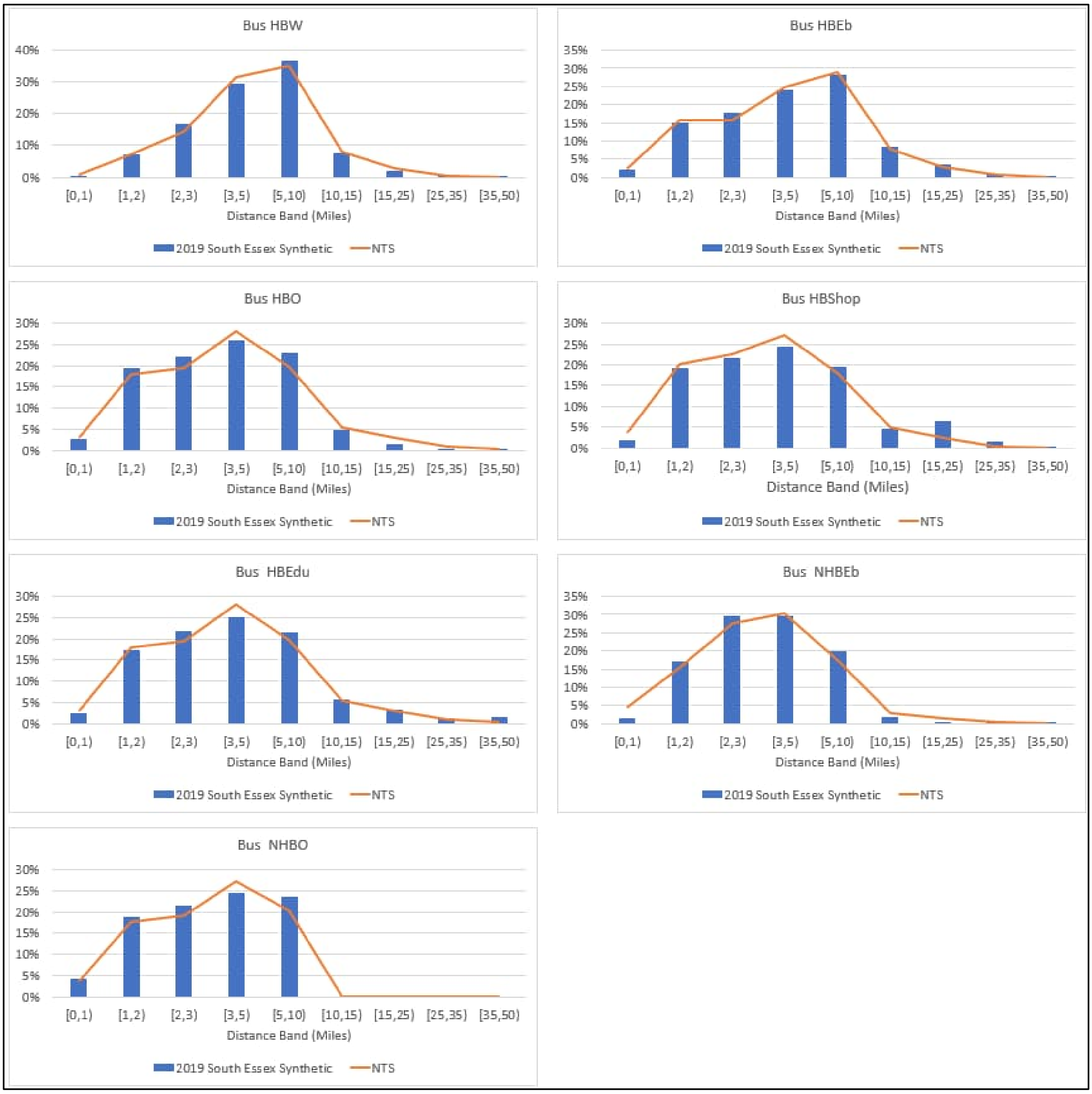
7.4.1.5 Gravity Model Performance and Results

The calibration of the gravity model followed an automated process which empirically searches for the optimum set of the model parameters (μ and σ) drawing randomly from a distribution. The process stops when better parameters (which improve the results further) cannot be found. It is expected to yield similar results to an analytical approach to solving the equations, more efficient than a manual search as it can be deployed efficiently in modern software and run to a high number of iterations (search steps) to find an optimum result.

This process delivered synthetic model matrices, which are later comnined and normalised with the Essex CW demand. The matrices obtained this way are naturally controlled to NTEM trip end totals as they form an input into the process and used as the target for the trip productions and attractions. The distribution of trips in these matrices emulates the trip length distributions from NTS. The resultant trip length distributions for bus are presented in Figure 7-4.

[4] See TAG Unit M2-1 Variable Demand Modelling, Section 2.4.5

Figure 7-4: Trip Length Distributions - Synthetic EECSM 2019 vs NTS



The synthetic bus matrices obtained from the gravity model show a plausible pattern for all journey purposes with a few variations for the longer distance bands. NTEM trip ends do not carry information about the accessibility of the bus network and there may be inaccuracies in the distribution of productions and attractions relative to the bus distance skims from the model, resulting in the slight variation in TLD, but overall the locall refined gravity model for SEM reprodcuces the expected TLDs very well.

7.4.2 Combining Data Sources

The final matrices for bus are a combination of different data sources described earlier in this section. Given the focus of SEM on the South Essex area, it is essential that the bus demand matrices represent good level of detail in this area and this gas been achieved with the development of the locally-enanced gravity model described in the ealrier secitons.

But the model, for completeness, also requires the more strategic representation of bus demand across the extranal areas. The bus demand representing the external areas has been sourced directly from the Essex Countywide model and the process of deriving the complete bus demand matrices covering the whole model area is described below:

- Use the synthetic matrices developed specifically for South Essex to represent trips with at least one production end in the internal area.
- Use the demand matrices sourced from Essex Countywide (uplifted to 2019) to infill the synthetic matrices.
- Normalise the output demand within Essex to Essex CW 2019 matrices.

As mentioned above, the Essex CW 2019 matrices were used to to infill the synthetic matrices for areas outside of the South Essex internal area but inside the Essex County. Table 7-2 below summarises what source of data was used to infill which movements within the bus matrices.

Table 7-2: Summary of data sources used to infill Bus Matrices

	Internal	External
Internal	Synthetic Matrices	Essex CW 2019
External	Essex CW 2019	Essex CW 2019

The final step to derive the complete bus matrices was the normalisation of the matrices to targets. The data are normalised to 2019 Essex CW trip productions (which have been based on TEMPro), but the targets are not strictly imposed to avoid over-fitting (a tolerance of ten percent around trip productions was allowed). The normalisation also only occurs inside the Essex County area, therefore Thurrock which is inside the EECSM FMA but outside of Essex is not normalised.

7.4.3 Matrix Verification and Final Requirements

This section describes the comparisons of the final bus matrices with the original Essex CW matrices to understand what changes have been made to the matrices through the EECSM matrix development and demonsgrate where the improvements have been achieved. The final matrices are compared against NTS data as well as the Essex CW data. The comparisons are therefore provided for illustrative purposes and to demonstrate the overall plausibility of the trends exhibited in the EECSM bus matrices.

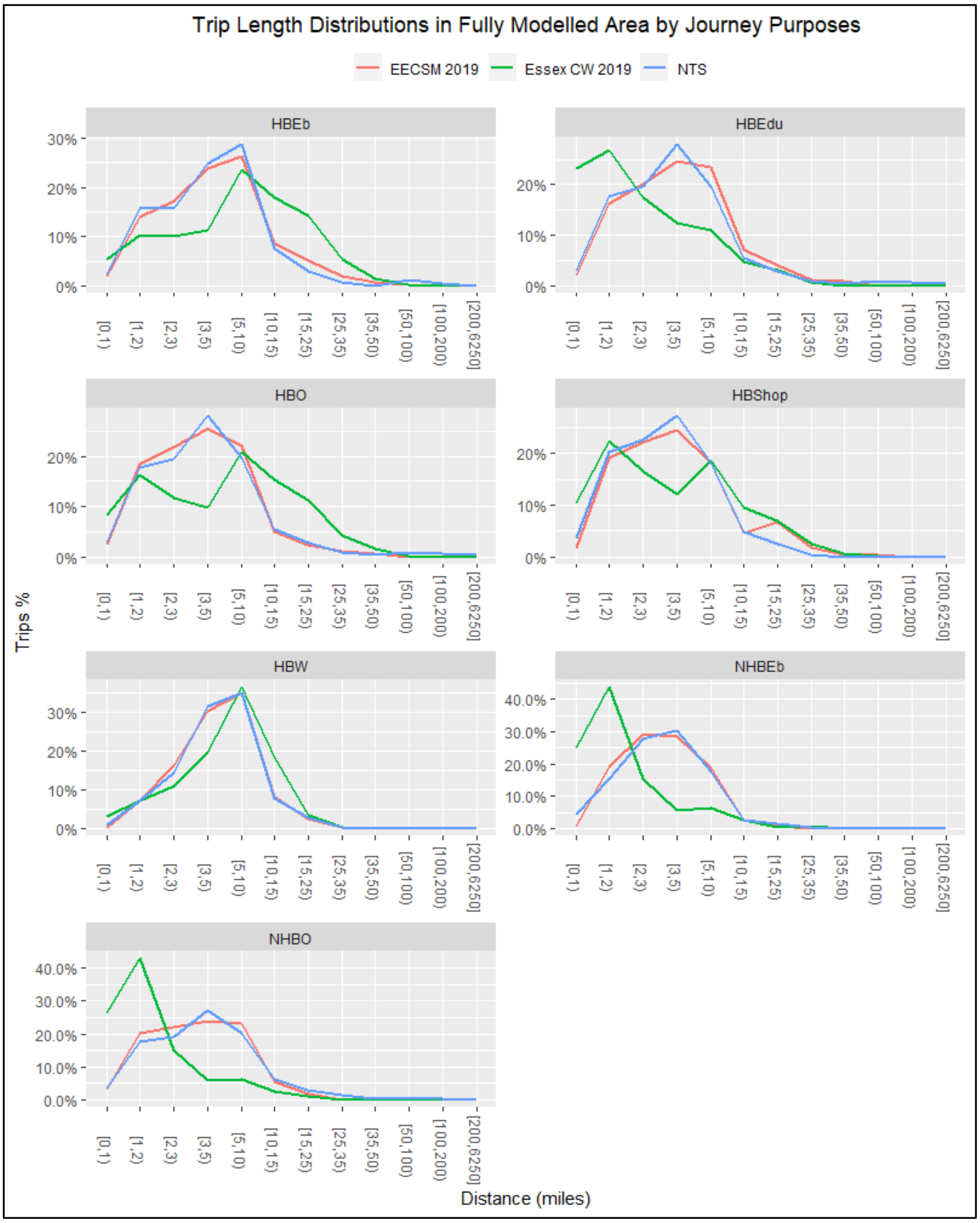
As described above, the final bus matrices consiste of the locally enhanced synthetic matrices for South Essex and the original Essex Countywide model mantrices covering the remainder of the model area. The comparisons are therefore presented for these two areas separately:

- Firstly, we present the results for the Fully Modelled Area to demonstrate what improvements have been made to the matrices in the area of South Essex.
- Secondly, we present the results for the entire model to show the overall consistency with the Essex Countywide model across the whole of the model.

7.4.3.1 Trip Length Distribution – Fully Modelled Area (FMA)

The first comparison of trip length distributions (TLDs) is only considered within the Fully Modelled Area of the EECSM. The 3 data sources compared in Figure 7-5 are the Essex CW bus matrices (uplifted to 2019 for consistency), the newly created SEM bus matrices and the NTS data.

Figure 7-5: TLDs inside FMA - Essex CW 2019 vs EECSM 2019 vs NTS

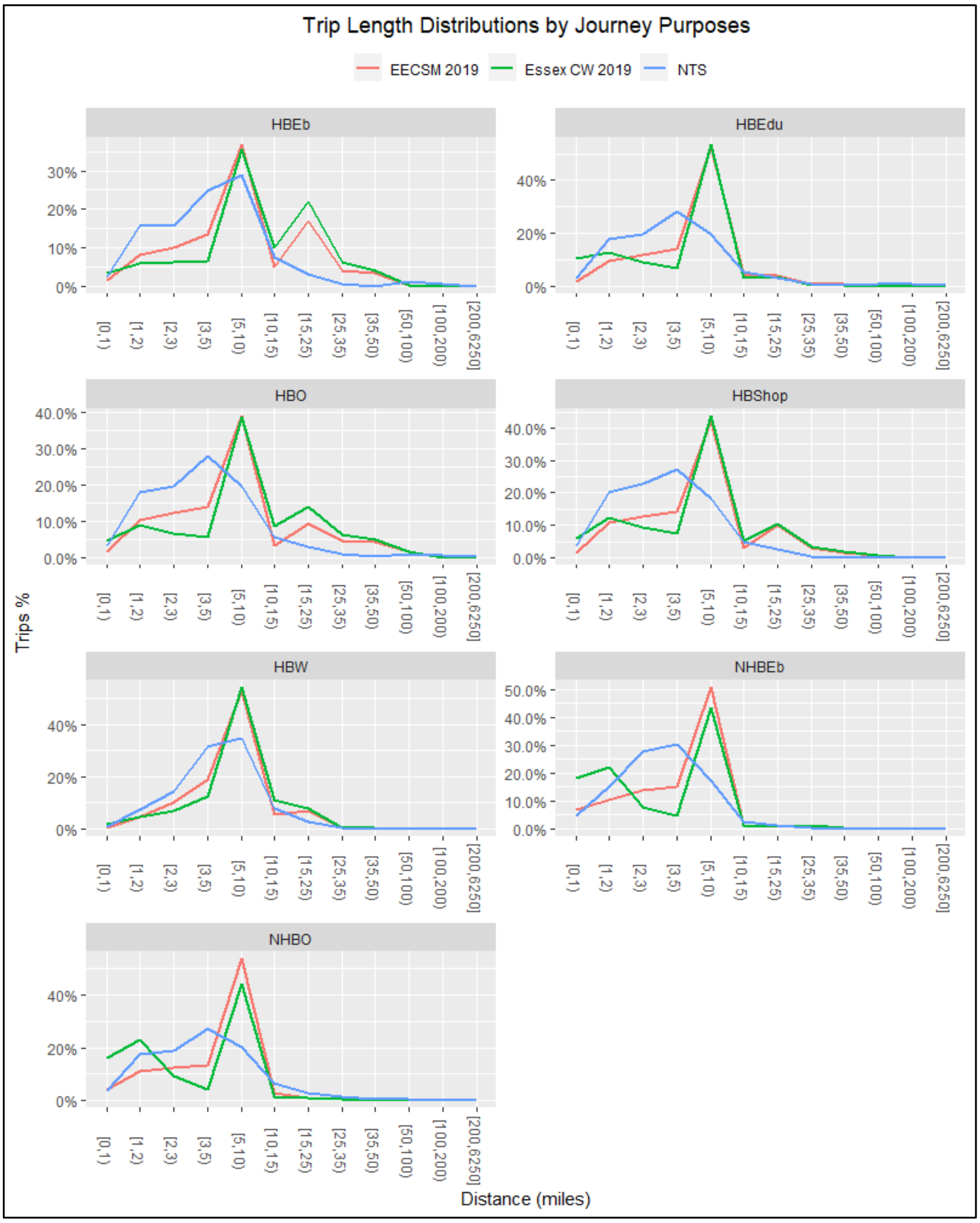


From Figure 7-5, we can see that inside the FMA, there is a good match between the final SEM matrices and the NTS TLDs across all seven journey purposes with some slight deviations which are not a cause for concern. It can also be seen that the Essex CW bus matrices differed signficantly from the other two sources and importanly from the data observed in NTS, for most journey purposes apart from HBW, where the distribution peak aligns well. For the Non-Home-Based purposes, Essex CW suggests a large peak in the lower distance band between 1 and 2 miles. SEM and NTS TLDs seem to be more spread out up to a distance of 10 miles inside the FMA, which is likely a reflection of the geography of South Essex where there are several towns inside the modelled area (like Southend, Brentwood, Basildon) and will likely have a larger proportion of inter-urban trips in this area. Overall, this comparison shows that the Essex CW matrices needed a significant improvement in the area os South Essex to align better with the NTS TLDs, which has been achived in the SEM matrices.

7.4.3.2 Trip Length Distribution – the Entire Model

The second comparison of TLDs is for the whole model area. The SEM bus matrices herel contain the infilled Essex CW demand for the external areas. Thus, the TLDs for Essex CW and SEM are similar given that across the whole model area, the proporiton of trips sourced from Essex CW dominates the marix total. Both models differ from NTS, but this is not a concern as the external areas are of little significance for modelling of bus demand in South Essex (Figure 7-6).

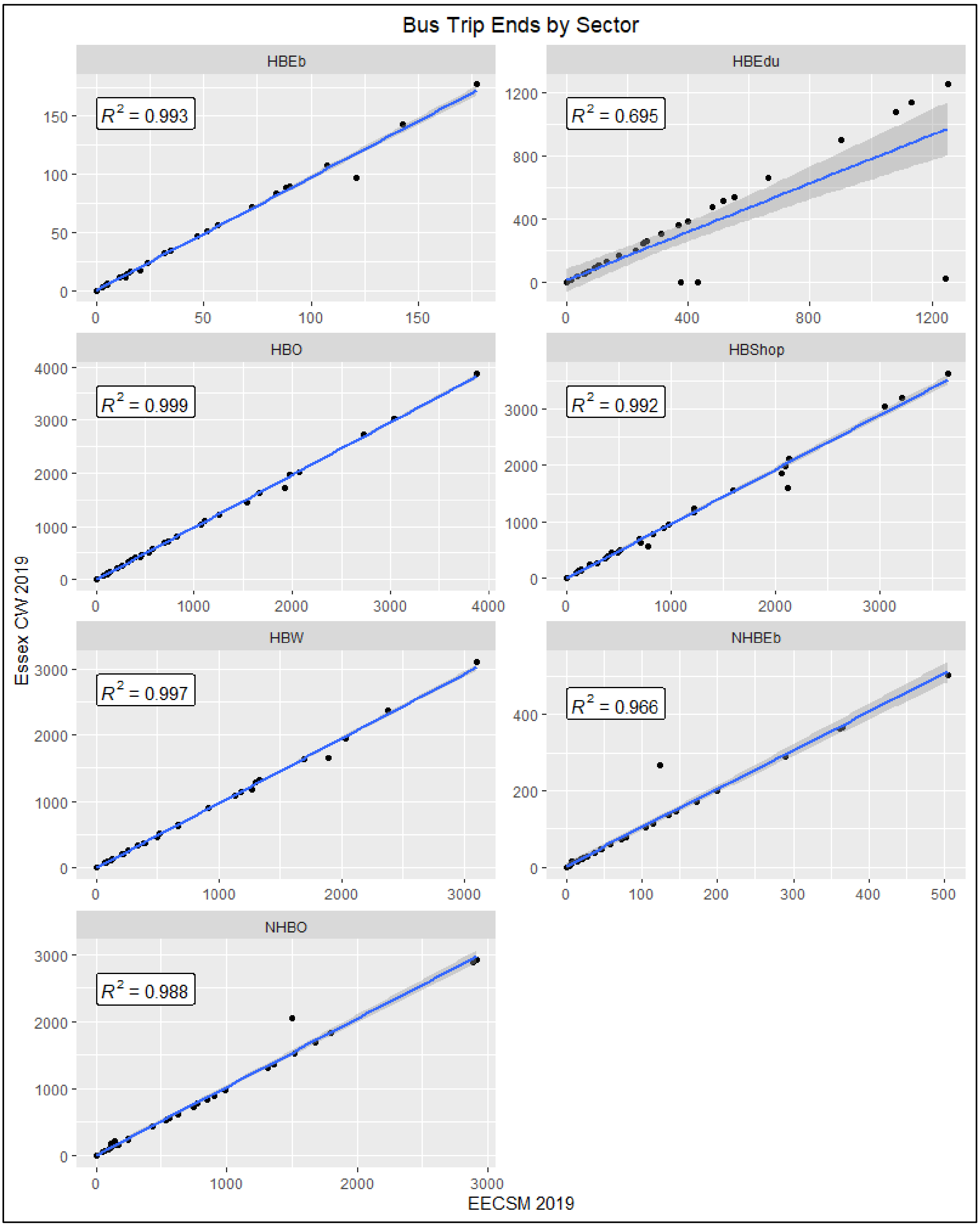
Figure 7-6: TLDs - Essex CW 2019 vs EECSM 2019 vs NTS



7.4.3.3 Bus Trip Ends by Sector

The comparoson of bus trip ends by sector for each journey purpose between Essex CW (on the y-axis) and SEM 2019 (on the x-axis) is shown on scatter plots in Figure 7-7. The line of best fit and its 95% confidence interval as well as the R^2 is shown on each plot. Secotrs used in this analysis are consistent with the sectors used in the calibraiton and validaiton of the EECSM Highway Assignment Model.

Figure 7-7: Bus Trip Ends by Sector Scatter Plots - SEM vs Essex CW



We can see that most of the journey purposes fit well with R^2 values close to 0.99, however HBEdu seems to have 3 significant outliers which negatively affect the regression analysis. These were further analysed in the later sections to find out what sectors they represent and understand why the values for these sectors differ between Essex CW and EECSM.

7.4.3.3.1 Analysis of outliers

The analysis showed that all 3 outliers were sectors within Thurrock. Thurrock is a local authority district that is classed as external in the Essex CW zoning system, thus it was not part of the Area of Detailed Modelling when Essex CW Model was developed. As a result, the demand for these sectors within Essex CW is not very well represented. However, in the SEM model development, these sectors are treated as internal and the demand matrices have been enhanced based on the local gegographical detail. This is the main reason for the differenceh between Essex CW and SEM and the SEM matrices.

We have investigated this further by looking at the land use data available on the government website[5] to check how the land in Thurrock is used compared to the other local authorities like Basildon, Southend-on-Sea, Castle Point, etc in 2018. The spreadsheet "P400b" in this file shows the total land area in hectares split by different uses. Looking at the "Community Service" section and focusing on "Community Buildings", which is the most likely classification of educational facilities (schools, colleges, etc.), we can see that Thurrock has a larger area used for this purpose than any of the other districts within the SEM model area. Table 7-3 shows the summary and comparison of the land used for community buildings for the SEM districts. This suggests the SEM matrices with the enhanced local detail and improvements to the representation of Education trips are preferable that the differences from Essex CW are an improvement rather than a concern.

Table 7-3: Land Use Comparison Between the EECSM Districts

District	Community Buildings (hectares)
Basildon	226.4
Brentwood	178.6
Castle Point	111.1
Maldon	74.5
Rochford	86.1
Southend-on-Sea	209.1
Thurrock	231.5

Furthermore, since there was no clear classification of educational facilities in the land use data, we also checked the number of schools for each of the districts modelled in SEM. These were collected from another data source provided by the government website[6]. The data for each district for 2019 is shown in Table 7-4.

[5] Land_Use_in_England__2018_-_Live_Tables.xlsx from https://www.gov.uk/government/statistical-data-sets/live-tables-on-land-use
[6] https://www.compare-school-performance.service.gov.uk/schools-by-type?step=default&table=schools&region=883&geographic=la&for=primary

Table 7-4: Number of schools in each EECSM district by type

District	Primary Schools	Secondary Schools	Sixth Form/ Colleges	Age 11+
Basildon	27	6	4	10
Brentwood (and Ongar)	42	12	10	22
Castle Point	25	8	4	12
Maldon	37	6	4	10
Rochford (and Southend East)	26	11	7	18
Southend-on-Sea	41	22	16	38
Thurrock	51	17	9	26

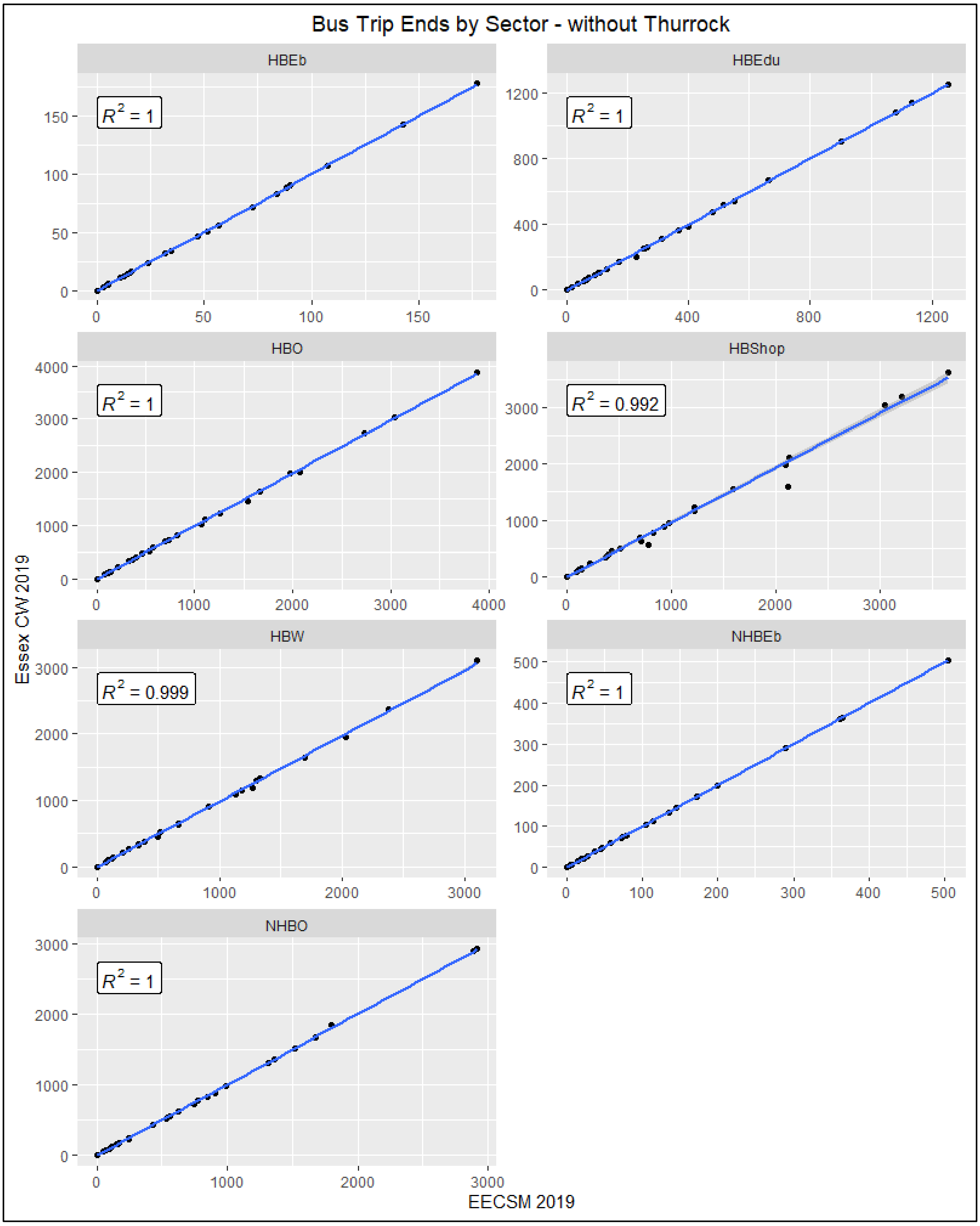
Primary school children are unlikely to be getting the bus to get to school, but rather will be dropped off and picked up by parents, hence we will focus on the numbers of educational facilities for those pupils aged 11 or older. We can see in the final column from Table 7-4 that Thurrock has the second highest number of schools/colleges for those aged 11 or over in the EECSM area. The only district with a higher number is Southend-on-Sea.

The land use data and the tally of schools in the districts are evidence to suggest that this increased demand coming into Thurrock in the AM peak is plausible as there is a large number of attractors there relative to other areas.

We repeated the sector trip end analysis excluding Thurrock (Figure 7-8) and these graphs show that there is improvement in both, the regression line and R^2 for every journey purpose apart from HBShop, which has remained virtually unaffected. We can see that HBEdu has improved significantly from an R^2 of 0.695 to an R^2 of 1 when Thurrock was removed from the analysis.

The findings documented here were later corroborated during the calibration of the PT assignment model (Chapter 9) where the modelled flows show bus passengers flows coming into Thurrock in the AM peak (Figure 8-9), consistently with the higher than average edcuation-related land use.

Figure 7-8: Bus Trip Ends by Sector Scatter Plots excluding Thurrock - EECSM 2019 vs Essex CW 2019



8 Public Transport Assignment Calibration and Validation

8.1 Introduction

The public transport model was calibrated in accordance with TAG Unit 3-2 “Public Transport Assignment Modelling”. TAG advises that the validation of a public transport model should involve three types of checks:

- Network and service validation.
- Validation of trip matrix.
- Assignment validation.

Each of these areas is covered in this chapter. Section 8.2 discusses the calibration and validation of both bus and rail networks. Section 8.3 combines the validation of trip matrix and the assignment together as the calibration of the public transport model did not include matrix estimation and focussed directly on the prior matrix improvements.

8.2 Network Calibration and Validation

8.2.1 Uncongested Bus Journey Times

TAG recommends that the validation checks should focus on the accuracy of the modelled journey times or speeds of the public transport journeys. Generally, public transport journey times are defined by the accuracy of the coded timetables. In addition, in South Essex Public Transport Model, the bus speeds are linked to highway speeds to allow the impact of congestion on bus journey times in model forecasts. This section first explains the method of implementation of this interaction and then reports the achieved performance of bus speeds in the model.

As a starting point, at the stage of coding transit lines from CIF files, the stop-to-stop bus journey time are based on the timetabled times and saved into transit segment attribute (us3). This stop-to-stop is then adjusted to reflect the link with the highway speeds. To implement the mechanism in a robust way, it was necessary to normalize the bus speeds to free-flow highway speeds and limit the bus speeds to an upper limit of 96kph (national speed limit for buses, coaches and minibuses). This process also controls for the possibility of excessive or erroneous bus speeds arising on very short links. The transit travel function (‘ft3’) was coded using the following principles:

- If the modelled bus speed is greater than the highway free-flow speed and the highway speed is greater than 96kph cap bus speeds to 96kph.
- If the modelled bus speed is lower or equal to the highway free-flow speed and modelled bus speed is greater than 96kph, cap bus speed to 96kph. E.g. (bus = 105kph < 112kph ffs => result = 96kph converted to minutes).
- If the modelled bus speed is greater than highway free-flow speed and the highway free-flow speed is lower than 96kph, set bus speed to the highway free-flow speed. E.g. (bus 65kph > 48kph (ffs) => bus speed = 48kph converted to minutes).
- If the modelled bus speed is lower or equal than the highway free-flow speed and modelled bus speed is lower or equal than 96kph, no change is needed, and the speed is set equal to the original timetabled speed in minutes (us3).

Interpreting the bullet points mentioned above, the formula below presents the transit travel function codded in the Public Transport Model as in:

$$FT3 = \left(\left(put\left(\frac{lenght}{\frac{us3}{60}}\right).gt.ul1\right) * (ul1.gt.96) * \left(\left(\frac{length}{96}\right) * 60\right)\right) + \left((get(1).le.ul1) * (get(1).gt.96) * \left(\left(\frac{length}{96}\right) * 60\right)\right) + \left((get(1).gt.ul1) * (ul1.le.96) * \left(\left(\frac{length}{ul1}\right) * 60\right)\right) + \left((get(1).le.ul1) * (get(1).le.96) * us3\right)$$

Where:

- ul1 - Highways free flow speed (km/h)
- us3 – Bus stop to stop bus timetable journey times (min)
- 'length' – link length (km)
- 96 – Bus national speed limit (km/h).

8.2.2 Congested Bus Journey Times

The in-vehicle time within the Area of Detail Model, AoDM, which use the highway congested journey times, was calibrated against the timetabled journey times. The AoDM calibration process is similar to the previous step of the bus speed normalization to the highway free flow speed, instead, using the highway congested journey times.

As part of the Public Transport assignment process, the congested highway journey times for links and turns are imported to the public transport model and saved into the transit line user segment us1 and us2 accordingly.

The bus transit lines segments within the AoDM, has been set to read the congested highway journey times, were a transit travel function, ft1, was coded following the criteria below:

- If the modelled bus speed is greater than Highway free flow Speed and the Highway free flow speed is greater than 96kph, bus speed equal to 96kph converted to minutes.
- If the modelled bus speed is lower or equal to the highway free flow speed and modelled bus speed is greater than 96kph, bus speed equal to 96kph converted to minutes; e.g.(bus 105 < 112 ffs => result = 96kph converted to minutes)
- If the modelled bus speed is greater than Highway Free Flow Speed and highway free flow speed is lower than 96kph, bus speed equal to Highway free flow speed (ul1) converted to minutes; e.g. ((bus) 65kph > 48kph (ffs) => result = bus speed = 48kph converted to minutes)
- If the modelled bus speed is lower or equal than the highway free flow speed and modelled bus speed is lower or equal than 96kph, no changes applied, bus speed equal to the original modelled bus speed in minutes (us3); and,
- Within the AoDM, Figure 4-3, if the congested highway times are greater than the normalized bus modelled journey times, bus journey times equal to the congested highway times.

The following transit travel function presents the coded components to reflect the principles mentioned above:

$$
\begin{aligned}
FT1 = \Bigg(& \text{put}\Bigg(\Bigg(\Bigg(\text{put}\left(\frac{\text{length}}{\frac{\text{us3}}{60}} \right).\text{gt.ul1} \Bigg) * (\text{ul1.gt.96}) * \left(\left(\frac{\text{length}}{96} \right) * 60 \right) \Bigg) \\
& + \left((\text{get}(1).\text{le.ul1}) * (\text{get}(1).\text{gt.96}) * \left(\left(\frac{\text{length}}{96} \right) * 60 \right) \right) \\
& + \left((\text{get}(1).\text{gt.ul1}) * (\text{ul1.le.96}) * \left(\left(\frac{\text{length}}{\text{ul1}} \right) * 60 \right) \right) \\
& + \left((\text{get}(1).\text{le.ul1}) * (\text{get}(1).\text{le.96}) * \text{us3} \right) \Bigg) * \left((\text{us1}).\text{le.get}(2) \right) \\
& + \left((\text{us1}).\text{gt.get}(2) \right) * (\text{us1} + \text{us2}) \Bigg)
\end{aligned}
$$

Where:

- ul1 - Highway free flow speed (km/h)
- us3 – BUS stop to stop timetable journey time (min)
- Length – link length (km)
- 96 – Bus national speed limit (km/h)
- us1 – Congested Highway auto time at link (min)
- us2 – Congested Highway auto time at turn (min).

The resulting journey times have been compared with the timetabled times in Table 8-1 below.

Table 8-1– Modelled (congested) vs Timetabled Bus Journey Times

Criteria	Full Model		AoDM	
AM Peak	**Total**	**%**	**Total**	**%**
Total Bus Transit Lines Passing	713	97.81%	231	97.47%
Total Bus Transit Lines Failed	16	2.19%	6	2.53%
Total Transit Lines	729	100%	237	100%
Inter-peak				
Total Transit lines Passing	660	98.07%	211	99.53%
Total Transit Lines Failed	13	1.93%	1	0.47%
Total Transit Lines	673	100%	212	100%
PM Peak				
Total Transit lines Passing	544	96.11%	192	93.66%
Total Transit Lines Failed	22	3.89%	13	6.34%
Total Transit Lines	566	100%	205	100%

Overall, the calibrated time function returns around 98% (97.5% within AoDM) of bus routes within 15% or less than one-minute difference from the timetabled times in the AM peak. Inter-peak and PM peak network results are equally good with the AoDM area reaching 97.5% and 93.7% fit respectively (Table 8-2).

Table 8-2 - Modelled (congested) vs Timetabled Journey Times by Band

Journey Time Difference [%]		Full Model	%	AoDM	%
AM Peak					
>=0	<=5	576	79.0%	163	68.8%
>5	<=10	106	14.5%	55	23.2%
>10	<=15	31	4.3%	13	5.5%
>15	<=20	11	1.5%	4	1.7%
>20	<=100	5	0.7%	2	0.8%
Total		729	100.0%	237	100.0%
Inter-peak					
>=0	<=5	531	78.9%	178	84.0%
>5	<=10	96	14.3%	28	13.2%
>10	<=15	33	4.9%	5	2.4%
>15	<=20	7	1.0%	1	0.5%
>20	<=100	6	0.9%	0	0.0%
Total		673	100.0%	212	100.0%
PM Peak					
>=0	<=5	439	77.6%	143	69.8%
>5	<=10	79	14.0%	38	18.5%
>10	<=15	26	4.6%	11	5.4%
>15	<=20	7	1.2%	6	2.9%
>20	<=100	15	2.7%	7	3.4%
Total		566	100.0%	205	100.0%

The analysis of bus journey times in Table 8-2 shows that the majority of the bus services remain within 0 and 5% threshold for the whole model and AoDM across all time periods. Calibrated tables for South Essex AoDM transit bus will be presented by time period in Appendix B.

8.2.3 Average Congested Bus Speeds by Bus Operator

The modelled bus transport services were inspected for unexpected congested speeds. The following images, Figure 8-1 and Figure 8-2, shows the minimum, average and maximum speeds per operator, ordered by 'average of average' speed for bus and coach modes respectivly

Figure 8-1 - Average Modelled (congested) Bus Speeds by Bus Operator

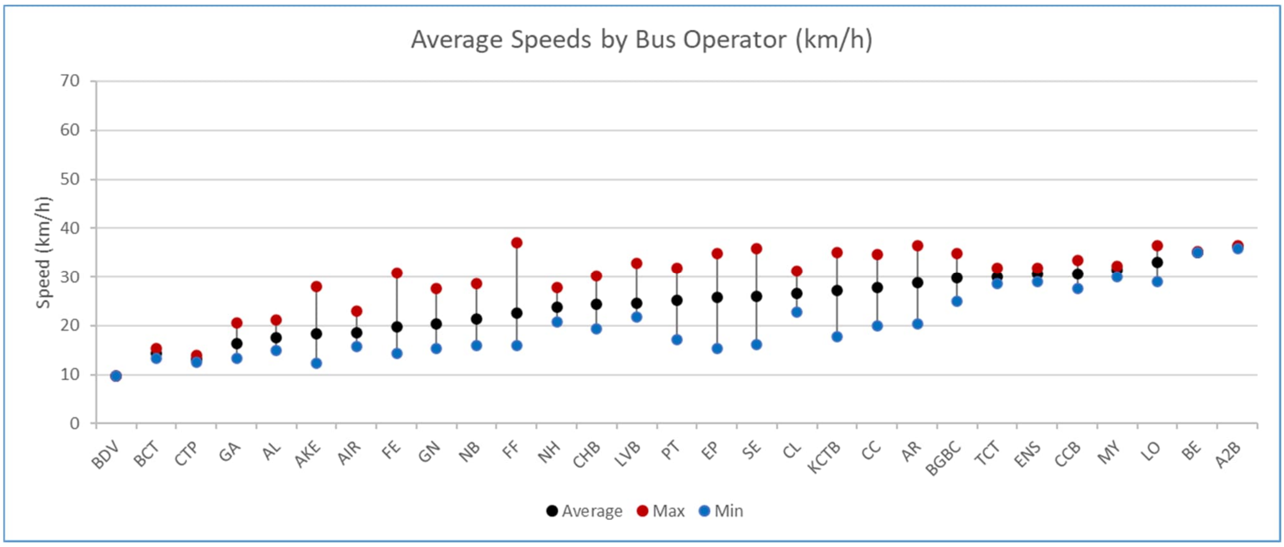
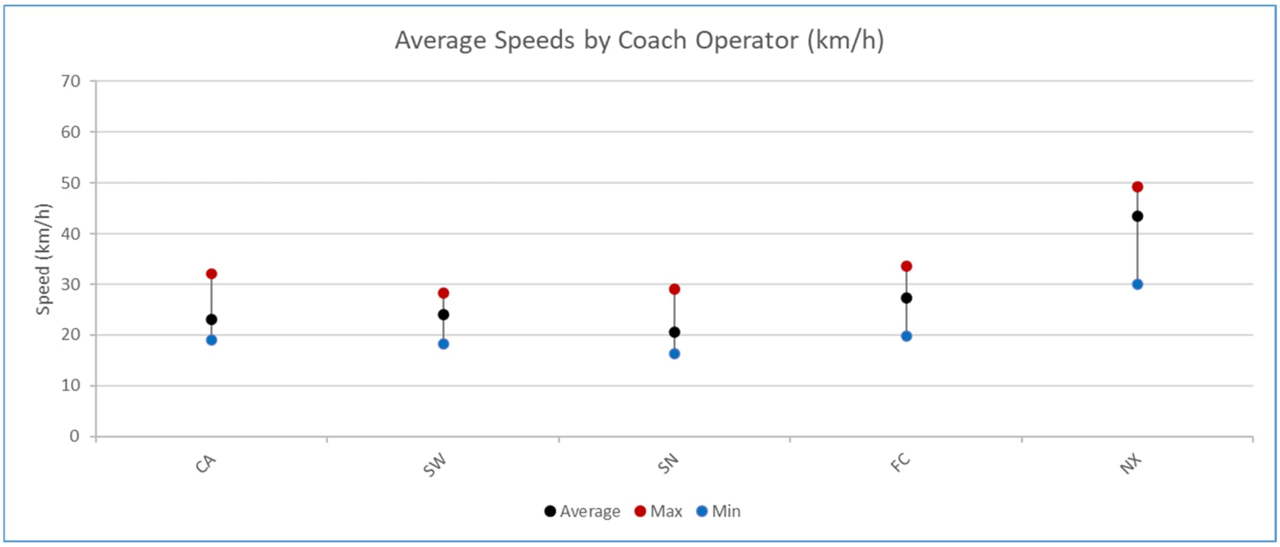


Figure 8-2 - Average Congested Coach Speeds by Coach Operator



The analysis in

Figure 8-1and Figure 8-2, shows a satisfactory spread of speeds by operator. As expected, National Express coach services denotes the higher average speed and it was found legitimate duo to the fact that these services will share the fastest highway routes.

8.2.4 Maximum Average Speed on Public Transport Links

The maximum average speed at links were inspected for bus and coach modes ensuring that the modelled transit speeds will concur with the congested transit time functions. Figure 8-3 shows the maximum average speed on bus and coach links showing a maximum average speed not more than 96km/h, consistent with the codded congested transit time functions, FT1 and FT3.

Figure 8-3 - Maximum Average Link Speed, Bus and Coach.

8.2.5 Bus Route Geometry

In addition to the bus journey time validation, the bus route geometry check was performed for the bus routes listed in Table 8-3.

Table 8-3 - Key Bus Routes for routes.

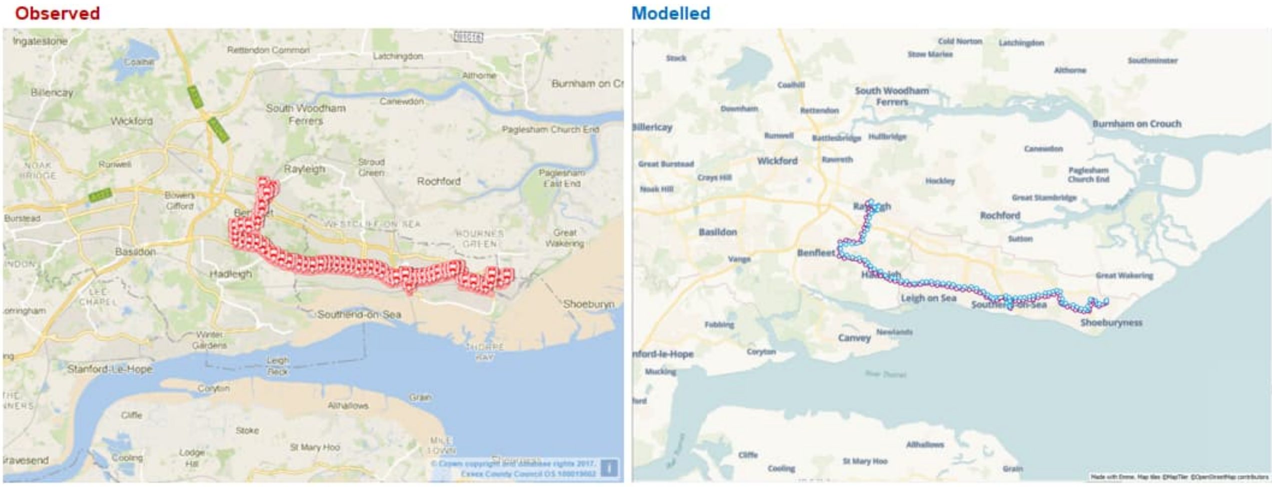
Bus Service N.	Bus Route Description
1	Shoeburyness - Rayleigh
8	Laindon - Pitsea
8A	Laindon - Pitsea
9	Shoeburyness - Rayleigh
20	Hullbridge - Southend
22	Basildon - Canvey
24	Southchurch - Southend Travel Centre
25	Basildon - Southend
27	Canvey - Southend
28	Basildon - Southend
100	Chelmsford -Billericay - Basildon
498	Romford - Brentwood

The bus routes listed in Table 8-3, were selected considering the following principles:

- High frequency bus routes.
- Bus routes connecting key cities such as Southend-on-Sea, Basildon, Brentwood.
- Bus lines running along or competing with the corridor A127 and potentially with major highway schemes along the A127 corridor.

The validation of bus routes was achieved by comparing the mapping of the routes held by ECC and comparing with those coded in the model through the automated processes. Figure 8-4 shows an example of the validation of the Shoeburyness - Rayleigh bus route. The full set of figures is presented in Appendix A.

Figure 8-4 - Shoeburyness - Rayleigh Bus Route Validation.



8.2.6 Rail Network Validation

Table 8-4 shows that services pass the criteria of being within 15% of the timetabled journey time. This is expected as the services are coded from the timetable CIF files without any further adjustments. The differences are likely to arise from averaging of stop-to-stop journey times of individual trains in EMME coding to form a transit line service. Overall, the comparisons provide good confidence in the quality of the timetable coding.

Table 8-4 - Validation of Rail Journey Times to London.

Line description	Train	Observed [min]	Modelled [min]	Diff [min]	Diff [%]	Criteria
AM Peak						
Southend Victoria - London Liverpool Street	2K37	64	65.0	1	1.56%	Pass
Southend Victoria - London Liverpool Street	1K41	63	63.0	0	0.00%	Pass
Southend Victoria - London Liverpool Street	1K21	60	61.0	0.99	1.65%	Pass
Southminster - London Liverpool Street	1J09	72	73.0	0.99	1.37%	Pass
Southminster - London Liverpool Street	1J07	72	70.0	-2	-2.78%	Pass
Southminster - Wickford	2J13	31	31.0	0	0.00%	Pass
Shoeburyness - London Fenchurch Street	1B03	64	66.0	2	3.13%	Pass
Shoeburyness - London Fenchurch Street	1B09	60	61.0	1	1.67%	Pass
Shoeburyness - London Fenchurch Street	1B17	58	62.5	4.49	7.74%	Pass
Shoeburyness - London Fenchurch Street	1B21	58-70	65.0			Pass
Shoeburyness - London Fenchurch Street	1B23	70	69.5	-0.5	-0.71%	Pass
Shoeburyness - London Fenchurch Street	1B25	68	66.5	-1.5	-2.21%	Pass
Shoeburyness - London Fenchurch Street	1B29	65	65.0	0	0.00%	Pass
Shoeburyness - London Fenchurch Street	1B37	66	68.0	2	3.03%	Pass
Shoeburyness - London Fenchurch Street	1F61	69	71.0	2	2.90%	Pass
Shoeburyness - London Fenchurch Street	1F63	70	70.5	0.5	0.71%	Pass
Shoeburyness - London Fenchurch Street	1F67	72	72.5	0.5	0.69%	Pass
Shoeburyness - London Fenchurch Street	1F79	67	67.5	0.5	0.75%	Pass
Shoeburyness - London Fenchurch Street	1P13	60	61.0	1	1.67%	Pass
Southend Central - London Fenchurch Street	2B81	61	62.5	1.5	2.46%	Pass
Thorpe Bay - London Fenchurch Street	1B07	63-67	58.0			Pass
Thorpe Bay - London Fenchurch Street	1B81	71	67.0	-4	-5.63%	Pass
Thorpe Bay - London Fenchurch Street	1P73	63	64.0	1	1.59%	Pass
Southend Central - London Fenchurch Street	2D11	78.0	79.5	1.5	1.92%	Pass
Shoeburyness - London Fenchurch Street	2R59	86.0	86.0	0	0.00%	Pass
Thorpe Bay - London Fenchurch Street	2R61	81.0	82.0	1	1.23%	Pass

Line description	Train	Observed [min]	Modelled [min]	Diff [min]	Diff [%]	Criteria
Pitsea - London Fenchurch Street	2R65	59.0	59.5	0.5	0.85%	Pass
Southend Central - London Fenchurch Street	2R67	79.0	76.5	-2.5	-3.16%	Pass
Inter-peak						
Southend Victoria - London Liverpool Street	2K73	60	62.0	2	3.33%	Pass
Southend Victoria - London Liverpool Street	1K77	58	59.5	1.5	2.59%	Pass
Wickford - Southminster	2J38	31	31.5	0.5	1.61%	Pass
Shoeburyness - London Fenchurch Street	1B43	64	63.0	-1	-1.56%	Pass
Shoeburyness - London Fenchurch Street	2B03	64	66.5	2.5	3.91%	Pass
Southend Central - London Fenchurch Street	2B85	58	57.0	-1	-1.72%	Pass
Southend Central - London Fenchurch Street	2D35	73	72.5	-0.5	-0.68%	Pass
Pitsea - London Fenchurch Street	2R83	55	55.0	0	0.00%	Pass
PM Peak						
Southend Victoria - London Liverpool Street	2K79	59.0	61.5	2.5	4.24%	Pass
Southend Victoria - London Liverpool Street	1K97	58.0	59.5	1.5	2.59%	Pass
Southminster - London Liverpool Street	1J35	67.0	67.5	0.5	0.75%	Pass
Shoeburyness - London Fenchurch Street	1P63	67	66.0	-1	-1.49%	Pass
Shoeburyness - London Fenchurch Street	1B67	62	64.5	2.5	4.03%	Pass
Shoeburyness - London Fenchurch Street	1B71	64	65.0	1	1.56%	Pass
Shoeburyness - London Fenchurch Street	1B73	65	66.0	1	1.54%	Pass
Shoeburyness - London Fenchurch Street	1B77	67	65.5	-1.5	-2.24%	Pass
Shoeburyness - London Fenchurch Street	1F15	65	66.0	1	1.54%	Pass
Shoeburyness - London Fenchurch Street	1F19	70	67.5	-2.5	-3.57%	Pass
Shoeburyness - London Fenchurch Street	1F23	60	62.0	2	3.33%	Pass
Shoeburyness - London Fenchurch Street	2B09	63	67.5	4.5	7.14%	Pass
Southend Central - London Fenchurch Street	1B83	55	56.5	1.5	2.73%	Pass
Southend Central - London Fenchurch Street	1B87	56.5-58	55.0			Pass
Southend Central - London Fenchurch Street	2B17	57	58.0	1	1.75%	Pass
Thorpe Bay - London Fenchurch Street	1B75	60	60.5	0.5	0.83%	Pass
Pitsea - London Fenchurch Street	1R21	54	55.0	1	1.85%	Pass
Shoeburyness - London Fenchurch Street	2R15	74	81.0	7	9.46%	Pass
Pitsea - London Fenchurch Street	1R17	55	55.5	0.5	0.91%	Pass
Pitsea - London Fenchurch Street	2R25	56	55.0	-1	-1.79%	Pass
Southend Central - London Fenchurch Street	2D59	75	75.5	0.5	0.67%	Pass

Table 8-5 shows equally good result in the opposite direction with very good correlation between journey times coded in the model and those expected from the timetables.

Table 8-5 - Validation of Rail Journey Times from London.

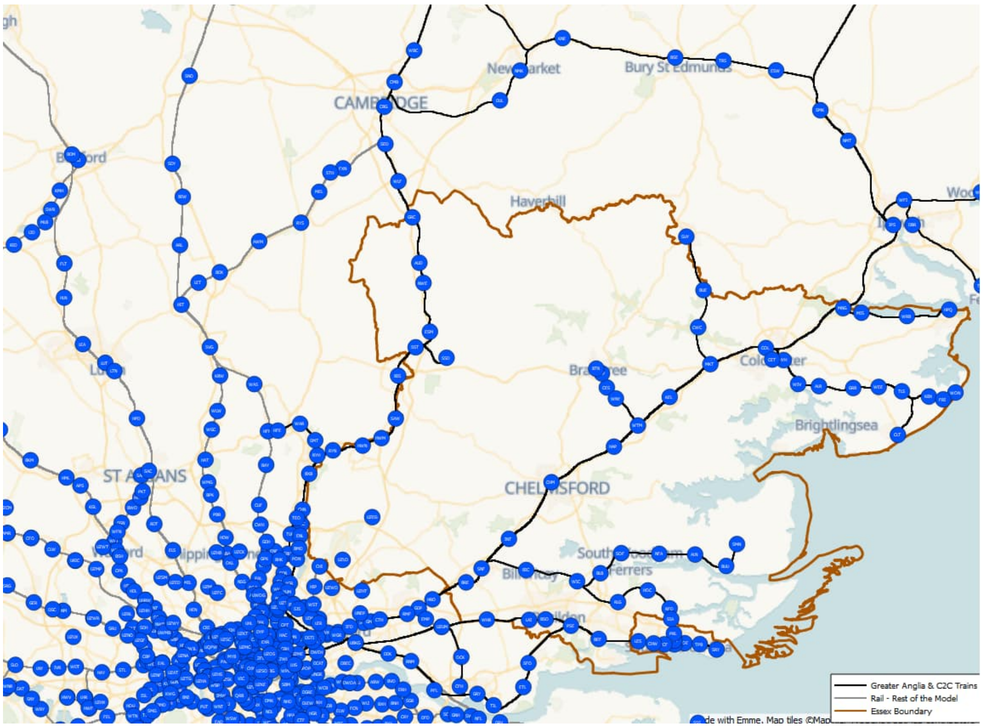
Line description	Train	Observed [min]	Modelled [min]	Diff [min]	Diff [%]	Criteria
AM Peak						
London Liverpool Street - Southend Victoria	1K28	59	59.0	0.00	0.00%	Pass
London Liverpool Street - Southminster	1J10	68	68.0	0.00	0.00%	Pass
Wickford - Southminster	2J20	31	32.0	1.00	3.23%	Pass
London Fenchurch Street - Shoeburyness	1B24	60	58.5	-1.51	-2.52%	Pass
London Fenchurch Street - Shoeburyness	1B10	63	63.5	0.50	0.79%	Pass
London Fenchurch Street - Shoeburyness	1B28	60-64min	61.0			Pass
London Fenchurch Street - Shoeburyness	1B38	60	62.5	2.50	4.17%	Pass
London Fenchurch Street - Shoeburyness	1F62	61	62.0	1.00	1.64%	Pass
London Fenchurch Street - Shoeburyness	1F68	62	64.5	2.50	4.03%	Pass
London Fenchurch Street - Shoeburyness	1P24	66	62.5	-3.50	-5.30%	Pass
London Fenchurch Street - Shoeburyness	2B60	64	65.0	1.00	1.56%	Pass
London Fenchurch Street - Southend Central	2F22	55	55.5	0.50	0.91%	Pass
London Fenchurch Street - Pitsea	1D14	57	59.5	2.50	4.39%	Pass
London Fenchurch Street - Pitsea	2D10	62	60	-2.00	-3.23%	Pass

Line description	Train	Observed [min]	Modelled [min]	Diff [min]	Diff [%]	Criteria
London Fenchurch Street - Southend Central	2D16	82	75.5	-6.50	-7.93%	Pass
London Fenchurch Street - Shoeburyness	2D18	77	85	8.00	10.39%	Pass
London Fenchurch Street - Pitsea	2R66	54	57	3.00	5.56%	Pass
Inter-peak						
London Liverpool Street - Southend Victoria	2K60	60	60.5	0.5	0.83%	Pass
London Liverpool Street - Southend Victoria	1K64	59	58.5	-0.5	-0.85%	Pass
Southminster - Wickford	2J31	30	30.5	0.5	1.67%	Pass
London Fenchurch Street - Shoeburyness	1B40	60	61.0	1	1.67%	Pass
London Fenchurch Street - Shoeburyness	2B74	63	63.5	0.5	0.79%	Pass
London Fenchurch Street - Southend Central	2D22	74	73.0	-1	-1.35%	Pass
London Fenchurch Street - Pitsea	2D44	59	57.5	-1.5	-2.54%	Pass
PM Peak						
London Liverpool Street - Southminster	1J48	72	68.5	-3.49	-4.85%	Pass
London Liverpool Street - Southend Victoria	1K98	63	62.5	-0.5	-0.79%	Pass
London Fenchurch Street - Southend Central	1B02	57	59.5	2.5	4.39%	Pass
London Fenchurch Street - Southend Central	1B92	57	54.5	-2.5	-4.39%	Pass
London Fenchurch Street - Southend Central	1F22	60	60.0	0	0.00%	Pass
London Fenchurch Street - Southend Central	2B00	57-60	60.0			Pass
London Fenchurch Street - Shoeburyness	1B64	63	65.0	2	3.17%	Pass
London Fenchurch Street - Shoeburyness	1B66	64	63.0	-1.01	-1.58%	Pass
London Fenchurch Street - Shoeburyness	1B70	68	62.0	-6.02	-8.85%	Pass
London Fenchurch Street - Shoeburyness	1B74	62	65.0	3	4.84%	Pass
London Fenchurch Street - Shoeburyness	1B84	64	62.5	-1.5	-2.34%	Pass
London Fenchurch Street - Shoeburyness	1B86	63	64.0	1	1.59%	Pass
London Fenchurch Street - Shoeburyness	1F00	62	64.5	2.5	4.03%	Pass
London Fenchurch Street - Shoeburyness	1F02	62	66.0	4	6.45%	Pass
London Fenchurch Street - Shoeburyness	1F08	69	70.0	1	1.45%	Pass
London Fenchurch Street - Shoeburyness	1P80	69	61.5	-7.5	-10.87%	Pass
London Fenchurch Street - Shoeburyness	2B04	68	70.5	2.5	3.68%	Pass
London Fenchurch Street - Southend Central	1D64	79	82.0	3	3.80%	Pass
London Fenchurch Street - Southend Central	2D66	79	82.5	3.5	4.43%	Pass
London Fenchurch Street - Pitsea	1R22	59	59.5	0.5	0.85%	Pass
London Fenchurch Street - Pitsea	2D46	61	65.0	4	6.56%	Pass
London Fenchurch Street - Pitsea	2R08	59	59.5	0.5	0.85%	Pass
London Fenchurch Street - Shoeburyness	2R10	90	87.5	-2.5	-2.78%	Pass

8.2.7 Rail Station nodes Connected

Rail station nodes check was undertaken to ensure a correct rail routing/stopping pattern across the stations served by Greater Anglia and C2C trains (Figure 8-5Figure 8-5). Furthermore, an additional check to the station entrance and exit walk links connectivity to ensure that the rail passengers interchange was made possible between the rail and bus public transport modes.

Figure 8-5 - Rail Station nodes.



8.2.8 Model Zones Connected

Model zones were checked to verify that all zones are reachable by public transport network, thus, ensuring all public transport trips to and from zone will successfully be assigned and avoiding excessive generalized costs outputs from the model. For this purpose, the following checks were completed:

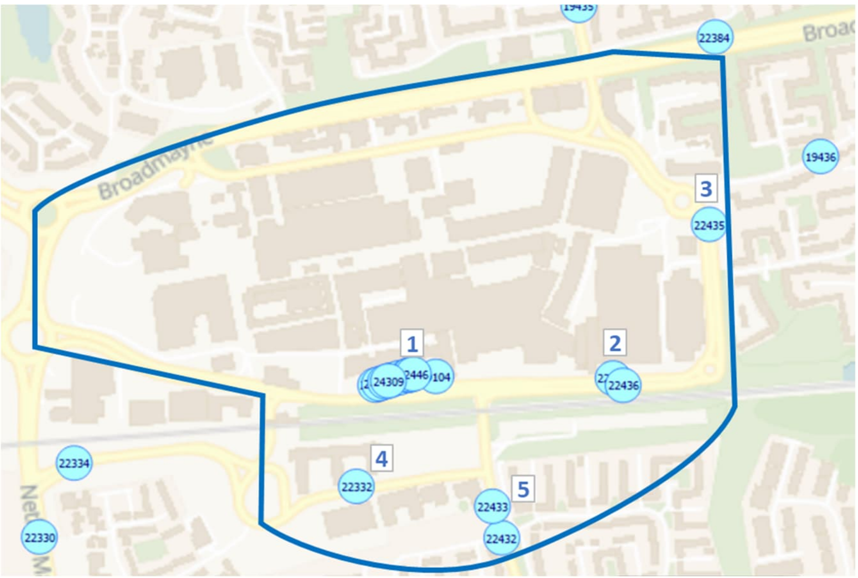
- Maximum generalised costs were inspected for the existence of infinite values (stored in EMME as 1e+20) – none were found; and
- The non-intrazonal totals of the matrices were compared to the outgoing zone connectors trip totals. Any discrepancy would point to disconnected zones – none were found.

8.3 Calibration and Validation Results

8.3.1 High-Level Bus Validation at Basildon Town Centre

The performance of the assignment of the bus trip matrix (development of which is described in Chapter 7) was assessed against the available bus data. The only available patronage data were the high-level 2017 bus patronage figures provided by ECC for the development of the Essex Countywide model. The bus boarders and alighters in the Basildon Town Centre were extracted from the assigned PT model for the cordoned bus stops presented in the Figure 8-6. The modelled results were then compared, at high-level, with bus data obtained from Essex County Council.

Figure 8-6 - Basildon Town Centre bus stops



The assigned demand from the area corresponding to this data was extracted from the model and the figures compared against the observed data (Table 8-6).

Table 8-6 - Comparison of Basildon Town Centre Bus Boardings

Description	Daily Boardings	Daily Alighters	Total
Basildon Town Centre Observed	8,690	8,690	17,380
Basildon Town Centre Modelled	6,804	7,113	13,917
Difference: Observed vs Modelled	-22%	-18%	-20%

Table 8-6 shows a resonable performance with modelled data being within 20% of observed. It is worth noting that the data is high-level and the accurace of comparisons relies on assumptions about the extent of the Basildon Town Centre network that the data represents as well as assumotions about de-annualisaiton factors to convert from annual to average day figures. Nevertheless, although Table 8-6 does not show a perfect fit, it is a reasonable benchmark of the level of demand represented in the model. In addition, extensive examinations were undertaken during the bus matrix development process to ensure that the levels of bus demand represented in the model are realistic. These checks have been undertaken interatively between matrix developent and PT assignment workstreams and are documented in the next section.

8.3.2 Bus Loading Factors – Sense Checks

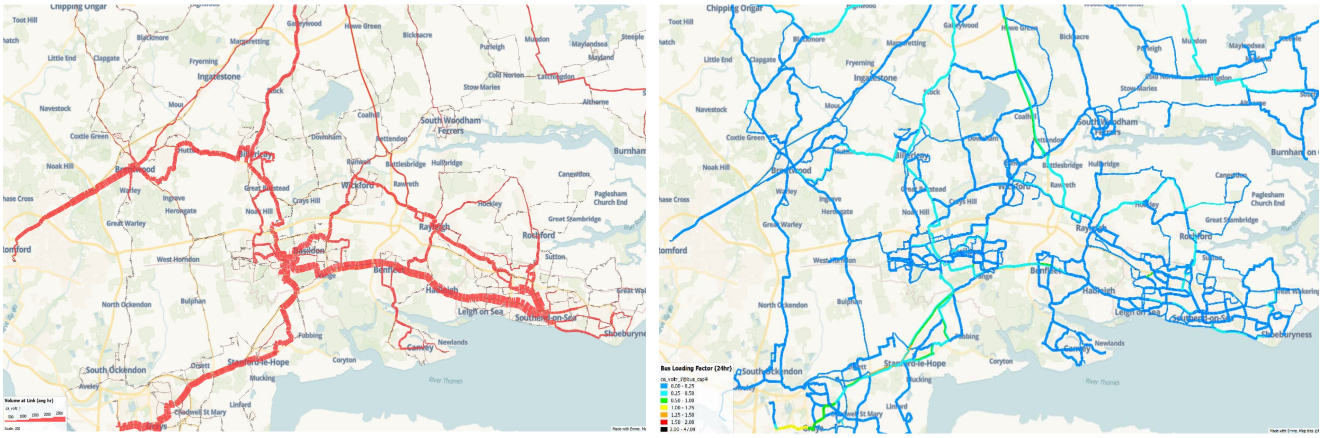
This section discusses the sense checks on the level of bus demand, which have been undertaken with the use of the allocated bus demand from gravity model against the seated bus capacity coded in the Southe Essex PT Model, previously discussed in the section 6.5.
The bus load factor plots have been used to review the average and maximum load factors on bus and coach within the AoDM and FMA. The initial comparisons are presented in the Figure 8-7 and Figure 8-8. The analysis firstly focussed on the assignment of the 24hr bus matrices and then the AM peak period, where the hourly flows are the highest and most likely to highlight anomalies across the bus network. The plots show the ratio of bus loading to seated capacity in 7 different colour bands specified in Table 8-7.

Table 8-7 – Bus and Coach Loading Factors by Band.

Colour Band	Volume over Seated Capacity Range
Blue	0 to 0.25
Light Blue	0.25 to 0.50

Green	0.5 to 1.00
Yellow	1.00 to 1.25
Orange	1.25 to 1.50
Red	1.50 to 2.00
Black	Higher than 2.00

Figure 8-7- 24h Bus Volumes vs Bus and Coach Average Loading Factors - Initial gravity model outputs.



Apart from the west section of the network, between London and Brentwood, the average 24hr Loading factors in Figure 8-7 within the available 24hr seated capacity and the bus services across AoDM are not overwhelmed when the synthetic bus demand is assigned to the network.

Figure 8-8 AM Bus and Coach Average Loading Factors - Initial gravity model outputs.

However, the AM peak average load factors in Figure 8-8 show that the intial bus demand estimates exceeded available capacity (load factors above 1). This was linked to the over-estimated of the bus demand from London towards South Essex, which is unrealsitic, particularly in the AM peak (see Section 7.5.1.3 for further detial). The load factors derived from the assignment of the final version of the synthetic bus demand, is shown in Figure 8-9. It shows improvements at the west section when comparing with the intial version shown above.

Figure 8-9 - AM Bus and Coach Average Loading Factors - final gravity model outputs.

Finally, maximum AM peak load factors in Figure 8-10 shows that the majority of bus services does not cary excess load. green sections were carefully inspected and load factors does not exceed 0.55 (so flows are comfotably within capacity).

Figure 8-10 - AM Bus and Coach Maximum Loading Factors - final gravity model outputs.

Bus and coach load factors sense checks presented above have been undertaken in all time periods and no anomalies have been found (results presented in Appendix D).

8.3.3 Rail Station Benchmark Calibration/Validation

Office of Rail and Road (ORR) Rail Station Usage data was used as a benchmark of rail boarders and alighters by rail station within Essex County Wide. Table 8-8 shows the comparison between the ORR data and the modelled rail demand for the stations served by the Greater Anglia and C2C trains in the South Essex Fully Modelled Area.

Table 8-8 - Rail Calibration results

Rail Station Description	Observed Daily Rail Station			24hr Adjusted Rail			Criteria	
	Entries	Exits	Total	Entries	Exits	Total	%Diff	GEH
ROMFORD	15,388	15,388	30,775	15,111	15,722	30,834	0.2%	0.3
UPMINSTER	9,814	9,814	19,627	10,088	9,680	19,767	0.7%	1.0
SHENFIELD	7,061	7,061	14,122	7,114	7,051	14,165	0.3%	0.4
GRAYS	7,013	7,013	14,025	6,718	7,365	14,083	0.4%	0.5

Rail Station Description	Observed Daily Rail Station			24hr Adjusted Rail			Criteria	
BENFLEET	6,325	6,325	12,649	6,317	6,207	12,524	-1.0%	1.1
SOUTHEND CENTRAL	5,994	5,994	11,989	5,592	5,880	11,472	-4.3%	4.8
BASILDON	5,606	5,606	11,212	5,511	5,521	11,032	-1.6%	1.7
BRENTWOOD	5,417	5,417	10,833	5,383	5,451	10,835	0.0%	0.0
BILLERICAY	5,360	5,360	10,720	5,341	5,305	10,646	-0.7%	0.7
HAROLD WOOD	5,204	5,204	10,407	5,172	5,233	10,405	0.0%	0.0
CHAFFORD HUNDRED LAKESIDE	4,827	4,827	9,654	4,955	4,635	9,590	-0.7%	0.7
GIDEA PARK	4,747	4,747	9,494	4,623	4,898	9,522	0.3%	0.3
LAINDON	4,046	4,046	8,092	3,992	4,020	8,012	-1.0%	0.9
LEIGH-ON-SEA	4,010	4,010	8,020	3,995	3,929	7,924	-1.2%	1.1
WICKFORD	3,982	3,982	7,964	3,990	3,972	7,962	0.0%	0.0
SOUTHEND VICTORIA	3,704	3,704	7,409	3,670	3,483	7,153	-3.4%	3.0
SOUTHEND EAST	3,401	3,401	6,802	3,629	3,157	6,786	-0.2%	0.2
CHALKWELL	3,310	3,310	6,620	3,328	3,235	6,563	-0.9%	0.7
RAYLEIGH	3,233	3,233	6,466	3,198	3,231	6,429	-0.6%	0.5
RAINHAM (ESSEX)	2,926	2,926	5,851	2,940	2,911	5,851	0.0%	0.0
PITSEA	2,225	2,225	4,451	2,232	2,144	4,376	-1.7%	1.1
TILBURY TOWN	2,141	2,141	4,283	2,188	2,143	4,331	1.1%	0.7
WESTCLIFF	2,124	2,124	4,248	1,997	2,208	4,205	-1.0%	0.7
STANFORD-LE-HOPE	1,937	1,937	3,874	1,936	1,920	3,856	-0.5%	0.3
OCKENDON	1,934	1,934	3,869	1,936	1,931	3,867	0.0%	0.0
INGATESTONE	1,627	1,627	3,253	1,636	1,617	3,253	0.0%	0.0
THORPE BAY	1,513	1,513	3,025	1,444	1,478	2,922	-3.4%	1.9
SHOEBURYNESS	1,290	1,290	2,580	1,272	1,238	2,510	-2.7%	1.4
HOCKLEY	1,252	1,252	2,504	1,226	1,238	2,465	-1.6%	0.8
PURFLEET	1,137	1,137	2,273	1,143	1,126	2,269	-0.2%	0.1
ROCHFORD	1,071	1,071	2,142	1,058	1,066	2,124	-0.8%	0.4
SOUTHEND AIRPORT	997	997	1,993	972	1,008	1,980	-0.7%	0.3
SOUTH WOODHAM FERRERS	911	911	1,822	909	902	1,811	-0.6%	0.2
EAST TILBURY	775	775	1,551	788	775	1,563	0.8%	0.3
WEST HORNDON	744	744	1,488	740	724	1,464	-1.6%	0.6
EMERSON PARK	586	586	1,172	679	458	1,137	-3.0%	1.0
BURNHAM-ON-CROUCH	420	420	839	421	414	834	-0.6%	0.2
PRITTLEWELL	379	379	758	366	387	753	-0.7%	0.2
SOUTHMINSTER	226	226	453	225	225	450	-0.6%	0.1
NORTH FAMBRIDGE	147	147	293	150	144	294	0.4%	0.1
ALTHORNE (ESSEX)	77	77	154	78	76	153	-0.6%	0.1
BATTLESBRIDGE	28	28	56	32	24	56	1.5%	0.1
TOTAL	134,906	134,906	269,813	134,093	134,135	268,228	-0.6%	3.1

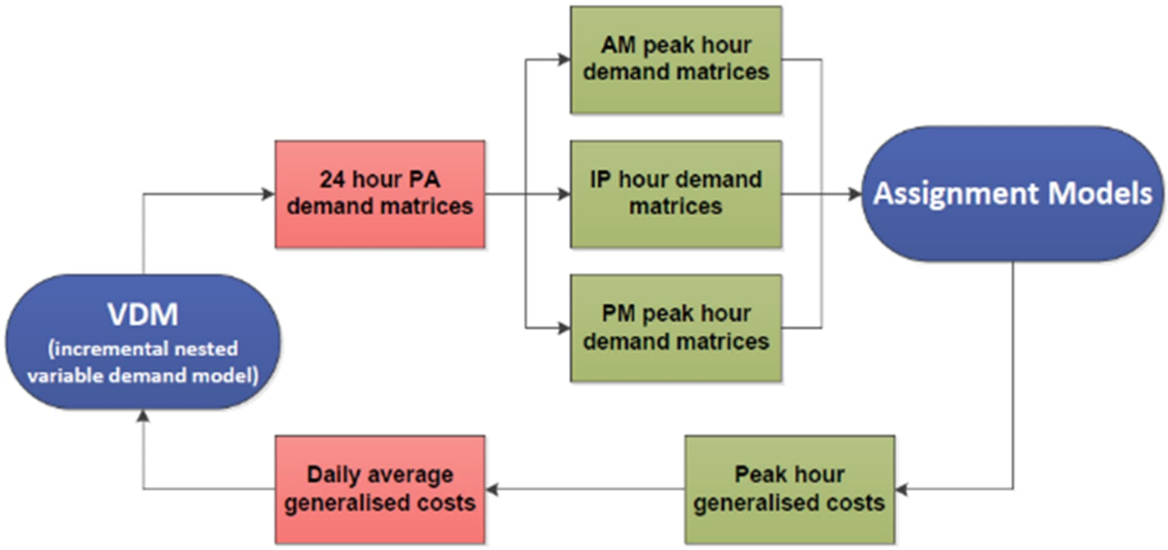
Overall, the rail calibration results in Table 8-8, show good performance and fit very well with the observed ticketing data across all satiations served by Greater Anglia and C2C trains.

9 Variable Demand Model

9.1 Overview

SEM has been built in line with the guidance set out in TAG Unit M2.1 and includes a Variable Demand Model (VDM) operating at a production/attraction (PA) 24-hour level. The model is of an incremental logit form and responds to changes in daily generalised costs. These costs are predicted by the highway and public transport assignment models and then converted to daily weighted average costs taking account of the time period and direction of journey prior to the demand modelling. The resultant demand matrices require conversion to AM, IP and PM Origin-Destination (OD) matrices for assignment. The process is repeated until the model converges, i.e. when the changes in demands and costs between iterations are regarded as sufficiently small. This relationship between the Demand Model and Assignment Models is shown in Figure 9-1.

Figure 9-1 – Relationship between Demand and Assignment Models

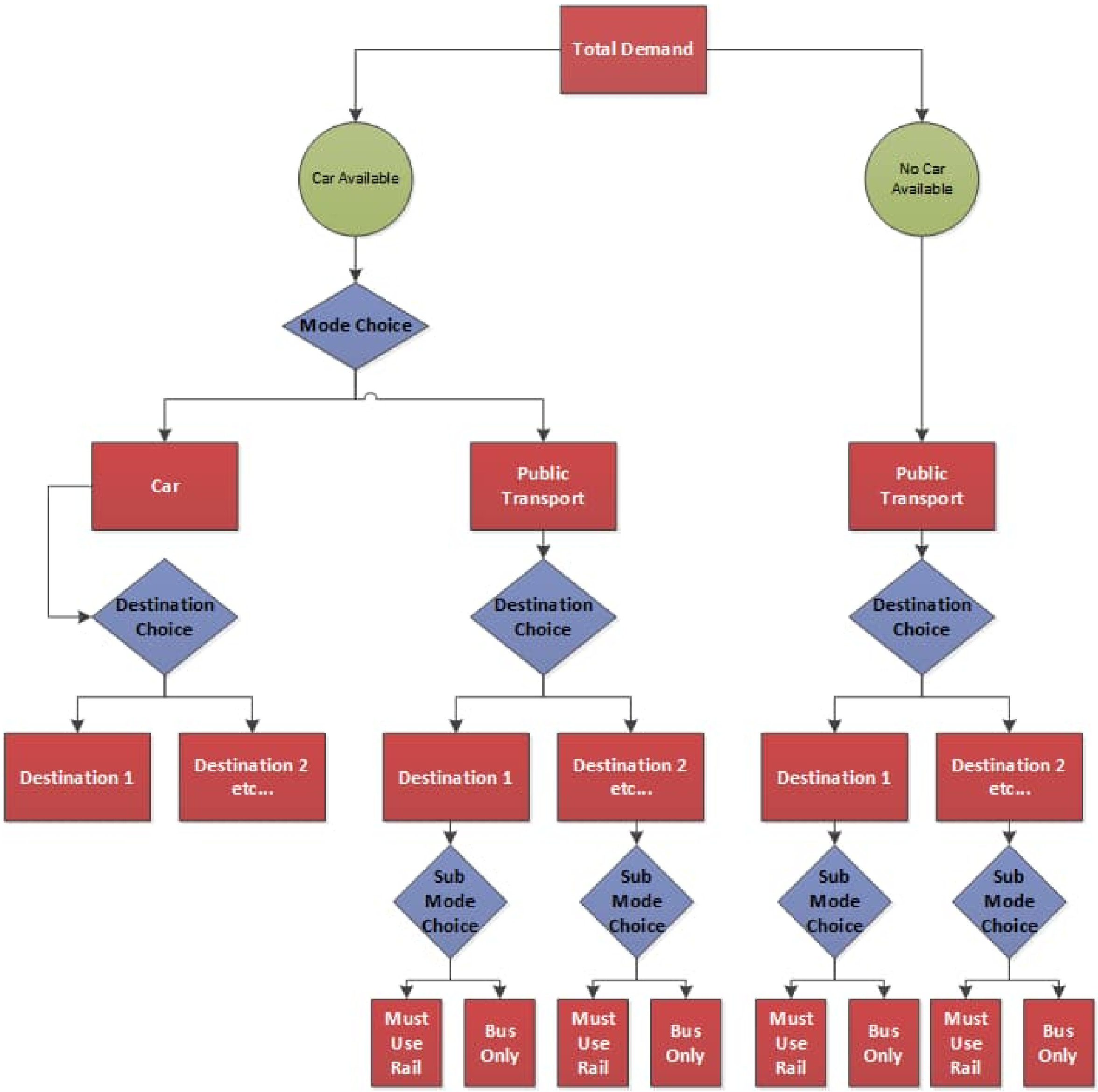


SEM is, via VDM, designed to take account of future strategic and local growth in population and employment and to be capable of predicting likely travel behaviour in terms of mode choice and trip distribution of trips with one or both trip-ends within South Essex over a temporal scale greater than a single peak hour.

The trip distribution response considers the attractiveness of alternative destinations whereas the mode choice response considers demand switching between car and public transport. Since mode choice depends on whether a traveller has a car available for the journey, the model also distinguishes between households that have a car available and those that do not. Under the public transport choice model there is also an additional sub-mode choice between rail and bus modes, where the model considers the attractiveness between travelling by bus only or via rail (and bus).

It was agreed that cycle and walk modes do not provide a realistic alternative for strategic journeys across a study area of this size and so they are not modelled. Goods vehicle trips are assumed to be non-responsive to changes in travel costs (with their trip making influenced by other, external, economic factors) and therefore remain fixed within the variable demand model. An overview of the demand model choice structure is shown in Figure 9-2.

Figure 9-2 – Mode Choice Structure



The inputs and functions applied in the demand model are detailed in the rest of this chapter.

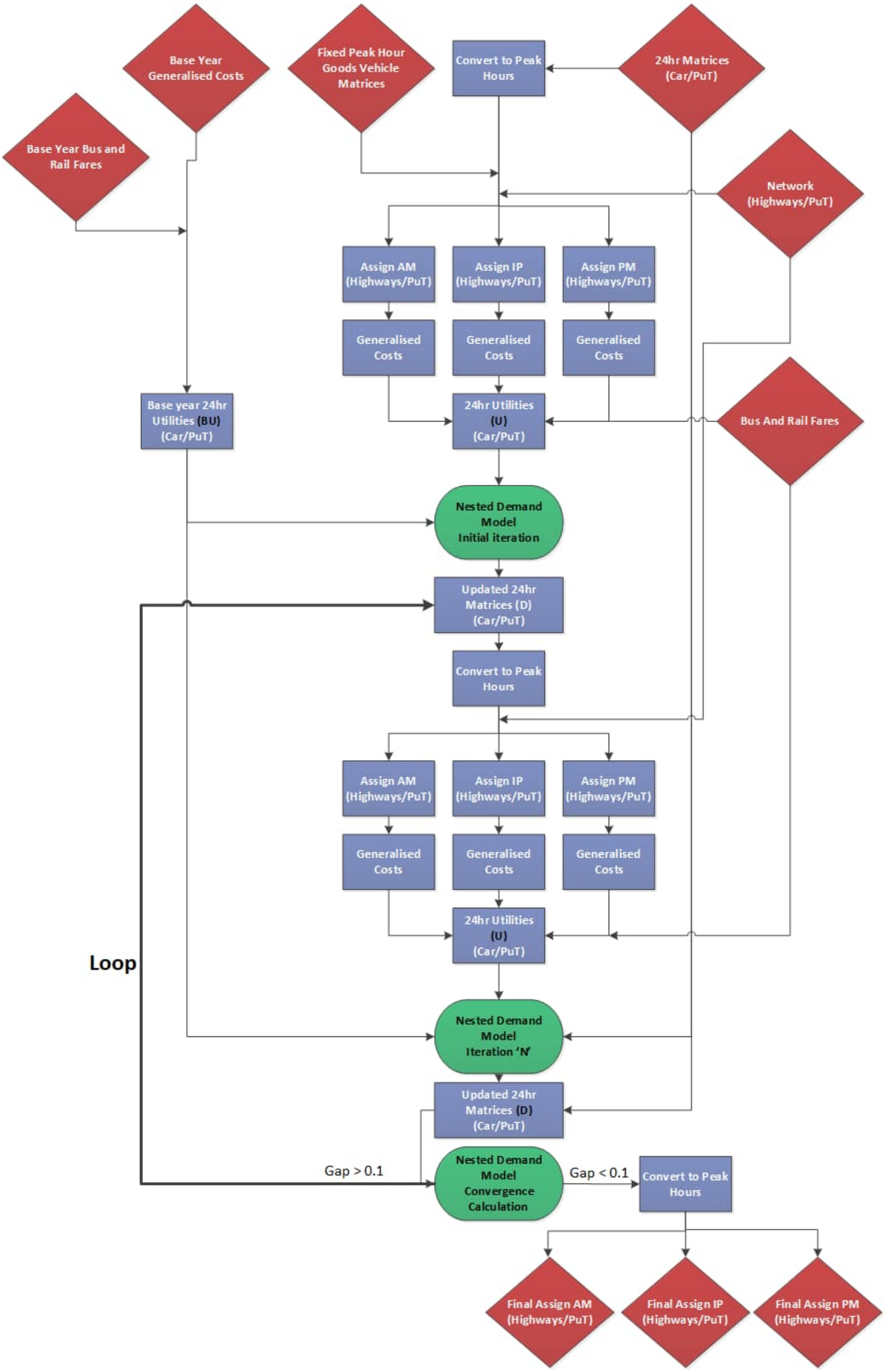
9.2 Model Process

A detailed schematic of the South Essex Variable Demand Model process is shown in Figure 9-3. The inputs and outputs from the model are shown in red:

- Pivot demand matrices for car and public transport representing "without scheme" demand. Depending on the run type this can be base year or reference case (Do-Minimum) demand.
- Fixed demand matrices for goods vehicles representing the base or future year demand.
- Generalised costs of travel in the base situation ("without scheme").
- Forecast networks (base or future year) representing the scheme/policy tested.
- Final peak hour assignments (AM, IP and PM) as an output from the demand model.

Model processes, such as matrix conversions and assignments (and the resulting outputs/inputs), are shown in blue and demand model calculations (containing the choice structure as shown in Figure 9-2) are shown in green.

Figure 9-3 – Demand Model Process



9.3 Journey Purposes and Demand Segmentation

The following journey purpose segmentation is used within the South Essex Demand Model:

- Home-Based Work (HBW) – travelling from home to work (and any return journeys) – a typical commuting journey (this travel purpose does not take place in employers' time).
- Home-Based Employer's Business (HBEB) – travelling from home to a destination where you are in employers' time as soon as you leave the home (and any return journeys).
- Home-Based Other (HBO) – travelling from home to a non-work-related location (other than shopping or education and any return journeys).
- Home-Based Shopping (HBShop) – travelling from home to a non-work, shopping-related location and any return journeys).
- Home-Based Education (HBEdu) – travelling from home to an education destination (primary/secondary schools and any return journeys).
- Non-Home-Based Employer's Business (NHBEB) – travelling during employers' time, such as travelling from a place of work to a business meeting, visiting customers etc.
- Non-Home-Based Other (NHBO) – travel between two non-home-based locations (for example, from work to shops).

These seven journey purposes have been duplicated across car, public transport car available and public transport no car available modes. Public Transport is further segmented into 'Bus only' and 'Must Use Rail' user classes. These are defined as:

- Rail or 'must use rail' – public transport tours which contain at least one instance of a journey by Underground/Overground/DLR/National Rail (buses can be used to access rail).
- Bus or 'bus only'– public transport tours undertaken solely by bus and tram.

Table 9-1 presents the correspondence between the demand model trip purposes and the assignment user classes:

Table 9-1 – Journey Purpose / Assignment User Class Correspondence

Mode	User Class	Demand Model Trip Purpose
PrT	Car Commute	Car Available - Home-Based Work – HBW
	Car Employers' Business	Car Available - Home-Based Employers' Business – HBEB
		Car Available - Non-Home-Based Employers' Business – NHBEB
	Car Other	Car Available - Home-Based Other – HBO
		Car Available - Home-Based Shopping – HBShop
		Car Available - Home-Based Education – HBEdu
		Car Available - Non-Home-Based Other – NHBO
	LGV	-
	HGV	-
PuT (Bus, train, Light Rail)	Must Use Rail	Must Use Rail - Car Available - Home-Based Work – HBW
		Must Use Rail - No Car Available - Home-Based Work – HBW
		Must Use Rail - Car Available - Home-Based Employers' Business – HBEB
		Must Use Rail - No Car Available - Home-Based Employers' Business – HBEB
		Must Use Rail - Car Available - Non-Home-Based Employers' Business –
		Must Use Rail - No Car Available - Non-Home-Based Employers' Business –
		Must Use Rail - Car Available - Home-Based Other – HBO
		Must Use Rail - No Car Available - Home-Based Other – HBO
		Must Use Rail - Car Available - Home-Based Shopping – HBShop
		Must Use Rail - No Car Available - Home-Based Shopping – HBShop
		Must Use Rail - Car Available - Home-Based Education – HBEdu

Mode	User Class	Demand Model Trip Purpose
		Must Use Rail - No Car Available - Home-Based Education – HBEdu
		Must Use Rail - Car Available - Non-Home-Based Other – NHBO
		Must Use Rail - No Car Available - Non-Home-Based Other – NHBO
	Bus Only	Bus Only - Car Available - Home-Based Work – HBW
		Bus Only - No Car Available - Home-Based Work – HBW
		Bus Only - Car Available - Home-Based Employers' Business – HBEB
		Bus Only - No Car Available - Home-Based Employers' Business – HBEB
		Bus Only - Car Available - Non-Home-Based Employers' Business – NHBEB
		Bus Only - No Car Available - Non-Home-Based Employers' Business –
		Bus Only - Car Available - Home-Based Other – HBO
		Bus Only - No Car Available - Home-Based Other – HBO
		Bus Only - Car Available - Home-Based Shopping – HBShop
		Bus Only - No Car Available - Home-Based Shopping – HBShop
		Bus Only - Car Available - Home-Based Education – HBEdu
		Bus Only - No Car Available - Home-Based Education – HBEdu
		Bus Only - Car Available - Non-Home-Based Other – NHBO
		Bus Only - No Car Available - Non-Home-Based Other – NHBO
		Bus Only - Car Available - Home-Based Work – HBW
		Bus Only - No Car Available - Home-Based Work – HBW

The model segmentation follows guidance in TAG and is consistent with the segmentation used in the development of the final demand matrices using TEMPro trip-ends and mobile network data. In line with TAG advice, Home-Based Work and Education purpose trips are doubly constrained within the variable demand model. Other purpose trips are run as a singly constrained process.

9.4 Demand Responsive Area

The study area and zoning system are described in Section 4.2 and 4.3. For the VDM, the study area is split into distinct areas reflecting the confidence in the accuracy of the assignment travel cost predictions and determining the responsiveness of the demand model. Any trip starting or ending within the Fully Modelled Area, as shown in Figure 2-1, is within the scope of the demand model and hence is fully responsive to cost changes. Any other trip with starting and ending outside of the Fully Modelled Area is fixed within the variable demand model.

9.5 Generalised Costs

9.5.1 Highway Assignment

In the highway assignment model, three parameters are defined for each user class to calculate generalised cost and applied to journey distance and any tolls included in the model. These three parameters used are Value of Time (VoT) (in pence per minute (ppm)), Vehicle Operating Cost (VOC) (in pence per kilometre (ppk)), and any tolls (in pence) associated with each user class, which may also vary by time of day. The following formula to determines the generalised cost:

$$GeneralisedCost_{minutes} = JourneyTime_{minutes} + \left(\frac{ppk}{ppm}\right) * JourneyDistance_{km} + \left(\frac{1}{ppm}\right) * Toll_{pence}$$

Within the South Essex base year highway model, a link toll has been included to represent the Dartford Crossing. Functionality is also in place to add tolls to the highway network as part of any potential testing of future pricing policies on the highway network in a given forecast scenario.

The values of the ppm and ppk parameters used in the SEM assignment are based on the latest TAG Unit A1.3 guidance and Data Book available at the time of the highway model development (May 2019 v1.12). TAG Unit M3.1 Paragraph 7.2.2 states that "it is often the case that the routes based on generalised costs given in TAG for heavy goods vehicles do not appear to take full account of the attractiveness of motorways and trunk roads and the unattractiveness of local roads for these vehicles…" and Paragraph 2.8.8 then goes on to state that "the value of time given in TAG Unit A1.3 for HGVs relates to the driver's time and does not take account of the influence of owners on the routeing of these vehicles. On these grounds, it is more appropriate to use a value of time around twice the TAG Unit A1.3 values". Following this advice, and based upon previous experience, the HGV VoT values for use in the model have been doubled.

Vehicle operating costs were derived from Highways England spreadsheet. Average speeds were extracted from a version of the highway assignment model for use in this calculation (Table 9-2).

Table 9-2 – Average Speeds by Time Period used in VOC Calculation

Time Period	Modelled Average Speed in South Essex (kph)
AM	49.5
IP	54.3
PM	48.4

TAG Databook provides different vehicle operating costs for Other Goods Vehicle (OGV) Type 1 and Type 2. These are aggregated as HGVs in the assignment model and it is necessary to apply a proportion of each type in the calculation. The proportions assumed are presented in Table 9-3.

Table 9-3 – OGV1 and OGV2 split used in HGV VOC Calculation

Vehicle Type	Proportion
OGV1	40%
OGV2	60%

The final values for highway VoT and VOC for the Colchester Transport Model base year are provided in Table 2 4. The final input for implementation in VISUM is also shown; the format required are coefficient for pence per metre (ppmetre) for VOC as a weighted ratio of the VoT pence per second (pps). Generalised costs for LGVs, HGVs have a higher emphasis on the distance component than cars.

Table 9-4 – Highway Generalised Cost Parameters, 2019

	User Class	TAG Databook		VISUM Units		VISUM Coefficients	
		VoT (ppm)	VOC (ppk)	VoT (pps)	VOC	VOT	VOC
AM	UC1 Car Commute	20.81	5.96	0.3468	0.0060	1.0	0.0172
	UC2 Car Business	31.02	12.49	0.5171	0.0125	1.0	0.0242
	UC3 Car Other	14.35	5.96	0.2392	0.0060	1.0	0.0249
	LGV	22.48	14.14	0.3747	0.0141	1.0	0.0377
	HGV (doubled VoT)	44.78	44.03	0.7464	0.0440	1.0	0.0590
IP	UC1 Car Commute	21.14	5.78	0.3524	0.0058	1.0	0.0164
	UC2 Car Business	31.79	12.10	0.5299	0.0121	1.0	0.0228
	UC3 Car Other	15.29	5.78	0.2549	0.0058	1.0	0.0227
	LGV	22.48	13.90	0.3747	0.0139	1.0	0.0371
	HGV (doubled VoT)	44.78	42.39	0.7464	0.0424	1.0	0.0568
PM	UC1 Car Commute	20.88	6.01	0.3480	0.0060	1.0	0.0173
	UC2 Car Business	31.47	12.59	0.5245	0.0126	1.0	0.0240
	UC3 Car Other	15.03	6.01	0.2505	0.0060	1.0	0.0240
	LGV	22.48	14.21	0.3747	0.0142	1.0	0.0379
	HGV (doubled VoT)	44.78	44.43	0.7464	0.0444	1.0	0.0595

9.5.2 Public Transport Assignment

The generalised cost formulation for public transport is derived from a number of different components. Each component is given its own weight or coefficient to convert the components to common units and to ensure that the relative importance of each component for passengers is reflected. These attributes are show in in section 4.8.

9.5.3 Public Transport Fares

The public transport fare matrices enable the model to consider monetary travel costs in the Variable Demand Model. These consist of three elements:

- Rail-only fare matrix.
- Bus-only fare matrix.
- Combined fare matrix (where bus is used as access mode to rail).

In creating the fare datasets, a balance was needed between precision and simplicity. In the case of rail, this meant taking incomplete raw fare data at the national level from the Association of Train Operating Companies (ATOC) website and using a regression method to produce a best-fit line that could create a distance-based formula for each of the three principal journey purposes.

In case of bus, this meant making assumptions about which bus fare products would be used, with the guiding principle that cheapest available fare for travel in particular area would be used. The review resulted in the allocation of each zone pair in the matrix to either pass area (if the trip could be completed within a given pass area), walk-up fares (if the zone was not part of any pass area) or a combination of both.

The process of constructing the combined fare matrix used fares matrices for the two separate modes and then examined mode proportions from the base year public transport model assignment for each zone-pair to calculate the share of modes for each trip. In VDM fares are converted from monetary costs to time using the Values of Time e based on TAG Unit A1.3 and TAG Databook and are shown in Table 9-5.

Table 9-5 – Public Transport Values of Time (Pence per Minute)

Purpose	Rail (ppm)	Bus (ppm)
Business	53.06	18.23
Commute	21.54	21.54
Leisure	9.83	9.83

9.6 Conversion of 24-Hour Demand to OD Assignment Matrices

The 24-hour PA variable demand model requires processes to convert the daily demand matrices into period OD demand for peak hour assignment. To prepare the matrices into this format three sets of factors are used. Firstly, time of day (ToD) factors (based initially on the mobile network data and NTS data) arranged into large sectors which represent internal, internal-to-external, and entirely external trips. These initial factors were subject to some adjustments as part of the calibration of the assignment models (described in the Colchester Transport Model Development and Validation Report). These factors are applied only to the demand matrices of personal travel by car, rail and bus, developed in the 24-hour PA format and used in the variable demand model in this format. Formulations are detailed below.

For home-based purposes:

$$ {}^{\text{peak}}_{\text{purpose}}\mathbf{D} = {}^{24\text{hr}}_{\text{purpose}}\mathbf{D} * {}^{24\text{hr to peak}}_{\text{purpose}}\mathbf{Outbound\ Factor} + \left[{}^{24\text{hr}}_{\text{purpose}}\mathbf{D} * {}^{24\text{hr to peak}}_{\text{purpose}}\mathbf{Return\ Factor} \right]^{T} $$

And for non-home-based purposes:

$${}^{\text{peak}}_{\text{purpose}}\mathbf{D} = {}^{\text{24hr}}_{\text{purpose}}\mathbf{D} * {}^{\text{24hr to peak}}_{\text{purpose}}\mathbf{Factor}$$

Next, vehicle occupancy factors (derived from TAG) are applied to the car matrices to convert them from person trips to vehicle trips for assignment. Finally, a step is required to convert the highway matrices into peak hour matrices. The peak hour factors (derived from count data collected for South Essex Transport Model development) shown in Table 2 7 are applied to the peak period matrices.

Table 9-6 – Peak Hour Factors used in Highway Matrices

Purpose	Peak Hour Factor
AM	2.662
IP	6.000
PM	2.680

For public transport, the peak period matrices are converted to average hour matrices by dividing by 3 (AM Peak), 6 (inter-peak), and 3 (PM peak).

9.7 Conversion of Peak Hour Generalised Costs to 24-Hour

The variable demand model is also required to undertake conversions from individual peak hour generalised costs to average daily 24-hour costs. This conversion is based on the same factors discussed in Section 9.7 explaining conversions of demand from PA 24-hour to peak hour origin and destination.

For each home-based purpose, the weighted average cost represents a total of the peak hour costs multiplied by the corresponding weights of outbound movements in each time-period and the transposed peak hour costs multiplied by the corresponding weights of return movements:

$${}^{\text{24hr}}_{\text{purpose}}\mathbf{GC} = \frac{1}{2} * \sum_{AM,IP,PM,OP(=IP)} {}^{\text{peak}}_{\text{purpose}}\mathbf{GC} * {}^{\text{24hr to peak}}_{\text{purpose}}\mathbf{Outbound\ Factor} + \left[{}^{\text{peak}}_{\text{purpose}}\boldsymbol{GC} * {}^{\text{24hr to peak}}_{\text{purpose}}\mathbf{Return\ Factor}\right]^{T}$$

For each non-home-based purpose, the peak hour generalised costs need to be multiplied by the corresponding factors representing a proportion of travel in each time period:

$${}^{\text{24hr}}_{\text{purpose}}\mathbf{GC} = \sum_{AM,IP,PM,OP(=IP)} {}^{\text{peak}}_{\text{purpose}}\mathbf{GC} * {}^{\text{24hr to peak}}_{\text{purpose}}\mathbf{Factor}$$

9.8 Nested Demand Model Functions

The South Essex Transport Model is a nested logit model that includes mode choice between Car and PT (least sensitive), destination choice (most sensitive for Car), and sub-mode choice between Rail and Bus Only (most sensitive for PT), as shown in Figure 9-2. Utilities are calculated and carried up the hierarchy starting from the bottom level to the top level. As the model uses an incremental pivot point approach, the revised mode probabilities are applied to the base (Pivot) demand (starting from the top of the hierarchy) for singly constrained journey purposes. For the choice at the bottom level of the hierarchy the change in utility is given by:

$$\Delta U_p = -\lambda\left(C_p - C_{pi}^0\right)$$

where:

C_p^0 is the reference generalised cost.

C_p is the forecast generalised cost, skimmed from the latest assignment.

λ is the sensitivity parameter.

For choices above the bottom level of the hierarchy the change in utility is the composite change over the alternatives in the level below:

$$\Delta U^* = \ln \sum_p p_p^0 \exp\left(\Delta U_p\right)$$

where:

p_p is the forecast probability of choosing alternative p.

p_p^0 is the reference case probability of choosing alternative p (calculated from the input reference demand).

Mode Choice probabilities are determined using the following formulation:

$$p_{m|ipc} = \frac{p_{m|ipc}^0 \exp\left(\theta^{mode} \Delta U_{impc}^*\right)}{\sum_k p_{k|ipc}^0 \exp\left(\theta^{mode} \Delta U_{ikpc}^*\right)}$$

where:

θ	is the Mode Choice scaling parameter.
i	is each zone.
p	is journey purpose.
m	mode (Car or PT).
c	Car Available person type.
k	is the index over all alternatives of a choice (Car and PT).

Destination Choice probabilities are determined using the following formulation:

$$p_{j|impc} = \frac{p_{ijmpc}^0 \exp\left(\theta \; \Delta U_{ijmpc}\right)}{\sum_k p_{ikmpc}^0 \exp\left(\theta \; \Delta U_{ikmpc}\right)}$$

where:

θ	is the Destination Choice scaling parameter.
j	is each Attraction zone.

m mode (Car or PT).

c Car Available person type.

k is the index over all alternatives of a choice (all zones).

Sub-Mode Choice probabilities are determined using the following formulation:

$$p_{s|ijmpc} = \frac{p^0_{sijmpc} \exp(\Delta U_{sijmpc})}{\sum_k p^0_{kijmpc} \exp(\Delta U_{kijmpc})}$$

where:

s sub-mode (Rail or Bus Only).

c Car Available person type.

k is the index over all alternatives of a choice (Rail or Bus Only).

The application of the conditional probabilities gives an updated trip matrix:

$$T_{sijmpc} = T^0_{ipc} p_{m|ipc} p_{j|impc} p_{s|ijmpc}$$

For the doubly constrained journey purpose (home-based commute), the calculation includes an iterative approach with loops between the bottom level and the top level of the hierarchy. Balancing factors are applied to the bottom level utilities which are updated to minimise the differences between the target attraction values and the number of predicted terminating commuting trips for each destination zones. After each loop, the %GAP criterion is checked and if convergence has not been achieved, and the maximum number of loops has not been reached, the balancing factors are updated.

9.9 Demand Model Parameters

The demand model parameters control the sensitivity of the model's mode, destination and sub-mode choice responses. These parameters are sensitivity parameters (λ) and the scaling parameters (θ). Scaling factors represent the ratio of sensitivity parameters from successive levels of the demand model choice structure (e.g. the sensitivity of main mode choice relative to that of destination choice).

The strength of the sensitivity parameters should be in line with the model hierarchy, i.e. these need to be stronger at lower levels of the model hierarchy than at the higher level. To be consistent with TAG recommended hierarchy of destination choice following main mode choice, the main mode choice scaling parameters should be less than or equal to one. TAG Unit M2 Section 5.6 provides a number of illustrative parameter values (minimum, median, and maximum) defined individually by mode and by purpose.

For the sensitivity parameters, the TAG median values by trip purpose and mode were adopted as a starting point for the calibration of the VDM. This is the standard approach recommended for those cases where no locally calibrated data is available. The initial sensitivity parameters of the VDM model are shown in Table 9-7.

These sensitivity parameter values have then been subject to realism testing and refinement as defined by TAG Unit M2. This process is detailed in Chapter 11.

Table 9-7 – Initial Sensitivity Parameters (Before Realism Testing)

Purpose	Bottom Level Sensitivity Parameters λ			Destination Choice Scaling Parameters θ	Mode Choice Scaling Parameters θ
	Highway	Bus	Rail		
Home-Based Work	0.065	0.033	0.033	1	0.68
Home-Based Employers' Business	0.067	0.036	0.036	1	0.45
Home-Based Other	0.090	0.036	0.036	1	0.53
Home-Based Shop	0.090	0.036	0.036	1	0.53
Home-Based Education	0.090	0.036	0.036	1	0.53
Non-Home-Based Employers' Business	0.081	0.042	0.042	1	0.73
Non-Home-Based Other	0.077	0.033	0.033	1	0.81

9.10 Cost Damping

There is strong empirical evidence that the sensitivity of demand responses to changes in generalised cost reduces with increasing trip length. In order to ensure that a model meets the requirements of the realism tests specified in Chapter 11, it may be necessary to include this variation. The mechanisms by which this may be achieved are generally referred to as 'cost damping'. TAG prescribes the application of cost damping in those instances where a model fails to yield elasticities within TAG specified ranges.

TAG states that if cost damping is employed, it should apply to all person demand responses. The same cost damping function should be applied to both car and public transport costs. While the starting position should be that the same cost damping parameter values are used for both modes, it may be necessary to vary the cost damping parameters between the modes in order to achieve satisfactory realism test results. It may also be necessary to vary cost damping parameters by trip purpose. However, these variations by mode and purpose should be avoided unless it is essential to achieve acceptable model performance.

In view of early analyses of the outturn elasticities from the model set up with TAG median parameter values, a decision was taken to employ generalised cost damping as a function of distance, achieved using the following formulation:

$$G' = \left(\frac{d}{k}\right)^{-\alpha} * \left(t + \frac{c}{VoT}\right)$$

where:

G' is the damped generalised cost.

t and c are the trip time and monetary cost respectively.

VoT is the value of time.

$\left(t + \frac{c}{VoT}\right)$ is the generalised cost.

d is the trip length.

α and k are parameters that need to be calibrated.

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. k must also be positive and in the same units as d. The ways in which its value may be determined include:

- Set to the mean trip length for the modelled area.
- Set to the national mean trip length.
- Experiment to find an appropriate distance such that the results of the realism tests and any necessary model adjustments accord with the advice in TAG.

With this form of cost damping it is also necessary to apply a minimum distance cut-off, below which the cost damping does not apply. The purpose of such a cut-off is to prevent short-distance trips, particularly intra-zonal trips, becoming unduly sensitive to cost changes. When a cut-off is used, it is necessary to specify the distance below which generalised costs would not be reduced, that is the distance, d', up to which $\left(t + \frac{c}{VoT}\right)$ would apply. When a cut-off d' is applied, k effectively needs to be set equal to d' so that G' is a continuous function of d at the cut-off.

TAG Unit M2 Paragraph 3.3.10 suggests commonly used parameter values as follows:

- α = 0.5
- k = 30 km
- d' = 30 km.

Following this advice, initial cost damping values of α = 0.5 and k = 30 km were employed during realism testing and then subject to further refinement if required.

9.11 Demand / Supply Convergence

It is of crucial importance to demonstrate that the whole model system converges to a satisfactory degree, in order to have confidence that the model results are as free from ‘noise’ as possible. TAG Unit M2 Paragraph 6.3.4 recommends convergence within the VDM to be measured through the relative demand/supply %GAP as defined by:

$$\frac{\sum_a C({X_a}^n)|D(C({X_a}^n)) - {X_a}^n|}{\sum_a C\,({X_a}^n){X_a}^n} * 100$$

where:

${X_a}^n$ is cell *a* in the previous assignment matrix for iteration *n*.

$C({X_a}^n)$is cell *a* in the generalised costs resulting from assigning that matrix.

$D(C({X_a}^n))$ is cell *a* in the matrix output by the model based on costs $C({X_a}^n)$.

a represents every combination of origin, destination, demand segment/user class, time period, and mode.

The %GAP is a measure of how far the current flow is from the equilibrium point and would therefore be 0 in a perfectly converged model. TAG Unit M2 Paragraph 6.3.8 states that final %GAP should be below 0.2%. It is also beneficial to monitor and report the %GAP for not only the last iteration of demand and supply, but for several iterations in order to understand the stability of the model. Following investigation and refinements to model setup, the South Essex Model runs until an overall demand-supply convergence %GAP of 0.15% is achieved, to ensure all modes are sufficiently converged. It also records the %GAP reached at each iteration of the model run by mode and purpose for reporting and model troubleshooting purposes.

9.12 24hour Matrix Adjustments

The South Essex Model VDM predicts 24hr person-trips in Production-Attraction (P/A) format. To convert from 24hr P/A demand to Origin-Destination (O/D) format, factors are applied to determine the proportion of from-home and return-home trips in each time period. A final step converts the highway car demand to peak hour vehicle demand for assignment on to the highway network, by the application of peak hour and vehicle occupancy factors.

Following the completion of the 2019 South Essex Highway Assignment Model (HAM) validation, it was agreed that a 24 P/A approach to VDM should be implemented in line with best practice and TAG advice. The highway model validation focused on making improvements to the O/D assignment matrices (prior matrices), without reconciliation with the source 24 P/A demand matrices as at that time only HAM was in scope of the project. Therefore, to feedback the changes made to the demand during the highway model calibration back to the 24hr P/A demand the conversions set out in this section were employed. This was done to improve the consistency of travel patterns between the 24hr P/A demand, which is used as the pivot point in VDM, and the final calibrated O/D time period matrices and to minimise deltas (differences between the 24hr derived and validated O/D matrices) that would be applied during the assignment.

9.12.1 Highway Matrix Adjustment Methodology

The 2019 South Essex HAM matrices were originally derived from the Essex Countywide model 24hr P/A matrices, which were converted to O/D peak period matrices using the following factors, also taken from the Essex Countywide model:

- Home-based outbound trips split into peak periods (AM, IP, PM & OP).
- Non-home-based trips split into peak periods (AM, IP, PM & OP).
- Home-based return trips split into peak periods (AM, IP, PM & OP)
- Peak period to peak hour factors derived from local area count data.
- Vehicle occupancy factors by journey purpose.

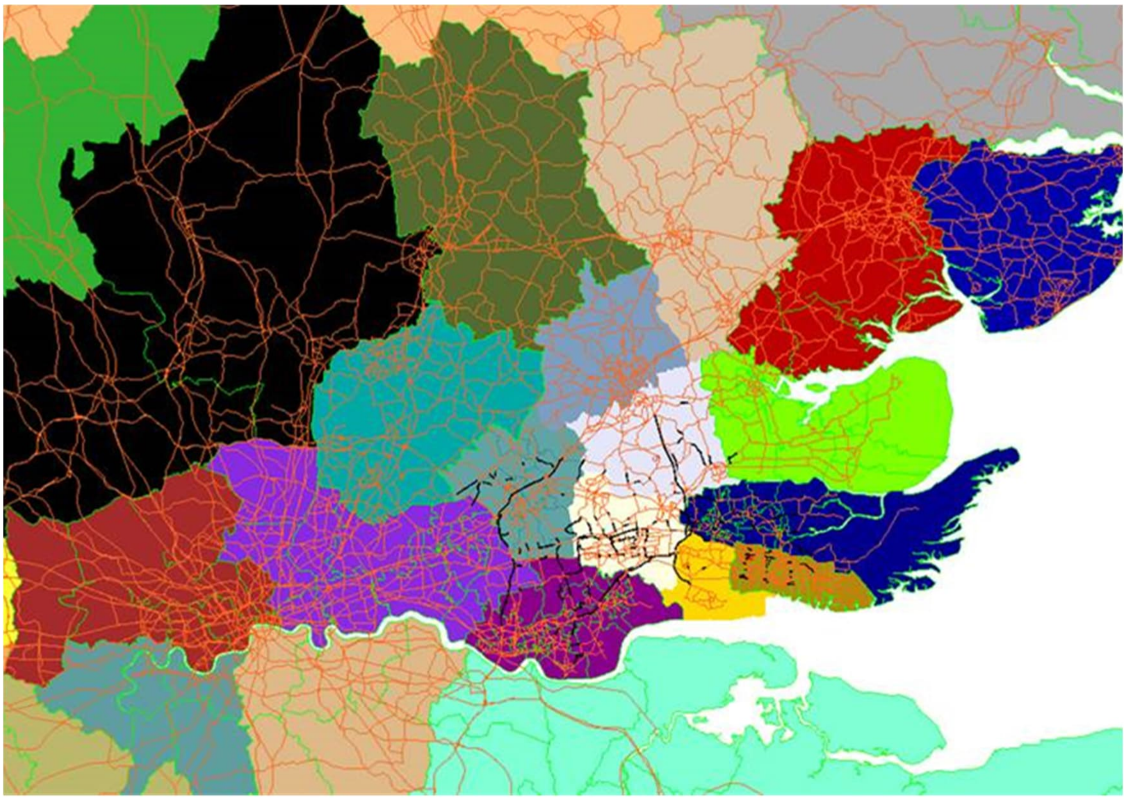
The resultant O/D vehicle peak hour matrices for each time period (AM, IP, PM) and journey purpose (commute, business, other) were used as a basis for the highway model calibration and validation, as described in the South Essex Highway Validation report.

The changes made to the O/D vehicle peak hour matrices in the highway model calibration were fed back into the 24hr P/A matrices using the methodology shown in Figure 9-5. The key feature of this methodology is that makes adjustments to the 24hr P/A matrices that reflect insights from counts obtained from model calibration (which would have been normally taken into account if matrix and VDM development was taking place at the same time as HAM calibration), whilst preserving the integrity and structure of the data used to develop the prior matrices. This is achieved by limiting the scope of adjustments to high-level corrections by sector as well as some revisions to time period allocation.

The first step to reconcile the P/A matrices with the changes made in the HAM calibration was to apply the same growth factors as applied to the O/D matrices in HAM to convert from 2016 to 2019 base year. The uplifted P/A matrices were then converted to O/D matrices using the original time of day, peak hour and vehicle occupancy factors.

The resultant O/D vehicle matrices were compared with the validated O/D vehicle matrices at the sector level (using the sector system in Figure 9-4 below) and the %age difference between the resultant and validated matrices for each time period were calculated.

Figure 9-4 – Matrix Adjustment Sector System



In Step 2 the remaining differences (OD factors (1)) were applied to the peak period person matrices. As the OD matrices did not distinguish between outbound, return and non-home-based trips, the same adjustments were applied to these components of the peak period matrices (as derived from the 24hr matrices). The matrices from each time period were combined to create adjusted 24 P/A outbound, return & non-home-based matrices. After applying the appropriate transposition to the return matrices, the adjusted outbound and return matrices were compared. Where the combined adjustment from each time period in the outbound and return matrices was different an average value was calculated.

In Step 3 the proportion of outbound, return & non-home-based trips in each time period (AM, IP, PM and unadjusted OP) was then recalculated at the sector level. Where the proportion of trips in each time period was more than 10% different than the original factors, the number of trips was constrained so that the revised proportions were within 10% of the original proportion. Following this adjustment, where the revised sum of proportions (AM + IP + PM + OP) did not add up to 100% the OP proportion was adjusted by a maximum of +/-10% so that the sum of the proportions in each time period was 100%. A final adjustment was made to normalise all the proportions if they still did not add up to 100%.

Figure 9-5 – Matrix Adjustment methodology

Step 1

Initial OD peak hour assignment amtrices are calculated sugun ToD, peak hour and vehicle occupamcy factors

Step 2

Adjusted 24hr PA matrices are obtained by applying factors to the peak period matrices. Resultant 24hr Outbound and Return matrices are averaged.

Step 3

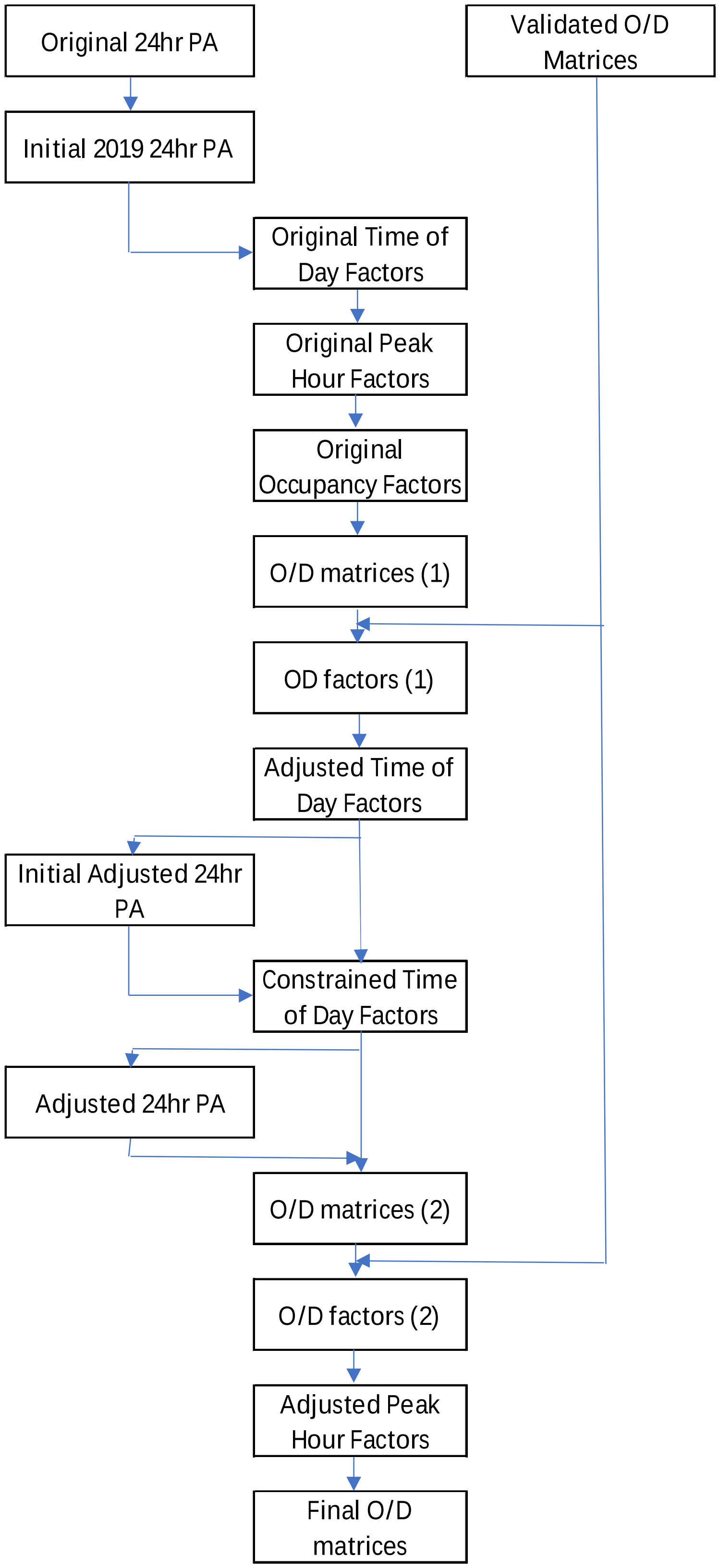
Maximum change in ToD factors are constrained to +/-10%

Step 4

OD assignment matrices are recalaulated

Step 5

Peak hour factors are adjusted by +/- by remaining difference in the O/D matrices from the validated matrices



Following application of the revised time of day factors, where differences remained from the validated OD matrices (calculated in Step 4), additional adjustments were made to the peak period to peak hour factors, in Step 5. Again, adjustments were made at the sector level and limited to a maximum of +/-10%.

9.12.2 24hr Matrix Validation

This section presents a comparison of the originally derived 24hr P/A matrices, and the final adjusted 24 P/A matrices. The following figures present the trip length distribution for the original and adjusted P/A matrices for each journey purpose.

It can be seen generally the adjusted matrices have only small variations in the trip length distribution of the original 24hr matrices for each journey purpose. The biggest variations are small increases in the region 1% to 2% in 2km to 4km and 4km to 6km distance bands, indicating the adjustment made to the matrices have not caused large distortions in the trip pattern in the matrices.

Figure 9-6 – HBEB Trip Length Distribution Comparison

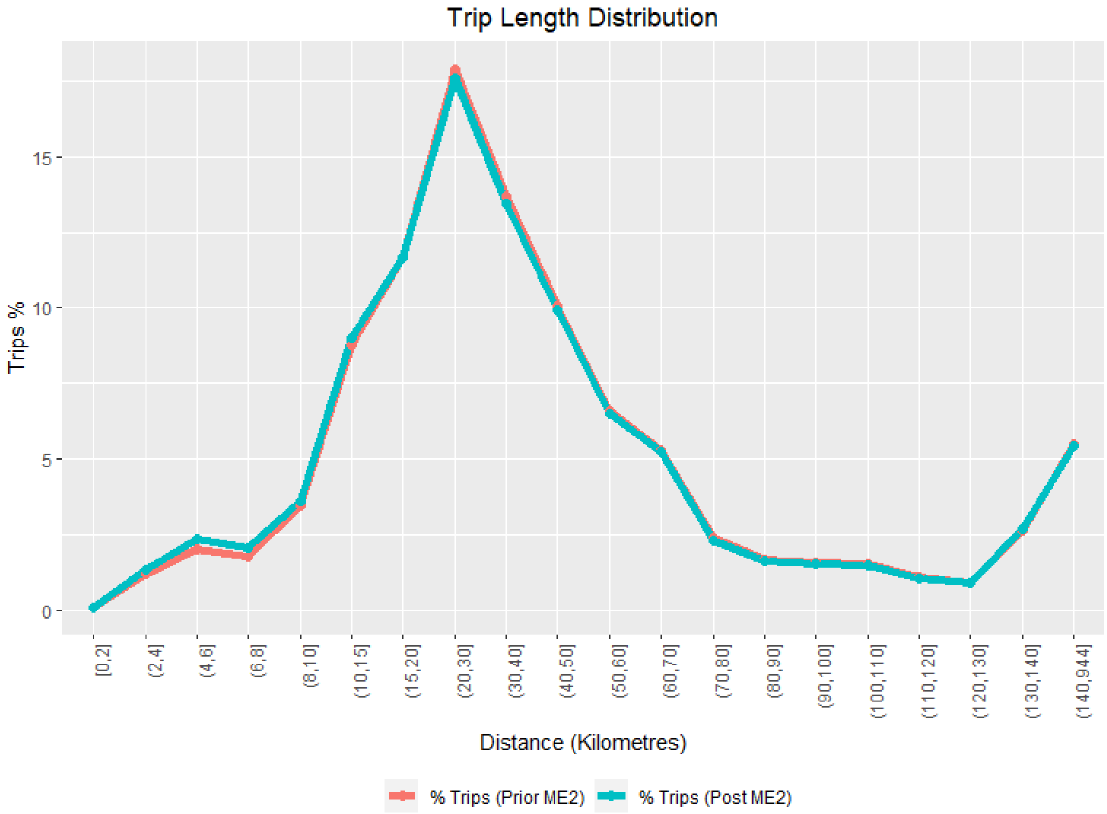


Figure 9-7 – NHBEB Trip Length Distribution Comparison

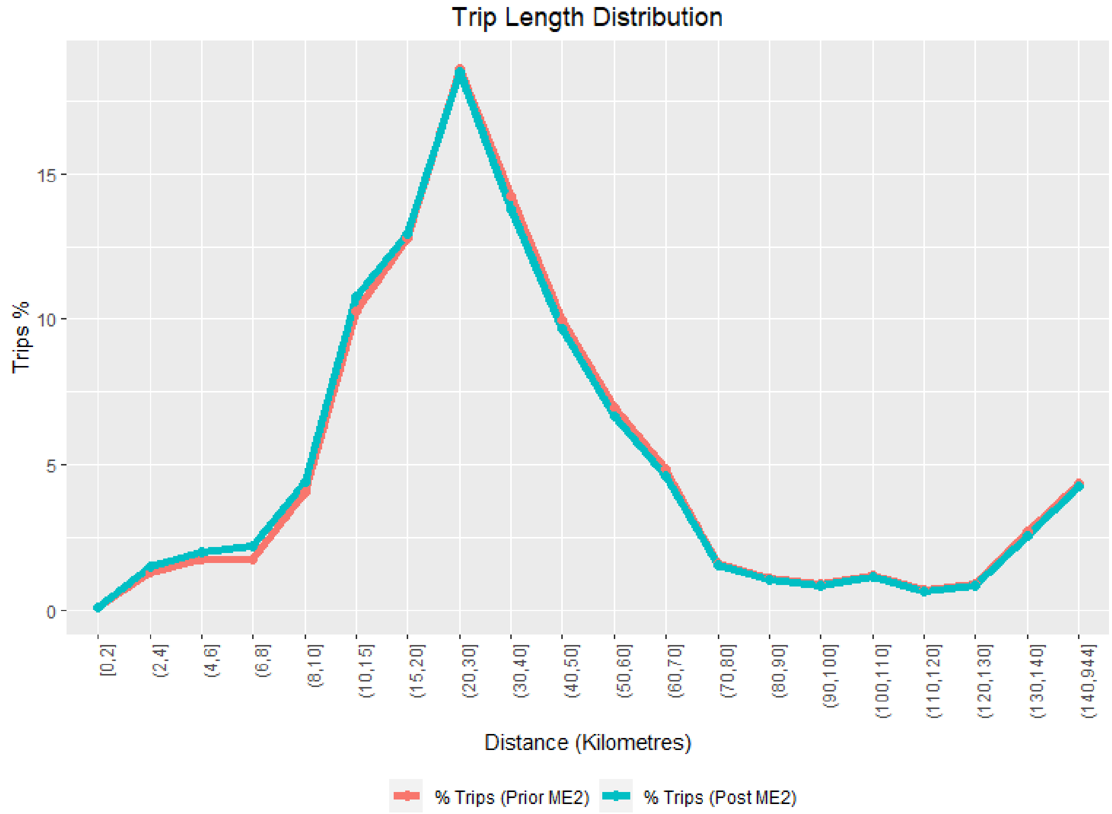


Figure 9-8 – HBW Trip Length Distribution Comparison

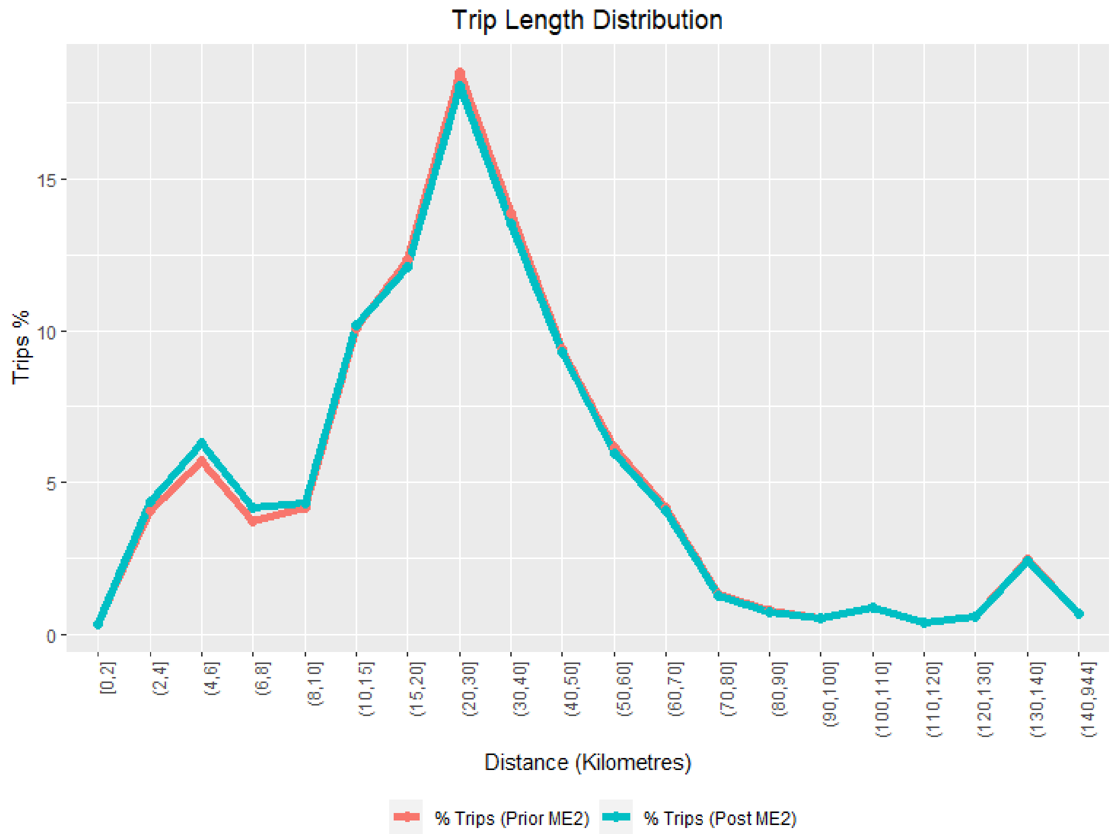


Figure 9-9 – HBO Trip Length Distribution Comparison

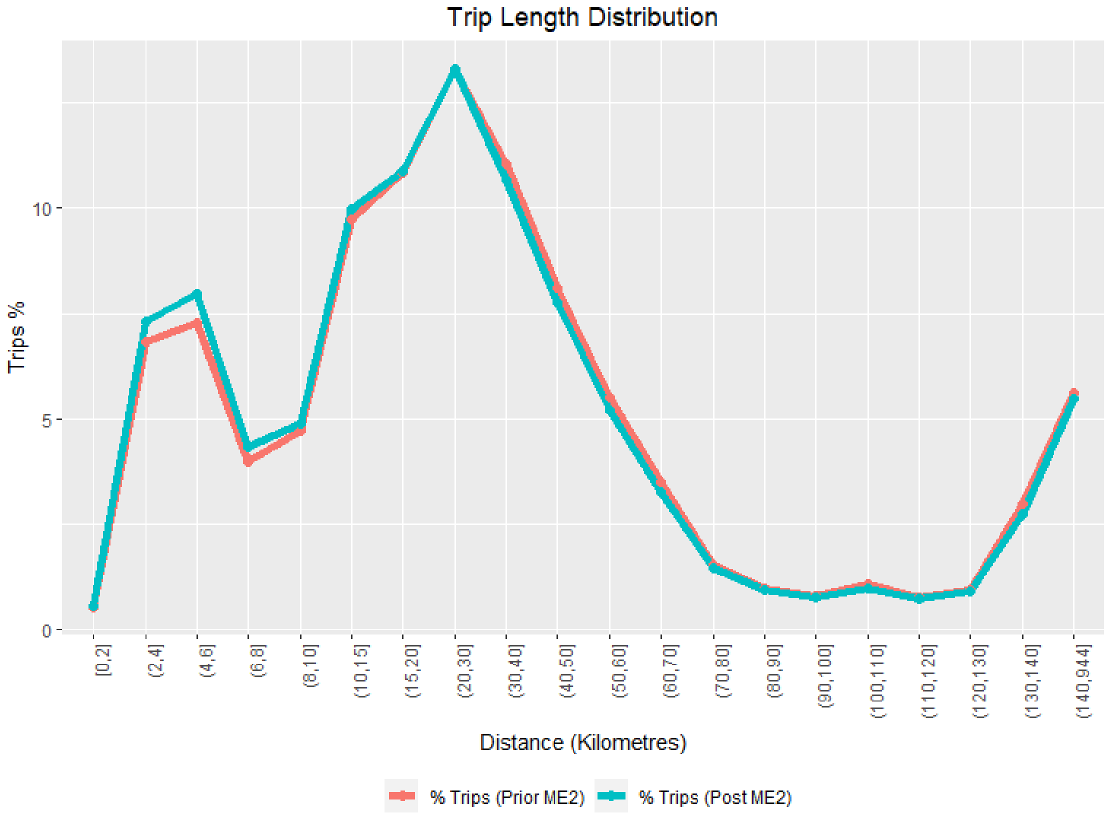


Figure 9-10 – HBShop Trip Length Distribution Comparison

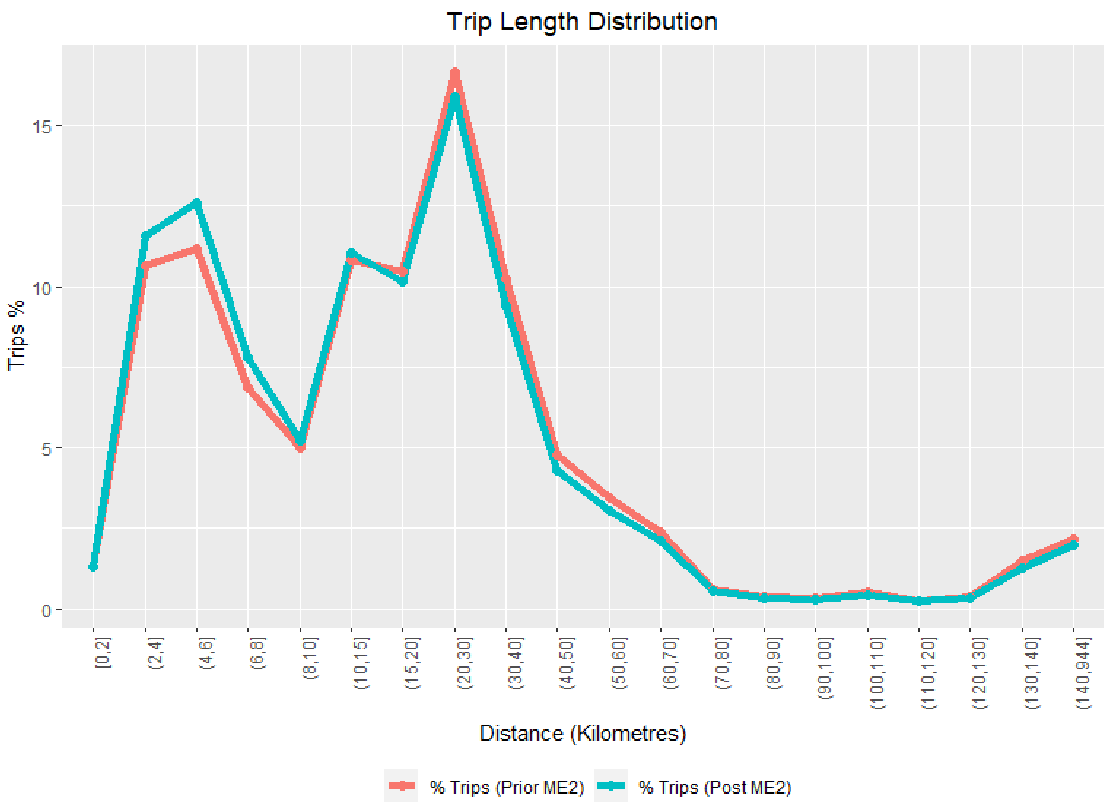


Figure 9-11 – HBEdu Trip Length Distribution Comparison

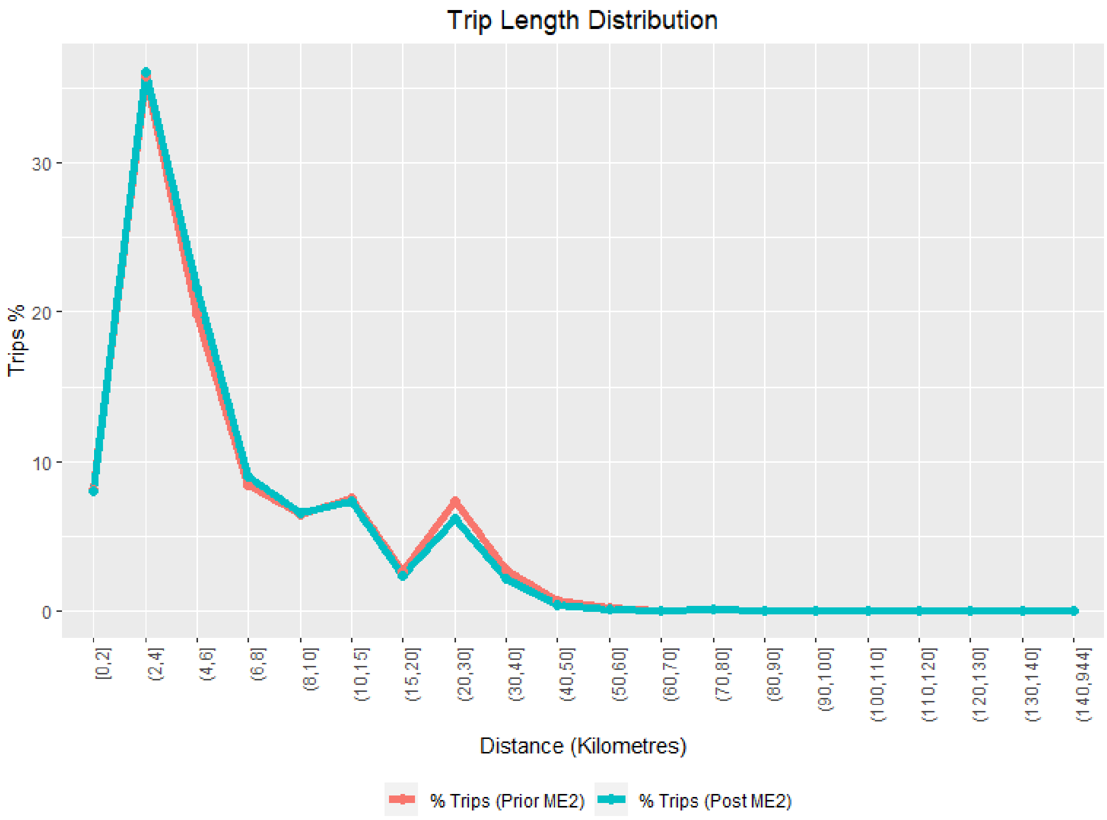
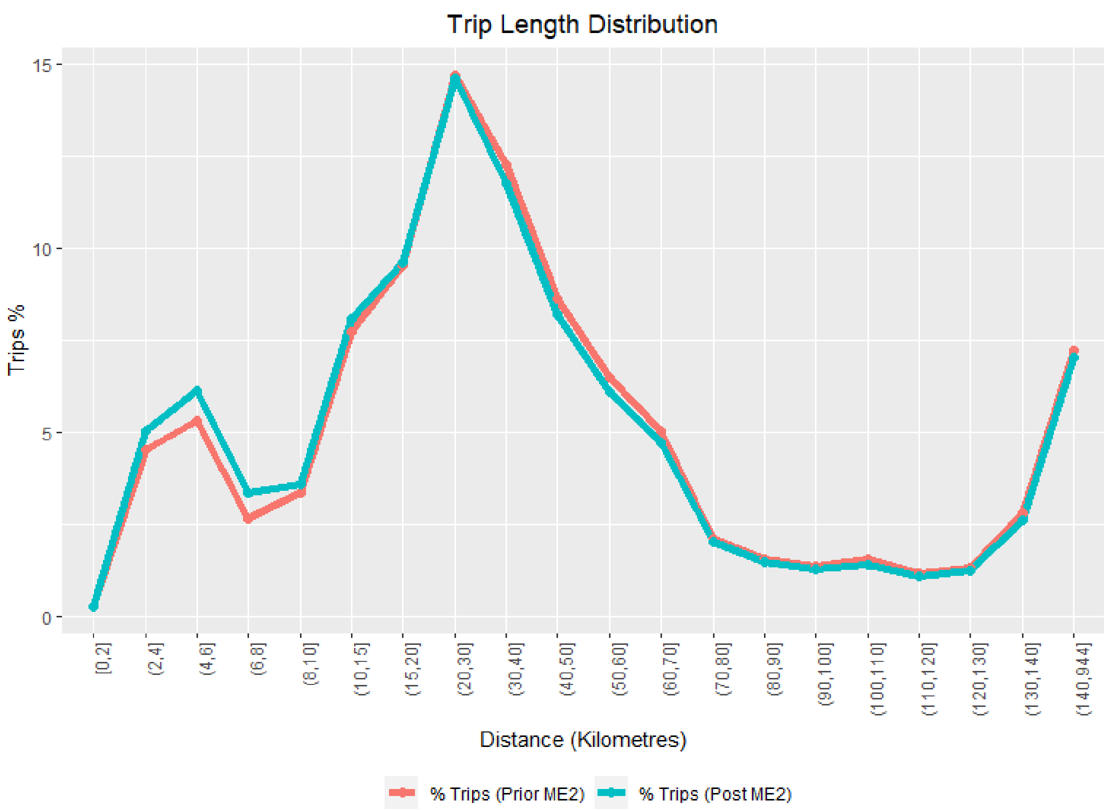


Figure 9-12 – NHBO Trip Length Distribution Comparison



Regression analysis was carried out on the origin and destination trip ends of the 24hr matrices for each journey purpose between the initial and final matrices. This is presented in Table 9-8 below and shows all values are close to 1 showing that there is not significant change in the trip ends.

Table 9-8 – Adjusted 24hr Trip End Regression Analysis

Purpose	Origin Tripends	Destination Tripends
Home-Based Work	1.000	0.999
Home-Based Employers' Business	0.999	0.999
Home-Based Other	0.998	0.998
Home-Based Shop	0.989	0.981
Home-Based Education	0.939	0.951
Non-Home-Based Employers' Business	0.999	0.998
Non-Home-Based Other	0.997	0.997

9.12.3 O/D Matrix Checks

A regression analysis of the unadjusted O/D matrices versus the validation O/D matrices and also regression analysis following the update to the matrices after the adjustment to the 24 P/A matrices. The regression was carried out at the sector-to-sector level (the level that adjustments were made to the 24hr matrices and factors) and is presented for each time period and assignment user class.

Table 9-9 below summarises the R squared values from the regression analysis for the initial matrices and the final adjusted matrices. The table shows that adjusted matrices have a close fit to the validated matrices at the sector level for all time period and purposes.

Table 9-9 Adjusted O/D matrix Regression Analysis

Purpose	AM		IP		PM	
	Initial	Final	Initial	Final	Initial	Final
Commute	0.997	1.000	0.997	1.000	0.998	1.000
Business	0.990	1.000	0.976	1.000	0.996	1.000
Other	0.998	1.000	0.987	1.000	0.997	1.000

Graphs comparing the O/D matrix cell values before and after the matrix adjustments are provided in Appendix E. While small differences remain at zonal due to the detailed adjustments made by matrix estimation it is clear that when the adjusted time of day, peak hour and vehicle occupancy factors are applied to the adjusted 24hr matrices they produce assignment O/D matrices that are a much closer fit the validated O/D assignment matrix. Therefore, improving their suitability for use in variable demand modelling.

10 Variable Demand Model Calibration & Realism Testing

10.1 Definition of Tests

It is necessary to ensure that the variable demand model behaves ‘realistically’. This is done by changing the various components of travel costs and times and checking the overall demand response. The acceptability of the model’s responses is determined by its demand elasticities. These demand elasticities are calculated by changing a cost or time component by a small global proportionate amount and calculating the proportionate change in travel made. These changes may be implemented on either a link basis and skimmed to yield the interzonal changes or directly at the matrix cell level. The elasticity recommended is:

$$e = (\log(T^1) - \log(T^0)) / (\log(C^1) - \log(C^0))$$

where the superscripts 0 and 1 indicate values of demand, T, and cost, C, before and after the change in cost, respectively. For example, if car fuel costs increase by 10% and trips by car fall by 2%, then the elasticity of car trips with respect to fuel cost would be log (0.98) / log (1.10) = -0.212. The demand is expressed in terms of vehicle kilometres (for cars) or person trips (for public transport). The model tests have been applied to the base model to demonstrate appropriate responsiveness to changes in highway fuel cost, highway journey times, public transport fares (rail and bus), and bus fares isolation.

10.2 Car Fuel Elasticity

The car fuel cost elasticity measures the percentage change in car vehicle kilometres with respect to the percentage change in fuel cost. TAG states that the calculations should be carried out for a 10% or a 20% fuel cost increase. 20% increase was used in this study.

The matrix-based approach compares the change in car vehicle kilometres using the car trip matrices and skimmed distance matrices relating to the before and after fuel cost change model runs. The movements included in this calculation relate only to the movements to which the full range of demand responses apply (internal productions) in the demand model (as detailed in Section 9.4). The calculations have been carried out on both time period and 24-hour production-attraction basis.

The network-based approach measures changes in car vehicle kilometres accumulated over the model network (links) from the before and after fuel cost change model runs. The network used for this calculation extends to cover the area over which the highway assignment model has been validated but excludes external areas where the model is more approximate. It therefore corresponds to the assignment model simulation network.

10.3 Car Journey Time Elasticity

The car journey time elasticity measures the change in car trips with respect to a change in journey time. Consistently with TAG guidance, the journey time elasticities have been calculated using a single (un-converged) run of the demand model (because the TAG target elasticities were derived from stated preference data, where the costs of each option and attribute were exogenous). For the purposes of the Colchester Transport Model, these tests have been implemented using a journey time increase of 20% and the elasticities have been calculated for the total change in car trips within the demand matrices, using a single run of the demand model.

10.4 Public Transport Fares Elasticity

The public transport fare elasticity measures the percentage change in public transport trips by all public transport modes with respect to the percentage change in public transport fares. For the purposes of the Colchester Transport Model, these tests have been implemented using a fare increase of 20%, applied to all public transport modes equally. Public transport fare elasticities are calculated on a matrix basis, by time period and trip purpose. The movements included in this calculation relate only to the movements to which the full range of demand responses apply in the demand model (internal productions). For the bus fares test the same process is applied except that only bus fares are increased by 20%.

10.5 Target Elastcities

Table 10-1 summarises the recommended elasticity ranges that should be achieved by the realism tests that have been carried out for the Colchester Countywide Model.

Table 10-1 – Summary of Recommended Elasticity Ranges

Test	High	Low
Average fuel cost (kms)	-0.35	-0.25
Car journey time (trips)	No stronger than -2.0	
PT main mode fare (trips)	-0.9	-0.2
Bus fare (trips)	-0.9	-0.7

10.5.1 Car Fuel Test Elasticity

The sensitivity (or demand elasticity) exhibited by the model should fall within a range of expected values. TAG M2 Paragraph 6.4.14 suggests that:

- The annual average fuel cost elasticity should lie within the range -0.25 to -0.35 (overall, across all purposes).

In addition, TAG M2 Paragraph 6.4.17 suggests that:

- The pattern of annual average elasticities shows values for employers' business trips near to -0.1, for discretionary trips near to -0.4, and for commuting somewhere near the average.
- The pattern of all-purpose elasticities shows peak period elasticities which are weaker than inter-peak elasticities.

However, these TAG recommended values by individual purpose were relevant to older Values of Time (VoT) from previous versions of the TAG Databook and TAG M2.1 Paragraph 6.4.18 goes on to state that "*while there is little or no empirical evidence to support the variation in elasticities by purpose and time period, most models show the pattern suggested above*". The suggested elasticities by purpose and time period are therefore used as a guide, and the variation in elasticities by purpose and time period will be explained.

10.5.2 Car Journey Time Test Elasticity

TAG M2 Paragraph 6.4.28 simply states that output elasticities of the car journey times test should be checked to ensure that the model does not produce overly strong output elasticities (not stronger than -2.0).

10.5.3 Public Transport Fares Elasticity

TAG M2 Paragraph 6.4.21 states that elasticities of public transport trips with respect to public transport fares have been found to lie typically in the range –0.2 to -0.9.

10.5.4 Bus Fares Elasticity

TAG M2 Paragraph 6.4.21 states that elasticities of bus trips with respect to bus fares have been found to lie typically in the range –0.7 to -0.9.

10.6 Car Fuel Costs Test Results

Realism testing has been undertaken to compare the modelled elasticities with standard published values, and to ensure that the responses are in line with expectations. In cases where they were not, the parameters were modified according to the advice stated in TAG M2 Section 6.5: "*the Department considers that analysts should start with the median lambdas and thetas and adopt a cautious, simple and systematic process for modifying these. In general, care should be taken to avoid overcomplicating the adjustments to the median lambdas and thetas. A record of all the changes made and their results should be kept and made available if requested. The aim should be to reduce the chances of peculiar combinations being selected for no good reason. Consistency in matters like this helps the Department interpret appraisals and check results for plausibility. Typically, revised lambdas and thetas which were within +25% of the median illustrative values would be regarded as acceptable and values outside this range would merit investigation*".

The demand model calibration was undertaken using the median TAG distribution parameter values presented in Table 9-7 above as a starting point. A sequence of model runs have been undertaken to convergence during the calibration. The following section presents the elasticities and the changes from the median parameter values made during the calibration. The car-kilometre elasticities to fuel cost were calculated in accordance with TAG Unit M2, and the elasticities for each run are shown in Table 3 2 below. It shows the elasticity results for the variable demand responsive area (internal productions) for 24-hour PA by journey purpose and for each time period.

10.6.1 Initial Parameter Values

An initial run was undertaken with the median parameter settings as shown in Table 9-7 and no cost-damping. The results show that elasticities for the 'other' purposes were well outside their target values and far too elastic in each time period. This could be seen in particular for long distance trip movements. This also applied to the commute and business purposes for long distance trip movements, although the overall average elasticity was within the DFT TAG criteria.

10.6.2 Final Parameter Values

The following section describes the difference in the parameters from the median values.

Distribution Parameters

Due to the high elasticities for long distance trip movements for all journey purposes cost damping has been applied using the TAG median parameters (as defined in section 9.10). However, other purpose was still too elastic, and commute and business inelastic in relation to their targets. Therefore, highway distribution (bottom level) parameters were reduced by 25% for 'other' purposes to reduce fuel cost elasticity and increased by 25% commute and business purposes to increase fuel cost elasticity.

Cost Damping Parameters

Cost damping was implemented for the following reasons, in line with TAG (as per section 9.10):

- TAG M2.1 3.3.1: "There is strong empirical evidence that the sensitivity of demand responses to changes in generalised cost reduces with increasing trip length (see, for example, Daly (2008, 2010))".
- TAG M2.1 3.3.3: "Cost damping is part of our current best understanding of travel behaviour and would be expected to be incorporated into models."
- The same cost damping parameters were applied to each mode and journey purpose.

10.6.3 Results

Table 10-2 shows the median parameters and final parameter elasticity results which includes changes to the Mode Choice and PT sub-mode choice parameters that were introduced during the Public Transport fare test elasticity calibration runs described in the following sections. The table shows the initial elasticities achieved with the median values. These are the followed by the final, average 24-hour demand elasticity of -0.335 lies within the TAG recommended range of -0.25 to -0.35 and the AM and PM peak period elasticities are weaker than the inter-peak elasticities. Furthermore, the relative pattern of elasticities across different journey purposes is in line with expectations and deemed plausible with discretionary trips (other and shopping purposes) exhibiting the strongest elasticities.

Table 10-2 – Fuel Test Elasticity Results

Time Period	Purpose	Median	Final
AM Peak	Commute	-0.174	-0.201
	Employers' Business	-0.161	-0.148
	Other	-0.769	-0.454
	Average	**-0.354**	**-0.270**
IP	Commute	-0.166	-0.186
	Employers' Business	-0.136	-0.121
	Other	-0.704	-0.428
	Average	**-0.503**	**-0.329**
PM Peak	Commute	-0.188	-0.212
	Employers' Business	-0.129	-0.118
	Other	-0.744	-0.444
	Average	**-0.423**	**-0.300**
24 hour	HBW	-0.183	-0.204
	HBEb	-0.127	-0.117
	HBO	-0.981	-0.547
	HBShop	-0.290	-0.264
	HBEdu	-0.101	-0.108
	NHBEb	-0.152	-0.136
	NHBO	-0.752	-0.422
	All	**-0.509**	**-0.335**

10.7 Car Journey Time Test Results

The car journey time elasticity results are show in Table 10-3.

Table 10-3 – Car Journey Time Elasticity Results

Purpose	AM	IP	PM
Commute	-0.6405	-0.6914	-0.7736
Employers Business	-0.3523	-0.3063	-0.2938
Other	-0.9666	-1.1175	-1.1389

Table 10-3 shows that the car journey time realism test produced elasticity results that align with expectations. The demand elasticities with respect to journey time are not overly strong, and are within -2.0 in each peak period and for each journey purpose.

10.8 Public Transport Fares Test Results

The public transport fares elasticity test increased the fare component of generalised cost by 20%. The model was run to convergence and the results for internal productions are shown in Table 10-4. The first column with results is based on median choice model parameters, followed by the final parameters.

Table 10-4 – Public Transport Fare Test Elasticity Results

Time Period	Purpose	Median	Final
AM Peak	Rail	-0.252	-0.214
	Bus	-0.022	-0.231
	All	**-0.198**	**-0.218**
IP	Rail	-0.751	-0.617
	Bus	0.105	-0.211
	All	**-0.442**	**-0.474**
PM Peak	Rail	-0.323	-0.270
	Bus	0.087	-0.196
	All	**-0.258**	**-0.259**
24 hour All Public Transport	HBW	-0.123	-0.126
	HBEb	-0.134	-0.135
	HBO	-0.831	-0.922
	HBShop	-0.294	-0.398
	HBEdu	-0.264	-0.409
	NHBEb	-0.284	-0.293
	NHBO	-0.410	-0.505
	All	**-0.307**	**-0.347**
24hr Rail	HBW	-0.135	-0.121
	HBEb	-0.138	-0.120
	HBO	-1.605	-1.348
	HBShop	-1.427	-1.045
	HBEdu	-2.108	-1.716
	NHBEb	-0.297	-0.274
	NHBO	-1.583	-1.186
	All	-0.459	-0.389
24hr Bus	HBW	-0.040	-0.164
	HBEb	-0.081	-0.330
	HBO	0.336	-0.229
	HBShop	0.000	-0.221
	HBEdu	-0.264	-0.409
	NHBEb	-0.181	-0.453
	NHBO	0.133	-0.170
	All	0.064	-0.227

Overall, the initial results showed that the average PT elasticities were within the target values (between -0.2 and -0.9). However, other, shopping, education and non-home-based other purposes show elasticities are between -1.4 and -2.1 for rail demand. The second column in Table 10-4 shows the final elasticities. It shows that the elasticities for All PT demand remains within the target range of -0.2 and -0.9 and the very large elasticities for the discretionary purposes decreased. This is primarily as result of the introduction of cost damping, as described in the previous fuel test calibration section. As expected, there is some variation by journey purpose remains, but the elasticity for the most sensitive journey purposes does not exceed -1.5, which is in line with elasticities seen in literature.

10.9 Bus Fares Test Results

The public transport sub-mode (bus) fares elasticity test was calculated by increasing the bus fare matrix inputs by 20%. The model was run iteratively to convergence. The results for internal productions are shown Table 10-5. As in earlier tables, the first column shows results based on the median choice parameters.

Table 10-5 – Bus Fare Test Elasticity Results

Time Period	Purpose	Median	Final
AM Peak	Rail	0.036	0.039
	Bus	**-0.329**	**-0.450**
	All	-0.046	-0.070
IP	Rail	0.129	0.141
	Bus	**-0.457**	**-0.625**
	All	-0.065	-0.110
PM Peak	Rail	0.043	0.046
	Bus	**-0.397**	**-0.538**
	All	-0.022	-0.039
24hr Bus	HBW	-0.212	-0.274
	HBEb	-0.510	-0.636
	HBO	-0.761	-0.991
	HBShop	-0.404	-0.557
	HBEdu	-0.265	-0.411
	NHBEb	-0.526	-0.671
	NHBO	-0.444	-0.606
	All	**-0.439**	**-0.587**

Overall, the bus elasticities per time period and at the 24hr level (-0.44) below the target values (between -0.7 and -0.9). To increase the sensitivity the bottom level sensitivity parameters for bus were increased by 25%. Additionally, the mode choice parameters were increased for all purposes by 25%. This change has a small effect on all modes and slightly benefits the car fuel elasticities.

The final results in Table 10-5 show the elasticities with these changes implemented and as well as the other changes in parameters as described in the previous car fuel tests and PT fare test sections. It shows that the elasticities for bus demand for 24hr PA is -0.587 which is close to but remains outside the target range of -0.7 and -0.9. This was deemed as acceptable due the lack of alternative rail services, particularly for the short distance trips, and those journeys not along the east to west rail corridor.

10.10 Final Sensitivity Parameters

The final sensitivity parameters used in the South Essex Model are summarised in Table 10-6.

Table 10-6 – Final Sensitivity Parameters (Before Realism Testing)

Purpose	Bottom Level Sensitivity Parameters λ			Destination Choice Scaling Parameters θ	Mode Choice Scaling Parameters θ
	Highway	Bus	Rail		
Home-Based Work	0.08125	0.04125	0.033	1	0.85
Home-Based Employers' Business	0.08375	0.045	0.036	1	0.5625
Home-Based Other	0.10125	0.045	0.036	1	0.6625
Home-Based Shop	0.07875	0.045	0.036	1	0.6625
Home-Based Education	0.09	0.045	0.036	1	0.6625
Non-Home-Based Employers'	0.09	0.0525	0.042	1	0.9125
Non-Home-Based Other	0.067375	0.04125	0.033	1	1.00

In line with the guidance, the final revised sensitivity and Mode Choice scaling parameters values lie within +/-25% of the TAG median illustrative values and are therefore regarded as acceptable.

11 Summary of Model

11.1 Summary of Model Development

The PT and VDM components of the South Essex Model have been developed to complement the Highway Assignment Model for South Essex developed earlier. The PT and VDM components have been designed to form a complete multi-modal model that maintaines internal conistency between the components and is consistent with TAG guidance.

The model has been developed on the basis of a single, consistent zone system for all components, has consistent base year (2019) and network structure, which provides the mechanism for reflecting congested highway speeds in the modelled bus speeds in the public transport assignment model. The PT model includes rail and bus modes and differentiaes between these two modes thriugh the use of separate user classes for trips that use rail and for trips than use bus only. This is further facilitated by the use of a bus-rail sub-mode split within the VDM structure. The cost of public ransport journeys (fares) is reflected wihtin VDM.

The structure of VDM follows a structure recommended in TAG: Prodcution-Attraction (PA) incremental pivot-point model. The model has been calibrated to standards expected by TAG. The modelled response include main mode choice (car vs public tranport), trip distribution and the sub-mode chocie (bus vs rail) for public transport.

11.2 Summary of Standards Achieved

The development of the PT and VDM components of the South Essex Model followed the best indutry practices and is consisted with modelling guidance set out in DfT's TAG. It uses the best available data sources representative of 2019 transport situaiton and achieved good calibration and validation standards that provide confidence in the suitablity of the model for application in transport studies.

11.3 Assessment of Fitness for Purpose

The architectre, calibration and validiton of the model is consistent with TAG standards and designed specifically to facilitate:

- The application of the model in forecasting the impacts of housing and employment developments on the transport network.
- Testing the impacts of and forecastign in support of business cases for major local transport schemes in the area of South Essex.
- Testing the impacts of smaller infrastructure interventions that impact in the highway infrastrcuture or demand as well as pubcli transport services and demand.
- Strategic planning of transport infrastructure and deman scenarios in the South Essex areas and support to policy development.

This model is suitable for use for these purposes and is capable of providing robust evidence base for decisions that affect transport network in the area of South Essex. It now forms the most up-to-date tool covering the whole South Essex area in a consistent manner and level of detail suitable for local modelling purposes.

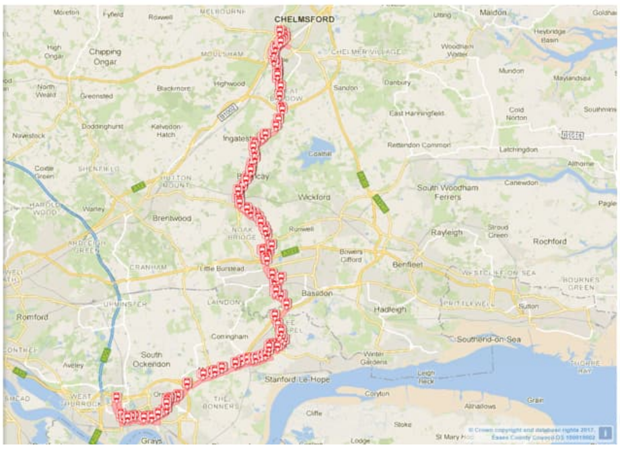
Appendix A - Bus Route Validation

Route Geometry Validation

This appendix summarises the bus routes considered in the South Essex Public Transport model network validation described in the section 8.2.5. The following pages show the result of the validation of bus routes listed in Table 8-3 - Key Bus Routes for routes. Figures on the left present the bus route from Essex bus web site; figures on the right show coding in the south Essex public transport model.

Figure A.1 - Route 100: Chelmsford -Billericay - Basildon

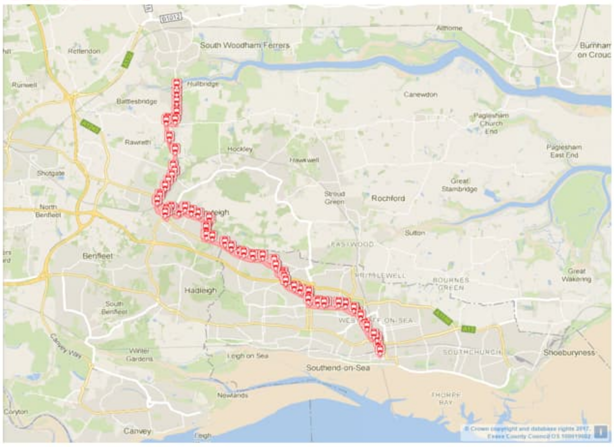
Observed



Modelled

Figure A.2 - Route 20: Hullbridge - Southend

Observed



Modelled

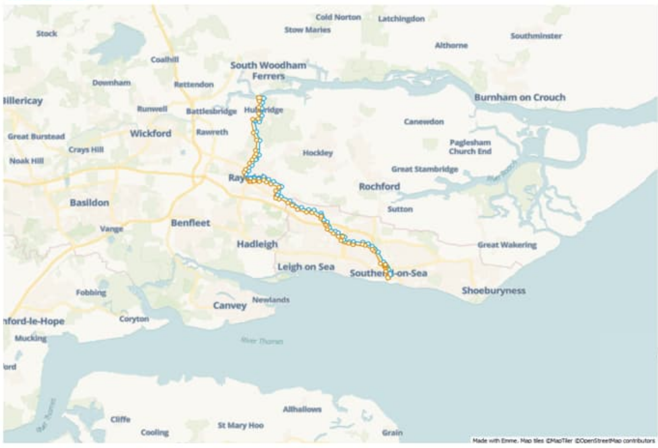


Figure A.3 – Route 27: Canvey - Southend

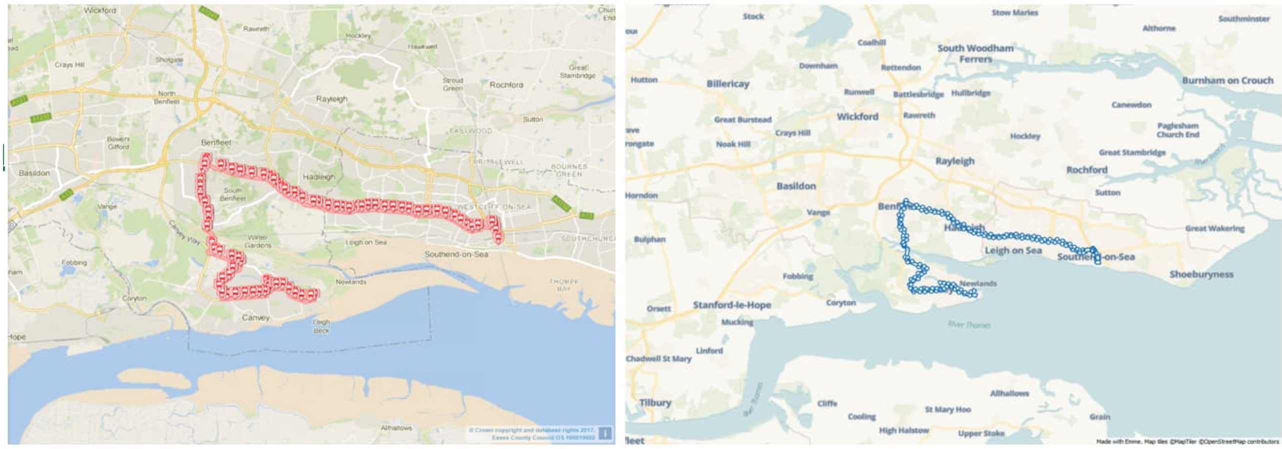


Figure A.4 – Route 9: Shoeburyness - Rayleigh

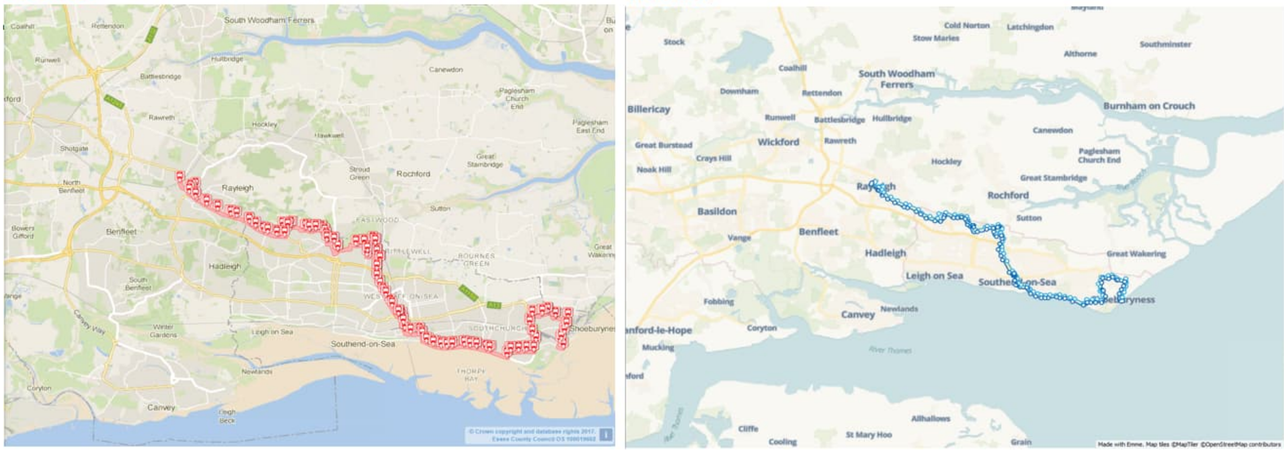


Figure A.5 – Route 22: Basildon - Canvey

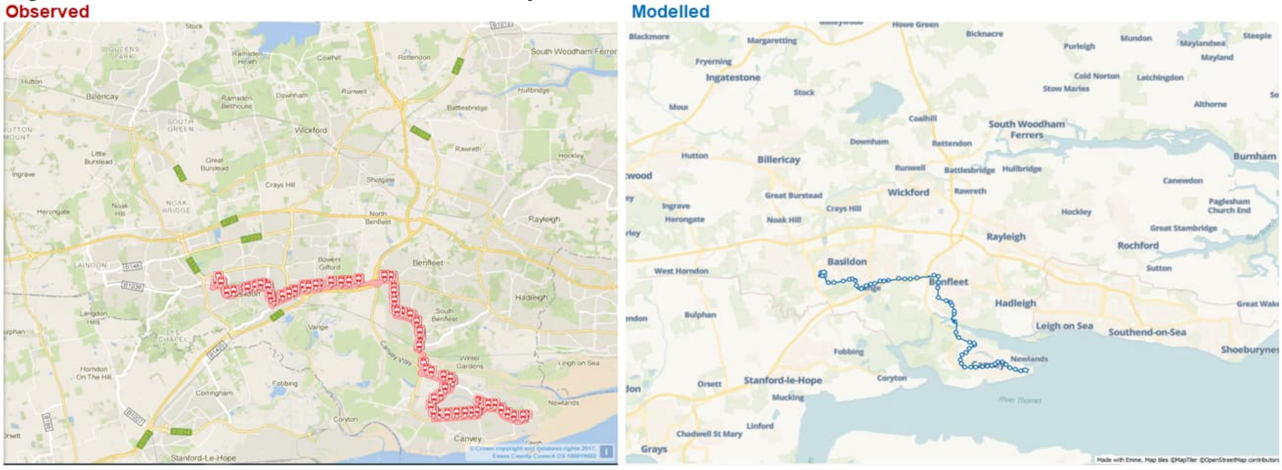
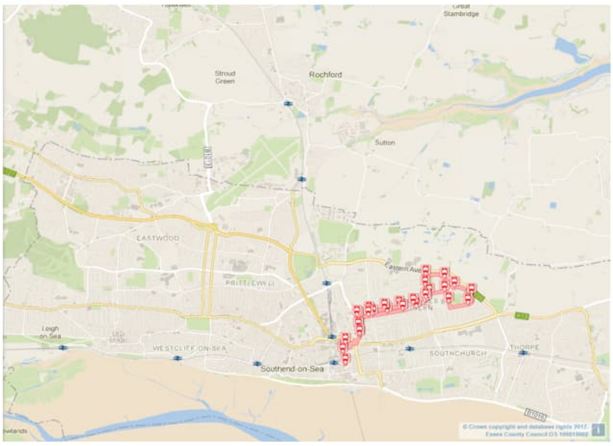


Figure A.6 – Route 24: Southchurch - Southend Travel Centre

Observed



Modelled

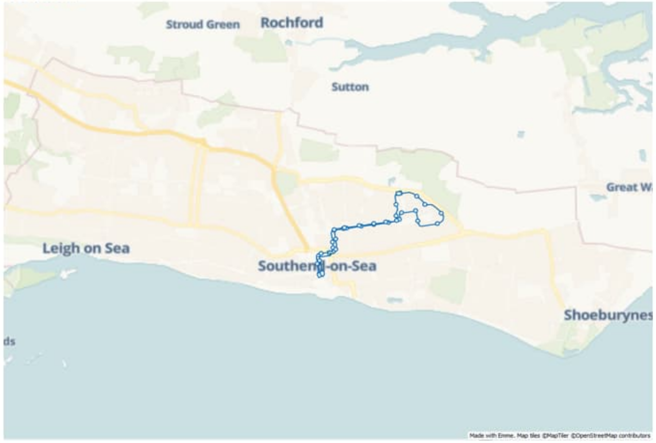
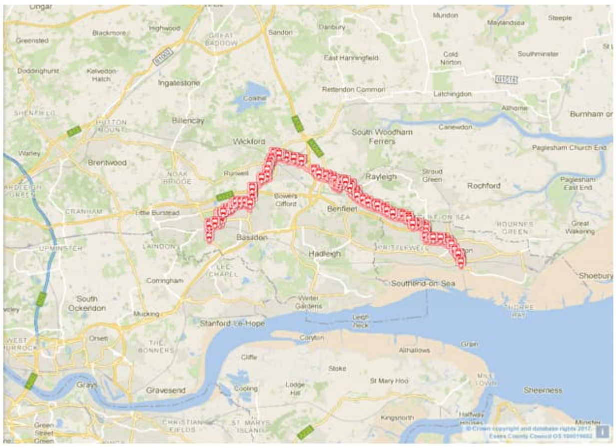


Figura A.7 – Route 25: Basildon – Southend (via Rayleigh Road)

Observed



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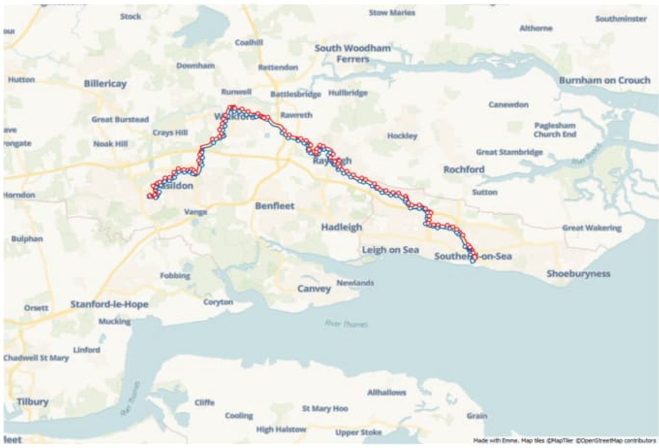
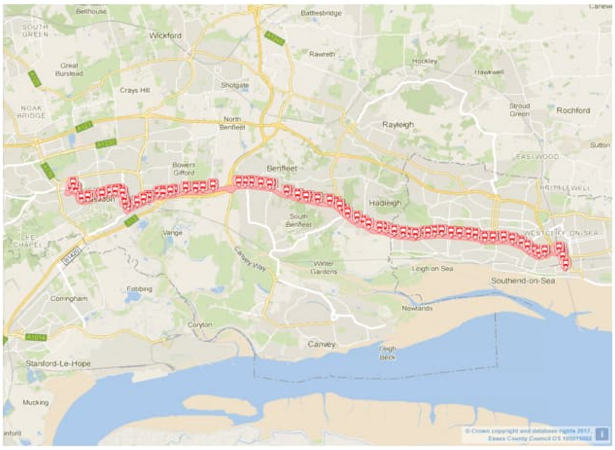


Figura A.8 – Route 28: Basildon – Southend (Via London Road)

Observed



Modelled

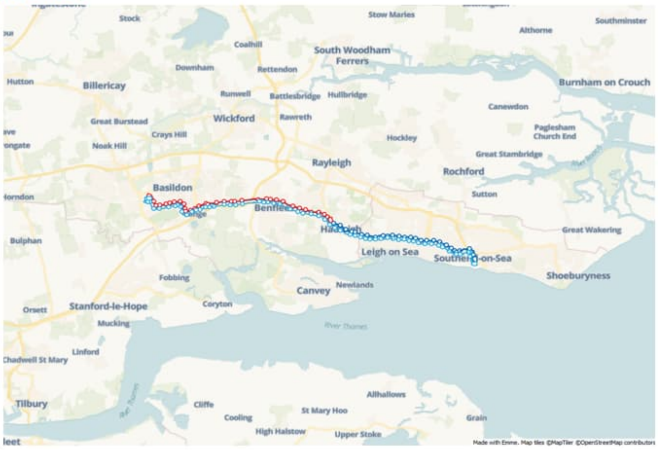
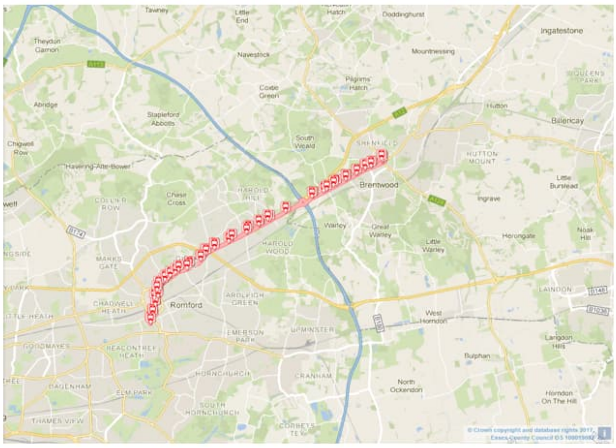


Figura A.9 – Route 498: Romford - Brentwood

Observed



Modelled

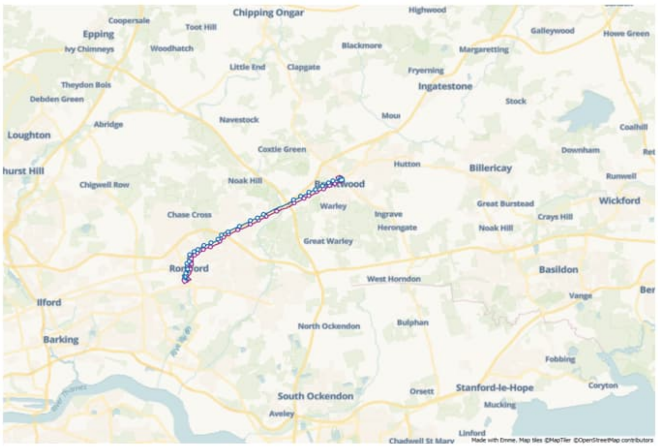
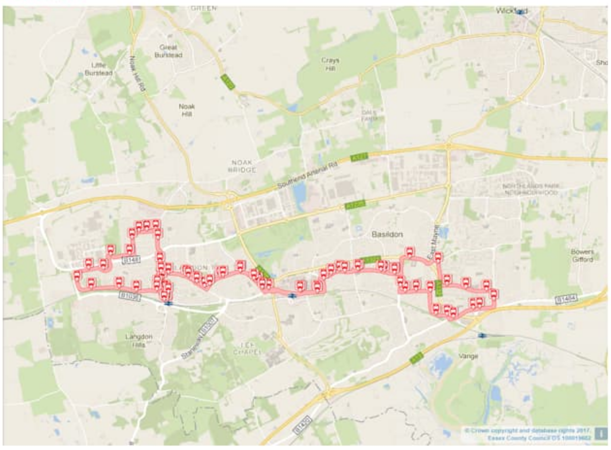


Figura A.10 – Route 8: Laindon - Pitsea

Observed



Modelled

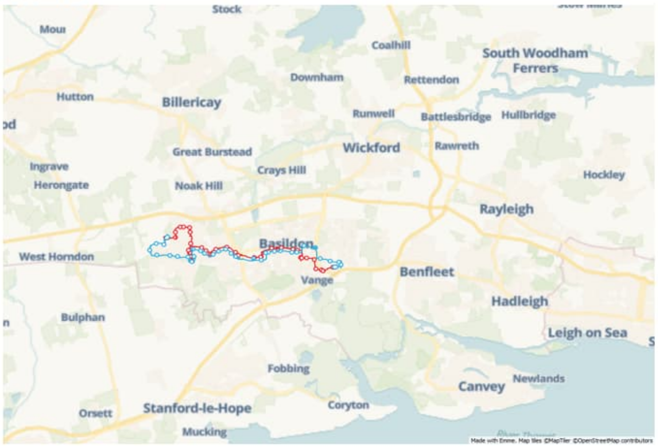
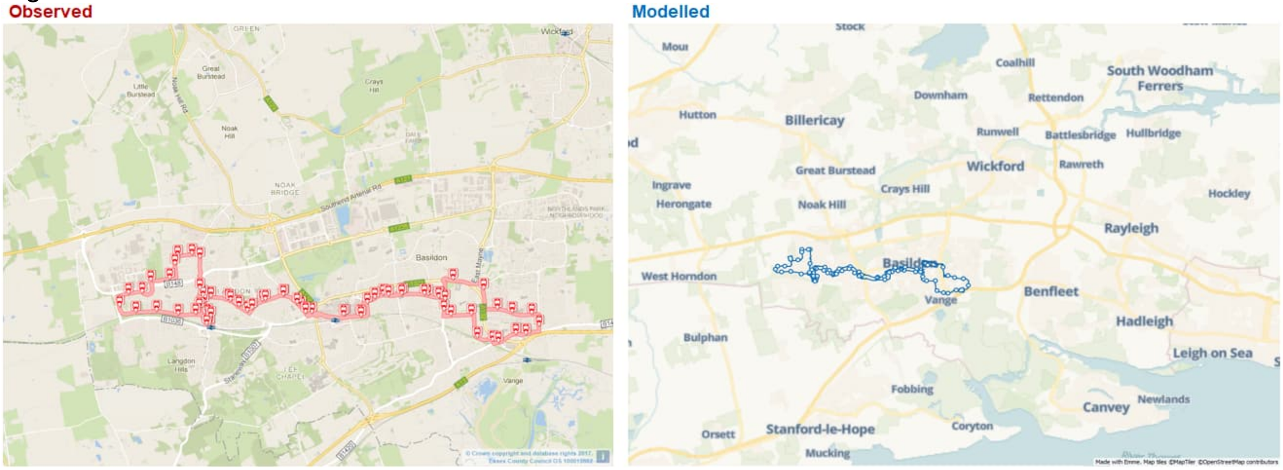


Figura A.11 – Route 8A: Laindon - Pitsea



Appendix B - Bus Journey Time Validation

South Essex Bus Services within AoDM – Timetables vs Modelled journey time

Table B1: Timetables vs Modelled Bus Journey Times – (AM peak period)

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
1	Arriva	Shoeburyness - Rayleigh	15	23.7	95.67	100.2	4.53	4.7%	Pass
1	Arriva	Shoeburyness - Rayleigh	45	15.03	38.75	45.93	7.18	18.5%	Fail
1	Arriva	Shoeburyness - Rayleigh	180	19.07	69	72.11	3.11	4.5%	Pass
1	Arriva	Shoeburyness - Rayleigh	180	15.65	63	65.79	2.79	4.4%	Pass
1	Arriva	Rayleigh - Shoeburyness	12.86	24.14	90.79	95.22	4.43	4.9%	Pass
1	Stephensons of Essex	Pitsea - Basildon	180	9.86	24	26.05	2.05	8.5%	Pass
10	First Essex	Wickford - Basildon	180	19.68	41	44.77	3.77	9.2%	Pass
10	First Essex	Basildon - Wickford	180	26.2	57	62.65	5.65	9.9%	Pass
100	First Essex	Basildon - Grays - Lakeside	18	24.67	55.6	59.44	3.84	6.9%	Pass
100	First Essex	Lakeside - Grays - Basildon	90	10.5	26.5	27.4	0.9	3.4%	Pass
100	First Essex	Lakeside - Grays - Basildon	60	19.99	50	51.04	1.04	2.1%	Pass
100	First Essex	Lakeside - Grays - Basildon	25.71	24.4	65.29	65.75	0.46	0.7%	Pass
100	First Essex	Chelmsford -Billericay - Basildon	18	24.08	56.5	59.7	3.2	5.7%	Pass
100	First Essex	Basildon - Billericay - Chelmsford	15	24.44	60.83	63.21	2.38	3.9%	Pass
104	NIBSbuses	Basildon Bus Station - Langdon Hills	180	8.5	22	23.18	1.18	5.4%	Pass
104	NIBSbuses	Langdon Hills - Basildon Bus Station	180	8.77	22	22.87	0.87	4.0%	Pass
106	NIBSbuses	Laindon Station - Langdon Hills - Laindon Station	90	2.4	6	6	0	0.0%	Pass
106	NIBSbuses	Langdon Hills - Laindon Station - Langdon Hills	60	3.55	10	10	0	0.0%	Pass
11	NIBSbuses	Basildon - Purfleet	180	31.64	71	73.15	2.15	3.0%	Pass
11	NIBSbuses	Purfleet - Basildon	180	45.84	103	106.93	3.93	3.8%	Pass
12	Stephensons of Essex	Wickford - Billericay	60	12.36	26.67	28.4	1.73	6.5%	Pass
12	Stephensons of Essex	Billericay - Wickford	180	12.58	28	30.14	2.14	7.6%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
12	Stephensons of Essex	Billericay - Wickford	180	13.92	31	33.59	2.59	8.4%	Pass
13A	First Essex	Chelmsford - Wickford	180	28.71	56	57.45	1.45	2.6%	Pass
13A	First Essex	Chelmsford - Wickford	180	31.96	63	64.69	1.69	2.7%	Pass
13A	First Essex	Wickford - Chelmsford	180	28.47	53	54.78	1.78	3.4%	Pass
13A	First Essex	Wickford - Chelmsford	180	29.65	76	77.06	1.06	1.4%	Pass
13A	First Essex	Wickford - Chelmsford	180	28.81	63	64.06	1.06	1.7%	Pass
14	First Essex	Chelmsford - Wickford	90	3.57	8.5	8.67	0.17	2.0%	Pass
14	First Essex	Chelmsford - Wickford	180	22.11	54	54.34	0.34	0.6%	Pass
14	First Essex	Wickford - Chelmsford	90	2.6	8	8	0	0.0%	Pass
14	NIBSbuses	Wickford Rail Station (circular via The Wick)	90	5.92	18	18.9	0.9	5.0%	Pass
14	Stephensons of Essex	Shoeburyness - Southend	180	22.24	41	41.58	0.58	1.4%	Pass
14	Stephensons of Essex	Southend - Shoeburyness	180	22.24	41	41.69	0.69	1.7%	Pass
14	Stephensons of Essex	Southend - Shoeburyness	180	15.16	34	34.94	0.94	2.8%	Pass
16	First Essex	Wickford Circular via Runwell	25.71	6.73	27	27.09	0.09	0.3%	Pass
17	Stephensons of Essex	Southend - Leigh	180	6.55	24	24.34	0.34	1.4%	Pass
17	Stephensons of Essex	Leigh - Southend	180	6.68	24	30.67	6.67	27.8%	Fail
2	NIBSbuses	Wickford - Billericay	180	15.4	32	33.42	1.42	4.4%	Pass
20	First Essex	Hullbridge - Southend	16.36	17.35	57	62.33	5.33	9.4%	Pass
20	First Essex	Hullbridge - Southend	180	12.15	44	48.25	4.25	9.7%	Pass
20	First Essex	Southend - Hullbridge	16.36	17.99	52.82	53.58	0.76	1.4%	Pass
820	First Essex	Sweyne Park School - Rayleigh	180	5.45	18	18.12	0.12	0.7%	Pass
21	First Essex	Canvey - Southend	30	31.43	97.5	102.04	4.54	4.7%	Pass
21	First Essex	Southend - Canvey	45	33.54	91	94.47	3.47	3.8%	Pass
21	First Essex	Southend - Canvey	180	22.33	71	72.72	1.72	2.4%	Pass
822	First Essex	Canvey Island - Southend	180	26.17	86	91.44	5.44	6.3%	Pass
21	NIBSbuses	Basildon - North Benfleet	60	11.03	22	23.65	1.65	7.5%	Pass
21	NIBSbuses	North Benfleet - Basildon	60	10.78	23	25.08	2.08	9.0%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
21	NIBSbuses	Ongar - Brentwood	60	13.38	27	27.81	0.81	3.0%	Pass
21	NIBSbuses	Brentwood - Ongar	60	13.53	25	26.39	1.39	5.6%	Pass
21C	NIBSbuses	Canvey - Hadleigh	180	11.99	28	30.22	2.22	7.9%	Pass
21C	NIBSbuses	Hadleigh - Canvey	180	13.28	28	31.1	3.1	11.1%	Pass
22	First Essex	Basildon - Canvey	20	18.95	54.67	55.31	0.64	1.2%	Pass
22	First Essex	Canvey - Basildon	20	19.01	61.56	62.14	0.58	0.9%	Pass
23	Stephensons of Essex	Leigh-on-Sea - Belfairs	180	5.1	15	15.09	0.09	0.6%	Pass
23	Stephensons of Essex	Belfairs - Leigh-on-Sea	180	5.2	15	15.35	0.35	2.3%	Pass
24	Stephensons of Essex	Southend Travel Centre - Southchurch	22.5	3.11	14	14	0	0.0%	Pass
24	Stephensons of Essex	Southchurch - Southend Travel Centre	20	4.98	17	17.01	0.01	0.1%	Pass
25	First Essex	Basildon - Southend	20	28.97	88.33	93.8	5.47	6.2%	Pass
25	First Essex	Southend - Basildon	20	30.53	90.67	94.68	4.01	4.4%	Pass
825	First Essex	Basildon - Westcliff - Southend	180	30.2	89	93.56	4.56	5.1%	Pass
256	NIBSbuses	Basildon - Billericay	180	7.06	16	16.96	0.96	6.0%	Pass
256	NIBSbuses	Basildon - Billericay	180	2.44	7	7.33	0.33	4.7%	Pass
257	NIBSbuses	Ramsden Heath - Billericay	180	6.07	18	18.15	0.15	0.8%	Pass
26	First Essex	Hadleigh - Southend - Southchurch	22.5	14.39	54	56.55	2.55	4.7%	Pass
26	First Essex	Southchurch - Southend - Hadleigh	30	14.71	56	58.34	2.34	4.2%	Pass
269	NIBSbuses	Grays - Brentwood	180	27.65	85	89.5	4.5	5.3%	Pass
269	NIBSbuses	Brentwood - Grays	180	27.52	72	78.68	6.68	9.3%	Pass
27	First Essex	Canvey - Southend	16.36	22.53	80.09	81.32	1.23	1.5%	Pass
27	First Essex	Canvey - Southend	180	9.1	31	32.58	1.58	5.1%	Pass
27	First Essex	Southend - Canvey	20	23	69.89	72.06	2.17	3.1%	Pass
27X	First Essex	Canvey - Benfleet - (Hadleigh)	90	11.59	36	36.99	0.99	2.8%	Pass
827	First Essex	Canvey - Hadleigh	180	19.15	72	72.41	0.41	0.6%	Pass
28	First Essex	Basildon - Southend	180	8.99	25	30.35	5.35	21.4%	Fail
28	First Essex	Basildon - Southend	20	20.22	69.22	71.71	2.49	3.6%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
28	First Essex	Basildon - Southend	90	11.23	40	40	0	0.0%	Pass
28	First Essex	Southend - Basildon	16.36	20.87	71.18	74.45	3.27	4.6%	Pass
29	Arriva	Temple Sutton - Belfairs	180	7.96	22	23.22	1.22	5.5%	Pass
29	Arriva	Temple Sutton - Belfairs	180	4.19	17	17	0	0.0%	Pass
29	Arriva	Temple Sutton - Belfairs	30	8.44	32	32.73	0.73	2.3%	Pass
29	Arriva	Belfairs - Temple Sutton	22.5	7.9	32.13	36.11	3.98	12.4%	Pass
3	NIBSbuses	Wickford - Billericay	180	15.36	38	40.81	2.81	7.4%	Pass
31	NIBSbuses	Basildon Bus Station - Endeavour Way	90	2.95	10	10	0	0.0%	Pass
31	NIBSbuses	Brentwood Circular (via Pilgrims Hatch)	22.5	9.34	31.63	32.35	0.72	2.3%	Pass
32	First Essex	Ongar - Chelmsford	180	24.71	72	72.3	0.3	0.4%	Pass
32	First Essex	Ongar - Chelmsford	180	25.18	58	58.3	0.3	0.5%	Pass
32	First Essex	Chelmsford - Ongar	180	25.48	54	54.76	0.76	1.4%	Pass
351	First Essex	(Warley) - Brentwood - Chelmsford	90	23.47	53	58.67	5.67	10.7%	Pass
351	First Essex	(Warley) - Brentwood - Chelmsford	60	21.96	54.33	59.98	5.65	10.4%	Pass
351	First Essex	Chelmsford - Brentwood - (Warley)	60	20.12	48.33	50.45	2.12	4.4%	Pass
351	First Essex	Chelmsford - Brentwood - (Warley)	90	21.72	58	59.38	1.38	2.4%	Pass
36	First Essex	Chelmsford - South Woodham	180	19.7	40	40.34	0.34	0.9%	Pass
36	First Essex	Chelmsford - South Woodham	45	21.59	44	44.37	0.37	0.8%	Pass
36	First Essex	South Woodham - Chelmsford	36	21.59	56	56.84	0.84	1.5%	Pass
36X	First Essex	South Woodham - Chelmsford	180	21.5	46	49.02	3.02	6.6%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	90	10.95	31	33.07	2.07	6.7%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	22.5	12.46	46.88	48.14	1.26	2.7%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	180	6.94	28	28.2	0.2	0.7%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	90	10.86	40	40.51	0.51	1.3%	Pass
374	NIBSbuses	Basildon - Grays	180	29.88	73	74.34	1.34	1.8%	Pass
374	NIBSbuses	Grays - Basildon	90	29.58	71	71.6	0.6	0.8%	Pass
42	First Essex	Galleywood - Broomfield - (Howe Street)	20	12.6	45.89	45.89	0	0.0%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
42	First Essex	(Howe Street) - Broomfield - Galleywood	22.5	12.63	43.25	43.25	0	0.0%	Pass
42A	First Essex	Galleywood - Broomfield - Stansted Airport	45	39.73	92.5	94.54	2.04	2.2%	Pass
42A	First Essex	Stansted Airport - Broomfield - Galleywood	60	39	98	98.84	0.84	0.9%	Pass
42B	First Essex	Galleywood - Broomfield - Braintree	36	27.75	76	76.99	0.99	1.3%	Pass
42B	First Essex	Braintree - Broomfield - Galleywood	180	28.8	92	92.55	0.55	0.6%	Pass
42B	First Essex	Braintree - Broomfield - Galleywood	36	26.62	73.6	74.58	0.98	1.3%	Pass
44	NIBSbuses	Wickford - Billericay	180	32.21	77	84.24	7.24	9.4%	Pass
46	NIBSbuses	Basildon - Billericay	180	16.74	50	51.4	1.4	2.8%	Pass
46	NIBSbuses	Basildon - Billericay	180	5.93	12	12.95	0.95	7.9%	Pass
50	NIBSbuses	Wickford - Billericay - Ingatestone	180	33.44	93	96.87	3.87	4.2%	Pass
431	NIBSbuses	Blackmore - Shenfield	180	17.48	44	44.91	0.91	2.1%	Pass
434	NIBSbuses	Kelvedon - Shenfield	180	16.34	36	37.67	1.67	4.6%	Pass
436	NIBSbuses	Ongar - Shenfield	180	17.3	31	31.9	0.9	2.9%	Pass
473	NIBSbuses	Fyfield - Ongar - Kelvedon - Brentwood	180	16.85	45	46.53	1.53	3.4%	Pass
474	NIBSbuses	High Ongar - Blackmore - Doddinghurst - Brentwood	180	24.41	63	64.64	1.64	2.6%	Pass
475	NIBSbuses	Stanford - Tilbury - Grays - Brentwood	180	34.72	71	76.14	5.14	7.2%	Pass
48	NIBSbuses	Laindon - Shenfield	180	19.22	60	62.28	2.28	3.8%	Pass
481	NIBSbuses	West Horndon - Hutton	180	8.93	34	34	0	0.0%	Pass
484	National Express	Clacton - London Victoria	180	119.4	225	238.23	13.23	5.9%	Pass
483	NIBSbuses	Doddinghurst - Kelvedon Hatch - St. Martins School	180	15.29	48	49.59	1.59	3.3%	Pass
484	NIBSbuses	Ongar - Kelvedon Hatch - St. Martins School	180	16.29	48	48.7	0.7	1.5%	Pass
485	NIBSbuses	Blackmore - Stondon Massey - St. Martins School	180	15.1	49	49.24	0.24	0.5%	Pass
49	NIBSbuses	Basildon - Brentwood	180	25.57	67	71.16	4.16	6.2%	Pass
498	Stagecoach London	Romford - Brentwood	20	11.89	38.78	40.04	1.26	3.2%	Pass
498	Stagecoach London	Brentwood - Romford	20	11.89	37.89	38.39	0.5	1.3%	Pass
5	First Essex	Langdon Hills - Basildon - Pitsea	30	14.38	50	50.89	0.89	1.8%	Pass
5	First Essex	Pitsea - Basildon - Langdon Hills	30	15.93	51	53.45	2.45	4.8%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
5	First Essex	Pitsea - Basildon - Langdon Hills	180	8.56	28	29.18	1.18	4.2%	Pass
5A	First Essex	Grays - Basildon - Pitsea	180	27.99	77	78.76	1.76	2.3%	Pass
5A	First Essex	Pitsea - Basildon - Grays	60	28.23	77	78.86	1.86	2.4%	Pass
5B	First Essex	Grays - Orsett - Basildon - Pitsea	180	17.64	54	55.25	1.25	2.3%	Pass
5B	First Essex	Grays - Orsett - Basildon - Pitsea	45	41.02	84	94.56	10.56	12.6%	Pass
5B	First Essex	Pitsea - Basildon - Orsett - Grays	60	41.07	83.67	96.31	12.64	15.1%	Pass
503	Stephensons of Essex	South Woodham Ferrers - Southend	180	26.26	56	62.87	6.87	12.3%	Pass
503	Stephensons of Essex	South Woodham Ferrers - Southend	180	26.26	71	76.74	5.74	8.1%	Pass
504	Stephensons of Essex	Wickham Bishops - Southend	180	47.29	90	96.53	6.53	7.3%	Pass
509	Stephensons of Essex	Southchurch - Westcliff-on-Sea	180	16.7	37	37.92	0.92	2.5%	Pass
560	Stephensons of Essex	Southchurch - Westcliff-on-Sea	180	10.44	34	40.8	6.8	20.0%	Fail
51	First Essex	Chelmsford Bus Station - Great Baddow	180	3.06	11	11	0	0.0%	Pass
51	First Essex	Great Baddow - Chelmsford Bus Station	180	7.17	25	25	0	0.0%	Pass
51	NIBSbuses	Chafford Hundred - Pitsea - Southend High School	180	47.81	90	102.79	12.79	14.2%	Pass
513	Stephensons of Essex	Chelmsford - Southend	180	45.3	90	98.86	8.86	9.8%	Pass
514	Stephensons of Essex	South Woodham - Westcliff	180	29.79	67	71.28	4.28	6.4%	Pass
515	Stephensons of Essex	Great Stambridge - Rayleigh	180	22.67	43	47.83	4.83	11.2%	Pass
552	NIBSbuses	Ramsden Heath - Billericay	90	6.98	15	16.08	1.08	7.2%	Pass
561	First Essex	Basildon - Chelmsford	180	30.43	95	98.15	3.15	3.3%	Pass
561A	First Essex	Billericay - Chelmsford	180	17.37	55	56.72	1.72	3.1%	Pass
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	180	5.57	15	17.49	2.49	16.6%	Fail
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	180	25.73	68	69.93	1.93	2.8%	Pass
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	180	26.17	58	62.07	4.07	7.0%	Pass
57	First Essex	Beaulieu - Galleywood	90	14.48	46.5	46.5	0	0.0%	Pass
57	First Essex	Beaulieu - Galleywood	25.71	12.66	46.14	46.14	0	0.0%	Pass
57	First Essex	Galleywood - Beaulieu	20	15.33	48.33	48.45	0.12	0.2%	Pass
57	First Essex	Galleywood - Beaulieu	180	8.23	25	25.08	0.08	0.3%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
5X	First Essex	Wickford - Basildon - Palmers College - Grays	180	26.89	71	72.41	1.41	2.0%	Pass
6	Arriva	Southend - Southchurch	22.5	3.71	14.75	14.75	0	0.0%	Pass
6	Arriva	Southchurch - Southend	22.5	3.72	17	17	0	0.0%	Pass
60	Stephensons of Essex	Southend (circular via Canewdon)	180	25.25	50	53.48	3.48	7.0%	Pass
608	Go-Ahead London	Gallows Corner - Shenfield High School	60	11.48	34.33	34.42	0.09	0.3%	Pass
61	Stephensons of Essex	Southend (circular via Southchurch)	180	3.31	12	12	0	0.0%	Pass
61	Swallow Coach Company	Brentwood - Blackmore	90	13.31	27	27.68	0.68	2.5%	Pass
61	Swallow Coach Company	Brentwood - Blackmore	180	12.55	25	25.56	0.56	2.2%	Pass
61	Swallow Coach Company	Blackmore - Brentwood	90	13.07	28	28.49	0.49	1.7%	Pass
61	Swallow Coach Company	Blackmore - Brentwood	180	13.11	26	26.6	0.6	2.3%	Pass
620	First Essex	Abridge - Epping - Ongar - Ingatestone	180	39.65	92	93.14	1.14	1.2%	Pass
625	First Essex	Chelmsford - Southend High School for Boys	180	42.69	88	96.84	8.84	10.0%	Pass
637	Stephensons of Essex	South Woodham - Chelmsford (St. John Payne School)	180	32.87	66	67.51	1.51	2.3%	Pass
6A	Stephensons of Essex	Belfairs - Leigh-on-Sea	90	3.82	13.5	13.58	0.08	0.6%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	90	20.46	56	58.81	2.81	5.0%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	60	32.53	105.33	107.87	2.54	2.4%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	180	19.63	61	62.44	1.44	2.4%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	180	20.85	71	73.57	2.57	3.6%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	180	28.39	98	100.79	2.79	2.8%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	180	27.3	95	97.65	2.65	2.8%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	90	23.29	76	81.34	5.34	7.0%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	180	14.32	46	50.11	4.11	8.9%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	90	25.47	94.5	98.54	4.04	4.3%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	180	30.7	110	113.56	3.56	3.2%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	90	26.54	98	101.54	3.54	3.6%	Pass
8	Arriva	Southend- Rayleigh	180	15.06	48	48.37	0.37	0.8%	Pass
8	Arriva	Southend- Rayleigh	90	32.36	110	112.99	2.99	2.7%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
8	Arriva	Rayleigh - Southend	60	25.74	85.67	92.05	6.38	7.4%	Pass
71	Stephensons of Essex	Stondon Massey (circular via Brentwood)	90	12.43	30	35.9	5.9	19.7%	Fail
71	Stephensons of Essex	Stondon Massey (circular via Brentwood)	180	9.14	16	17.49	1.49	9.3%	Pass
71C	Stephensons of Essex	Brentwood Circular	180	7.86	32	32.63	0.63	2.0%	Pass
71C	Stephensons of Essex	Brentwood Circular	180	7.85	33	33.63	0.63	1.9%	Pass
71C	Stephensons of Essex	Brentwood Circular	180	6.02	28	28.57	0.57	2.0%	Pass
71C	Stephensons of Essex	Brentwood Circular	180	2.94	14	14.35	0.35	2.5%	Pass
72	Stephensons of Essex	Stondon Massey (circular via Brentwood)	180	13.04	32	32.52	0.52	1.6%	Pass
725	First Essex	Basildon - Southend High School for Boys	180	36.43	85	87.46	2.46	2.9%	Pass
8	First Essex	Laindon - Pitsea	20	10.9	39.89	40.01	0.12	0.3%	Pass
8	First Essex	Pitsea - Laindon	20	11.86	35	35.19	0.19	0.5%	Pass
8A	First Essex	Laindon - Pitsea	20	12.95	40	42.02	2.02	5.1%	Pass
8A	First Essex	Pitsea - Laindon	20	11.02	36	37.06	1.06	2.9%	Pass
806	Stephensons of Essex	Great Stambridge - Canewdon - Rochford	180	11.91	19	19.39	0.39	2.1%	Pass
807	Stephensons of Essex	Foulness - Gt. Wakering - N. Shoebury - Rochford	180	24.52	40	42.94	2.94	7.3%	Pass
808	Stephensons of Essex	Lansdowne Corner - Great Wakering - Rochford	180	13.29	30	30.45	0.45	1.5%	Pass
809	Stephensons of Essex	Great Wakering - Rochford	180	11.62	25	25.43	0.43	1.7%	Pass
810	Stephensons of Essex	Bournes Green - Rochford	180	9.95	29	30.72	1.72	5.9%	Pass
811	Stephensons of Essex	Great Wakering - Rochford	180	11.62	29	29	0	0.0%	Pass
812	Stephensons of Essex	Stonebridge - Little Wakering - Rochford	180	14.79	25	27.57	2.57	10.3%	Pass
813	Stephensons of Essex	Stonebridge - Little Wakering - Rochford	180	14.98	25	26.5	1.5	6.0%	Pass
808	Brentwood CT	Brentwood Community Hospital (circular)	180	15.66	60	61.37	1.37	2.3%	Pass
808	Brentwood CT	Brentwood Community Hospital (circular)	180	7.86	35	35.54	0.54	1.5%	Pass
81	NIBSbuses	(Warley) - Brentwood - Hutton	45	6.45	22	22.72	0.72	3.3%	Pass
81	NIBSbuses	(Warley) - Brentwood - Hutton	36	7.96	26	26.72	0.72	2.8%	Pass
81	NIBSbuses	Hutton - Brentwood - (Warley)	60	7.88	29	29.85	0.85	2.9%	Pass
81	NIBSbuses	Hutton - Brentwood - (Warley)	30	6.28	25	25.75	0.75	3.0%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
814	Stephensons of Essex	Southchurch - Westcliff	180	18.83	45	48.89	3.89	8.6%	Pass
815	Stephensons of Essex	Rochford - Westcliff	180	21.31	60	61.73	1.73	2.9%	Pass
816	Stephensons of Essex	Rochford - Leigh-on-Sea	180	24.7	66	72.4	6.4	9.7%	Pass
9	Arriva	Shoeburyness - Rayleigh	60	13.87	36	38.07	2.07	5.8%	Pass
9	Arriva	Shoeburyness - Rayleigh	16.36	24.19	77.82	80.83	3.01	3.9%	Pass
9	Arriva	Rayleigh - Shoeburyness	90	9.86	23	23.13	0.13	0.6%	Pass
9	Arriva	Rayleigh - Shoeburyness	15	24.1	74.92	77.27	2.35	3.1%	Pass
9	First Essex	Brentwood - Basildon	180	14.03	32	35.19	3.19	10.0%	Pass
9	First Essex	Brentwood - Basildon	36	26.56	67.4	70.63	3.23	4.8%	Pass
9	First Essex	Basildon - Brentwood	45	27.48	68.5	73.22	4.72	6.9%	Pass
9A	First Essex	Hutton - Shenfield	90	4.27	11	11.17	0.17	1.5%	Pass
9A	First Essex	Hutton - Shenfield	180	7.65	38	38	0	0.0%	Pass
94	First Essex	Basildon - South Woodham	180	28.85	58	60.72	2.72	4.7%	Pass
94	First Essex	South Woodham - Basildon	180	18.16	34	37.35	3.35	9.9%	Pass
94	First Essex	South Woodham - Basildon	180	27.02	51	56.6	5.6	11.0%	Pass
94A	First Essex	Basildon - South Woodham	90	5.04	8	9.11	1.11	13.9%	Pass
94A	First Essex	South Woodham - Basildon	180	5.04	11	11.06	0.06	0.5%	Pass
94A	First Essex	South Woodham - Basildon	180	28.09	56	59.58	3.58	6.4%	Pass
94B	First Essex	Basildon - South Woodham	180	35.75	94	97.57	3.57	3.8%	Pass
FC07	Fords Coaches	Mundon - South Woodham Ferrers	180	24.4	42	43.99	1.99	4.7%	Pass
SB81	Basildon CT	Glebe Field - Basildon Bus Station	180	2.49	15	15.2	0.2	1.3%	Pass
X10	First Essex	Chelmsford - Basildon	60	26.22	41.67	43.08	1.41	3.4%	Pass
X10	First Essex	Basildon - Chelmsford	60	26.36	50	51.45	1.45	2.9%	Pass
X30	First Essex	Southend - Chelmsford	60	35.15	67.67	69.41	1.74	2.6%	Pass
X30	First Essex	Chelmsford - Southend	60	35.13	61	62.15	1.15	1.9%	Pass
Z4	Ensignbus	Pitsea - Basildon - Tilbury (Amazon)	90	24.36	45	47.61	2.61	5.8%	Pass

Table B2: Timetables vs Modelled Bus Journey Times – (Inter-peak period)

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
1	Arriva	Shoeburyness - Rayleigh	10.29	23.7	87.34	89.04	1.7	1.9%	Pass
1	Arriva	Rayleigh - Shoeburyness	10.29	24.14	86.23	88.07	1.84	2.1%	Pass
1	Stephensons of Essex	Basildon - Pitsea	72	9.86	24	24.73	0.73	3.0%	Pass
1	Stephensons of Essex	Pitsea - Basildon	90	10.48	27	28.5	1.5	5.6%	Pass
1	Stephensons of Essex	Pitsea - Basildon	360	5.92	16	16.45	0.45	2.8%	Pass
10	First Essex	Wickford - Basildon	120	26.5	58.67	62.55	3.88	6.6%	Pass
10	First Essex	Basildon - Wickford	120	26.2	57	62.37	5.37	9.4%	Pass
100	First Essex	Basildon - Grays - Lakeside	15.65	24.67	54.65	56.52	1.87	3.4%	Pass
100	First Essex	Lakeside - Grays - Basildon	15.65	24.4	57	58.4	1.4	2.5%	Pass
100	First Essex	Chelmsford -Billericay - Basildon	15	24.08	56.29	57.02	0.73	1.3%	Pass
100	First Essex	Basildon - Billericay - Chelmsford	15	24.44	56.5	58.04	1.54	2.7%	Pass
104	NIBSbuses	Basildon Bus Station - Langdon Hills	90	8.5	22	22.94	0.94	4.3%	Pass
104	NIBSbuses	Langdon Hills - Basildon Bus Station	90	8.77	22	22.74	0.74	3.4%	Pass
11	NIBSbuses	Basildon - Purfleet	120	46.56	105	107.2	2.2	2.1%	Pass
11	NIBSbuses	Purfleet - Basildon	120	45.84	103	105.66	2.66	2.6%	Pass
12	Stephensons of Essex	Wickford - Billericay	72	12.36	24	25.36	1.36	5.7%	Pass
12	Stephensons of Essex	Billericay - Wickford	72	13.92	30	31.25	1.25	4.2%	Pass
13	First Essex	Chelmsford - Wickford	60	3.57	9	9	0	0.0%	Pass
13	First Essex	Chelmsford - Wickford	120	25.88	54	55.25	1.25	2.3%	Pass
13	First Essex	Wickford - Chelmsford	120	24.99	55	55.35	0.35	0.6%	Pass
13	First Essex	Wickford - Chelmsford	60	2.6	8	8	0	0.0%	Pass
14	First Essex	Chelmsford - Wickford	120	22.11	54.67	54.94	0.27	0.5%	Pass
14	First Essex	Wickford - Chelmsford	120	21.26	50.67	51.11	0.44	0.9%	Pass
14	Stephensons of Essex	Shoeburyness - Southend	90	15.16	34	34.84	0.84	2.5%	Pass
14	Stephensons of Essex	Southend - Shoeburyness	90	15.16	34	34.98	0.98	2.9%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
16	First Essex	Wickford Circular via Runwell	30	6.73	25	25.06	0.06	0.2%	Pass
17	Stephensons of Essex	Southend - Leigh	90	6.55	24	24.27	0.27	1.1%	Pass
17	Stephensons of Essex	Leigh - Southend	90	6.68	24	25.12	1.12	4.7%	Pass
2	NIBSbuses	Billericay - Wickford	360	14.82	30	31.9	1.9	6.3%	Pass
20	First Essex	Hullbridge - Southend	15	17.35	54.08	54.39	0.31	0.6%	Pass
20	First Essex	Southend - Hullbridge	15	17.99	52.13	52.27	0.14	0.3%	Pass
820	First Essex	Rayleigh - Sweyne Park School	360	5.45	13	13	0	0.0%	Pass
220	Stephensons of Essex	Basildon - South Woodham - (Burnham)	360	21.64	40	43.86	3.86	9.7%	Pass
220	Stephensons of Essex	Basildon - South Woodham - (Burnham)	360	43.82	75	79.25	4.25	5.7%	Pass
220	Stephensons of Essex	(Burnham) - South Woodham - Basildon	360	40.36	64	66.31	2.31	3.6%	Pass
220	Stephensons of Essex	(Burnham) - South Woodham - Basildon	360	18.18	30	32.24	2.24	7.5%	Pass
21	First Essex	Canvey - Southend	30	31.43	93.42	95.41	1.99	2.1%	Pass
21	First Essex	Southend - Canvey	30	33.54	91.92	93.62	1.7	1.8%	Pass
21	NIBSbuses	Basildon - North Benfleet	60	11.03	22	23.41	1.41	6.4%	Pass
21	NIBSbuses	North Benfleet - Basildon	60	10.78	23	24.31	1.31	5.7%	Pass
21	NIBSbuses	Ongar - Brentwood	60	13.38	26	26.27	0.27	1.0%	Pass
21	NIBSbuses	Brentwood - Ongar	72	13.53	25	26.11	1.11	4.4%	Pass
21C	NIBSbuses	Canvey - Hadleigh	72	11.99	28	28.77	0.77	2.8%	Pass
21C	NIBSbuses	Hadleigh - Canvey	90	13.28	28	30.64	2.64	9.4%	Pass
22	First Essex	Basildon - Canvey	15	18.95	52.33	52.77	0.44	0.8%	Pass
22	First Essex	Canvey - Basildon	15	19.01	54.33	54.83	0.5	0.9%	Pass
23	Stephensons of Essex	Leigh-on-Sea - Belfairs	120	5.1	15	15.09	0.09	0.6%	Pass
23	Stephensons of Essex	Belfairs - Leigh-on-Sea	120	5.2	15	15.29	0.29	1.9%	Pass
24	Stephensons of Essex	Southend Travel Centre - Southchurch	20	3.11	14	14	0	0.0%	Pass
24	Stephensons of Essex	Southchurch - Southend Travel Centre	20	4.98	17	17.01	0.01	0.1%	Pass
25	First Essex	Basildon - Southend	15.65	28.97	86.3	86.67	0.37	0.4%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
25	First Essex	Basildon - Southend	360	11.12	30	30.13	0.13	0.4%	Pass
25	First Essex	Southend - Basildon	15	30.53	88	90.07	2.07	2.4%	Pass
25	First Essex	Southend - Basildon	360	11.17	35	35.78	0.78	2.2%	Pass
256	NIBSbuses	Basildon - Billericay	180	16.64	45	45.01	0.01	0.0%	Pass
256	NIBSbuses	Billericay - Basildon	360	16.73	48	48.31	0.31	0.6%	Pass
256	NIBSbuses	Billericay - Basildon	360	2.77	8	8.25	0.25	3.1%	Pass
256	NIBSbuses	Billericay - Basildon	360	8.71	21	21.25	0.25	1.2%	Pass
257	NIBSbuses	Billericay - Ramsden Heath	360	6.05	23	23	0	0.0%	Pass
26	First Essex	Hadleigh - Southend - Southchurch	15	14.39	54	55.46	1.46	2.7%	Pass
26	First Essex	Southchurch - Southend - Hadleigh	15.65	14.71	56	57.43	1.43	2.6%	Pass
265	Stephensons of Essex	Grays Circular (via West Horndon and Bulphan)	360	19.9	42	42.8	0.8	1.9%	Pass
265	Stephensons of Essex	Grays Circular (via West Horndon and Bulphan)	360	38.37	75	76.74	1.74	2.3%	Pass
265	Stephensons of Essex	Grays Circular (via West Horndon and Bulphan)	360	23.22	41	41.94	0.94	2.3%	Pass
269	NIBSbuses	Grays - Brentwood	180	26.65	57	59.23	2.23	3.9%	Pass
269	NIBSbuses	Grays - Brentwood	360	27.65	65	68.11	3.11	4.8%	Pass
269	NIBSbuses	Brentwood - Grays	180	26.64	57	61.15	4.15	7.3%	Pass
27	First Essex	Canvey - Southend	15.65	22.53	75.04	75.67	0.63	0.8%	Pass
27	First Essex	Southend - Canvey	15	23	74.54	76.01	1.47	2.0%	Pass
27	First Essex	Southend - Canvey	360	8.94	35	35.68	0.68	1.9%	Pass
28	First Essex	Basildon - Southend	15	20.22	69.17	69.17	0	0.0%	Pass
28	First Essex	Southend - Basildon	15	20.87	69.13	70.3	1.17	1.7%	Pass
29	Arriva	Temple Sutton - Belfairs	21.18	8.44	29.47	30.57	1.1	3.7%	Pass
29	Arriva	Temple Sutton - Belfairs	360	5.16	21	22.12	1.12	5.3%	Pass
29	Arriva	Belfairs - Temple Sutton	21.18	7.9	29.41	29.74	0.33	1.1%	Pass
3	NIBSbuses	Billericay - Wickford	360	15.57	28	30.89	2.89	10.3%	Pass
31B	First Essex	Burnham - Chelmsford	60	39.47	76	77.39	1.39	1.8%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
31B	First Essex	Chelmsford - Burnham	60	39.27	75	75.67	0.67	0.9%	Pass
31X	First Essex	Burnham - Maldon - Chelmsford	60	41.08	82	83.33	1.33	1.6%	Pass
31X	First Essex	Chelmsford - Maldon - Burnham	60	40.88	81	81.82	0.82	1.0%	Pass
31	NIBSbuses	Brentwood Circular (via Pilgrims Hatch)	20	9.34	32	32	0	0.0%	Pass
32	First Essex	Ongar - Chelmsford	180	25.18	58	58.3	0.3	0.5%	Pass
32	First Essex	Chelmsford - Ongar	180	25.48	54	54.76	0.76	1.4%	Pass
32	First Essex	Chelmsford - Ongar	360	25.35	64	65.19	1.19	1.9%	Pass
339	The London Bus Company	Shenfield - Epping	180	26.62	62	67.19	5.19	8.4%	Pass
339	The London Bus Company	Epping - Shenfield	360	14.07	25	27.32	2.32	9.3%	Pass
339	The London Bus Company	Epping - Shenfield	180	26.68	54.5	58.48	3.98	7.3%	Pass
351	First Essex	(Warley) - Brentwood - Chelmsford	30	23.47	52.25	56.13	3.88	7.4%	Pass
351	First Essex	Chelmsford - Brentwood - (Warley)	32.73	21.72	49	50.42	1.42	2.9%	Pass
351	First Essex	Chelmsford - Brentwood - (Warley)	360	20.12	50	50.48	0.48	1.0%	Pass
36	First Essex	Chelmsford - South Woodham	32.73	21.59	44.91	45.19	0.28	0.6%	Pass
36	First Essex	South Woodham - Chelmsford	32.73	21.59	46.18	47.2	1.02	2.2%	Pass
36A	First Essex	Chelmsford - South Woodham	360	23.05	47	47.56	0.56	1.2%	Pass
36A	First Essex	South Woodham - Chelmsford	360	23.05	51	52.03	1.03	2.0%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	360	10.86	41	41	0	0.0%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	16.36	9.34	34	34	0	0.0%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	360	10.95	38	38.03	0.03	0.1%	Pass
374	NIBSbuses	Basildon - Grays	90	29.88	73	74.03	1.03	1.4%	Pass
374	NIBSbuses	Grays - Basildon	90	29.58	71	71.36	0.36	0.5%	Pass
40	First Essex	(Boreham) - Central Chelmsford - Channels	30	17.96	44.5	45.53	1.03	2.3%	Pass
40	First Essex	Channels - Central Chelmsford - (Boreham)	30	13.96	42.5	42.55	0.05	0.1%	Pass
42	First Essex	Galleywood - Broomfield - (Howe Street)	20	12.6	42.67	42.67	0	0.0%	Pass
42	First Essex	(Howe Street) - Broomfield - Galleywood	20	12.63	41.06	41.06	0	0.0%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
42A	First Essex	Galleywood - Broomfield - Stansted Airport	60	39.73	90	91.93	1.93	2.1%	Pass
42A	First Essex	Stansted Airport - Broomfield - Galleywood	60	39	92.17	93.61	1.44	1.6%	Pass
42B	First Essex	Galleywood - Broomfield - Braintree	30	27.75	75.08	75.98	0.9	1.2%	Pass
42B	First Essex	Braintree - Broomfield - Galleywood	30	26.62	72.25	72.93	0.68	0.9%	Pass
46	NIBSbuses	Billericay - Wickford	360	12.94	27	27.68	0.68	2.5%	Pass
431	NIBSbuses	Shenfield - Blackmore	360	18.42	48	48.38	0.38	0.8%	Pass
434	NIBSbuses	Shenfield - Kelvedon	360	16.25	33	33.81	0.81	2.5%	Pass
436	NIBSbuses	Shenfield - Ongar	360	17.23	28	29.62	1.62	5.8%	Pass
45	First Essex	Oxney Green - Chelmsford - Moulsham Lodge	15	10.74	35.42	35.42	0	0.0%	Pass
45	First Essex	Moulsham Lodge - Chelmsford - Oxney Green	14.4	10.95	39.48	39.63	0.15	0.4%	Pass
47	First Essex	Moulsham - Broomfield Hospital	120	14.98	50	50	0	0.0%	Pass
47	First Essex	Moulsham - Broomfield Hospital	180	17.73	58	58.14	0.14	0.2%	Pass
47	First Essex	Moulsham - Broomfield Hospital	360	17.33	53	53.14	0.14	0.3%	Pass
47	First Essex	Broomfield Hospital - Moulsham	180	16.77	56	56.39	0.39	0.7%	Pass
47	First Essex	Broomfield Hospital - Moulsham	120	15.69	50	50.39	0.39	0.8%	Pass
47	First Essex	Broomfield Hospital - Moulsham	360	2.89	10	10	0	0.0%	Pass
47	First Essex	Broomfield Hospital - Moulsham	360	15.69	52	52	0	0.0%	Pass
48	NIBSbuses	Shenfield - Laindon	360	19.14	38	39.04	1.04	2.7%	Pass
481	NIBSbuses	Hutton - West Horndon	360	9.11	22	22.54	0.54	2.5%	Pass
481	National Express	London Victoria - Stratford - Colchester - Ipswich	360	120.41	200	204.34	4.34	2.2%	Pass
481	National Express	Ipswich - Colchester - Stratford - London Victoria	360	139.32	230	241.13	11.13	4.8%	Pass
481	National Express	Ipswich - Colchester - Stratford - London Victoria	180	120.38	237.5	237.6	0.1	0.0%	Pass
483	NIBSbuses	St. Martins School - Kelvedon Hatch - Doddinghurst	360	15.48	32	34.03	2.03	6.3%	Pass
485	NIBSbuses	St. Martins School - Stondon Massey - Blackmore	360	16.32	34	34.3	0.3	0.9%	Pass
498	Stagecoach London	Romford - Brentwood	20	11.89	40.28	41.04	0.76	1.9%	Pass
498	Stagecoach London	Brentwood - Romford	20	11.89	37.17	37.82	0.65	1.7%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
5	First Essex	Langdon Hills - Basildon - Pitsea	30	14.38	50	50.14	0.14	0.3%	Pass
5	First Essex	Pitsea - Basildon - Langdon Hills	30	15.93	51	52.7	1.7	3.3%	Pass
5A	First Essex	Grays - Basildon - Pitsea	60	27.99	77	77.78	0.78	1.0%	Pass
5A	First Essex	Pitsea - Basildon - Grays	60	28.23	77	78.04	1.04	1.4%	Pass
5B	First Essex	Grays - Orsett - Basildon - Pitsea	60	41.02	84	93.06	9.06	10.8%	Pass
5B	First Essex	Pitsea - Basildon - Orsett - Grays	60	41.07	84	95.03	11.03	13.1%	Pass
51	First Essex	Chelmsford Bus Station - Great Baddow	60	7.36	27	27	0	0.0%	Pass
51	First Essex	Great Baddow - Chelmsford Bus Station	72	7.17	25	25	0	0.0%	Pass
510	Stephensons of Essex	Chelmsford - Southminster	360	37.93	73	75.35	2.35	3.2%	Pass
515	Stephensons of Essex	Rayleigh - Rochford	360	24.72	37	39.14	2.14	5.8%	Pass
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	90	5.67	15	15.85	0.85	5.7%	Pass
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	90	5.57	15	15.76	0.76	5.1%	Pass
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	360	26.17	58	59.77	1.77	3.1%	Pass
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	360	26.17	58	59.77	1.77	3.1%	Pass
57	First Essex	Beaulieu - Galleywood	20	12.66	44.33	44.33	0	0.0%	Pass
57	First Essex	Galleywood - Beaulieu	21.18	15.33	45.71	45.78	0.07	0.2%	Pass
57	First Essex	Galleywood - Beaulieu	360	10.54	36	36	0	0.0%	Pass
6	Arriva	Southend - Southchurch	20	3.71	13.89	13.89	0	0.0%	Pass
6	Arriva	Southchurch - Southend	20	3.72	14.06	14.06	0	0.0%	Pass
60	Stephensons of Essex	Southend (circular via Canewdon)	360	45.73	86	89.67	3.67	4.3%	Pass
60	Stephensons of Essex	Southend (circular via Canewdon)	180	31.74	72	72.94	0.94	1.3%	Pass
60	Stephensons of Essex	Southend (circular via Canewdon)	360	23.06	40	43.14	3.14	7.9%	Pass
60A	Stephensons of Essex	Southend - Canewdon - Paglesham	360	28.47	49	50.76	1.76	3.6%	Pass
608	Go-Ahead London	Shenfield High School - Gallows Corner	360	11.44	34	40.62	6.62	19.5%	Fail
61	Stephensons of Essex	Southend (circular via Southchurch)	36	8.62	28	28.28	0.28	1.0%	Pass
61	Stephensons of Essex	Southend (circular via Southchurch)	360	5.31	13	13.28	0.28	2.2%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
61	Swallow Coach Company	Brentwood - Blackmore	60	12.55	25	25.24	0.24	1.0%	Pass
61	Swallow Coach Company	Blackmore - Brentwood	60	13.11	26	26.32	0.32	1.2%	Pass
620	First Essex	Ingatestone - Ongar - Epping - Abridge	360	39.11	75	76.37	1.37	1.8%	Pass
63	NIBSbuses	Landwick - Rayleigh	360	38.17	76	83.01	7.01	9.2%	Pass
63	NIBSbuses	Landwick - Rayleigh	360	19.46	35	37.81	2.81	8.0%	Pass
63	NIBSbuses	Landwick - Rayleigh	360	37.42	74	80.1	6.1	8.2%	Pass
63	NIBSbuses	Rayleigh - Landwick	360	38.11	73	81.9	8.9	12.2%	Pass
63	NIBSbuses	Rayleigh - Landwick	360	37.83	75	83.27	8.27	11.0%	Pass
637	Stephensons of Essex	Chelmsford (St. John Payne School) - South Woodham	360	32.47	70	71.14	1.14	1.6%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	360	27.3	96	96.32	0.32	0.3%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	72	28.39	93	93.54	0.54	0.6%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	72	26.54	92.73	93.28	0.55	0.6%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	360	25.47	90	90.52	0.52	0.6%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	360	11.71	47	47	0	0.0%	Pass
8	Arriva	Southend- Rayleigh	32.73	32.36	106.27	106.89	0.62	0.6%	Pass
8	Arriva	Southend- Rayleigh	360	27.13	89	89.1	0.1	0.1%	Pass
8	Arriva	Rayleigh - Southend	120	30.53	104.75	105.33	0.58	0.6%	Pass
701	First Essex	Chelmer Valley P&R - Sandon P&R	10	10.81	22	22	0	0.0%	Pass
701	First Essex	Sandon P&R - Chelmer Valley P&R	10	10.96	22	22	0	0.0%	Pass
71	First Essex	Chelmsford - Witham - Kelvedon - Colchester	30	40.16	90.17	91.8	1.63	1.8%	Pass
71	First Essex	Colchester - Kelvedon - Witham - Chelmsford	30	39.31	84	84.88	0.88	1.0%	Pass
71X	First Essex	Chelmsford - Witham - Colchester	360	40.08	80	82.12	2.12	2.7%	Pass
71	Stephensons of Essex	Stondon Massey (circular via Brentwood)	180	16.46	41	41.36	0.36	0.9%	Pass
71	Stephensons of Essex	Stondon Massey (circular via Brentwood)	180	16.38	45	46.08	1.08	2.4%	Pass
71	Stephensons of Essex	Stondon Massey (circular via Brentwood)	360	27.77	75	76.19	1.19	1.6%	Pass
72	Stephensons of Essex	Stondon Massey (circular via Brentwood)	360	17.08	43	43.36	0.36	0.8%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
8	First Essex	Laindon - Pitsea	20	10.9	40	40.08	0.08	0.2%	Pass
8	First Essex	Pitsea - Laindon	20	11.86	35	35.1	0.1	0.3%	Pass
8A	First Essex	Laindon - Pitsea	20	12.95	40	41.32	1.32	3.3%	Pass
8A	First Essex	Pitsea - Laindon	20	11.02	36	36.82	0.82	2.3%	Pass
806	Stephensons of Essex	Rochford - Canewdon - Great Stambridge	360	11.91	18	18.45	0.45	2.5%	Pass
807	Stephensons of Essex	Rochford - N. Shoebury - Gt. Wakering - Foulness	360	24.71	49	49.77	0.77	1.6%	Pass
808	Stephensons of Essex	Rochford - Great Wakering - Lansdowne Corner	360	13.37	33	33	0	0.0%	Pass
809	Stephensons of Essex	Rochford - Great Wakering	360	11.62	28	28	0	0.0%	Pass
810	Stephensons of Essex	Rochford - Bournes Green	360	9.95	23	24.1	1.1	4.8%	Pass
811	Stephensons of Essex	Rochford - Great Wakering	360	11.62	29	29	0	0.0%	Pass
812	Stephensons of Essex	Rochford - Little Wakering - Stonebridge	360	14.79	32	32.02	0.02	0.1%	Pass
813	Stephensons of Essex	Rochford - Little Wakering	360	10.94	24	24.02	0.02	0.1%	Pass
808	Brentwood CT	Brentwood Community Hospital (circular)	36	15.66	60	60.84	0.84	1.4%	Pass
808	Brentwood CT	Brentwood Community Hospital (circular)	360	9.84	35	35.67	0.67	1.9%	Pass
81	NIBSbuses	(Warley) - Brentwood - Hutton	30	6.45	22	22.59	0.59	2.7%	Pass
81	NIBSbuses	Hutton - Brentwood - (Warley)	30	6.28	25	25.12	0.12	0.5%	Pass
9	Arriva	Shoeburyness - Rayleigh	12	24.19	72.8	73.97	1.17	1.6%	Pass
9	Arriva	Rayleigh - Shoeburyness	12.41	24.1	74.14	74.95	0.81	1.1%	Pass
9	First Essex	Brentwood - Basildon	32.73	26.56	65.82	68.36	2.54	3.9%	Pass
9	First Essex	Brentwood - Basildon	360	23.52	58	59.74	1.74	3.0%	Pass
9	First Essex	Basildon - Brentwood	30	27.48	67.67	68.93	1.26	1.9%	Pass
94	First Essex	Basildon - South Woodham	72	28.85	58	59.93	1.93	3.3%	Pass
94	First Essex	Basildon - South Woodham	360	12.43	26	27.68	1.68	6.5%	Pass
94	First Essex	South Woodham - Basildon	72	27.02	51	53.29	2.29	4.5%	Pass
94B	First Essex	Wickford - Basildon	360	20.71	60	60.73	0.73	1.2%	Pass
FC07	Fords Coaches	South Woodham Ferrers - Mundon	360	24.4	40	42.23	2.23	5.6%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
SB81	Basildon CT	Basildon Bus Station - Glebe Field	360	2.47	15	15	0	0.0%	Pass
X10	First Essex	Chelmsford - Basildon	60	26.22	40.83	42.47	1.64	4.0%	Pass
X10	First Essex	Basildon - Chelmsford	60	26.36	40.33	40.49	0.16	0.4%	Pass
X30	First Essex	Southend - Chelmsford	60	35.15	60.83	61.53	0.7	1.2%	Pass
X30	First Essex	Chelmsford - Southend	60	35.13	58.33	59.15	0.82	1.4%	Pass

Table D3: Timetables vs Modelled Bus Journey Times – (PM peak period)

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
1	Arriva	Shoeburyness - Rayleigh	11.25	23.7	95.38	97.35	1.97	2.1%	Pass
1	Arriva	Shoeburyness - Rayleigh	90	16.34	63.5	65.88	2.38	3.7%	Pass
1	Arriva	Rayleigh - Shoeburyness	11.25	24.14	98.75	101.25	2.5	2.5%	Pass
1	Arriva	Rayleigh - Shoeburyness	60	15.68	56.67	60.14	3.47	6.1%	Pass
10	First Essex	Wickford - Basildon	180	26.5	58	62.97	4.97	8.6%	Pass
10	First Essex	Wickford - Basildon	180	19.68	41	44.14	3.14	7.7%	Pass
10	First Essex	Basildon - Wickford	180	19.75	45	47.98	2.98	6.6%	Pass
100	First Essex	Basildon - Grays - Lakeside	16.36	24.67	55	57.41	2.41	4.4%	Pass
100	First Essex	Basildon - Grays - Lakeside	180	10.96	27	28.44	1.44	5.3%	Pass
100	First Essex	Lakeside - Grays - Basildon	16.36	24.4	58.55	61.55	3	5.1%	Pass
100	First Essex	Chelmsford -Billericay - Basildon	16.36	24.08	58.45	61.67	3.22	5.5%	Pass
100	First Essex	Basildon - Billericay - Chelmsford	16.36	24.44	61	62.13	1.13	1.9%	Pass
100	First Essex	Basildon - Billericay - Chelmsford	180	14.88	35	36.73	1.73	4.9%	Pass
106	NIBSbuses	Laindon Station - Langdon Hills - Laindon Station	36	3.04	10	10	0	0.0%	Pass
106	NIBSbuses	Langdon Hills - Laindon Station - Langdon Hills	36	2.4	6	6	0	0.0%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
11	NIBSbuses	Basildon - Purfleet	180	46.56	105	108.2	3.2	3.0%	Pass
11	NIBSbuses	Purfleet - Basildon	90	45.84	103	107.26	4.26	4.1%	Pass
12	Stephensons of Essex	Wickford - Billericay	60	12.36	24.67	26.95	2.28	9.2%	Pass
12	Stephensons of Essex	Billericay - Wickford	90	13.92	30	32.28	2.28	7.6%	Pass
12	Stephensons of Essex	Billericay - Wickford	180	12.58	28	29.79	1.79	6.4%	Pass
13	First Essex	Wickford - Chelmsford	180	24.99	58	58.47	0.47	0.8%	Pass
13A	First Essex	Chelmsford - Wickford	180	32.76	79	80.38	1.38	1.7%	Pass
13A	First Essex	Chelmsford - Wickford	180	31.96	67	68.38	1.38	2.1%	Pass
14	First Essex	Chelmsford - Wickford	180	22.11	61	61.88	0.88	1.4%	Pass
14	First Essex	Wickford - Chelmsford	180	20.85	49	49.54	0.54	1.1%	Pass
14	First Essex	Wickford - Chelmsford	180	21.26	54	54.54	0.54	1.0%	Pass
14	NIBSbuses	Wickford Rail Station (circular via The Wick)	90	5.92	11	12.21	1.21	11.0%	Pass
14	Stephensons of Essex	Shoeburyness - Southend	90	15.16	35	35.99	0.99	2.8%	Pass
14	Stephensons of Essex	Southend - Shoeburyness	180	15.16	34	35.16	1.16	3.4%	Pass
14	Stephensons of Essex	Southend - Shoeburyness	180	22.24	42	42.92	0.92	2.2%	Pass
16	First Essex	Wickford Circular via Runwell	22.5	6.73	27.13	27.28	0.15	0.6%	Pass
17	Stephensons of Essex	Southend - Leigh	180	6.55	24	24.48	0.48	2.0%	Pass
20	First Essex	Hullbridge - Southend	15	17.35	54.5	56.62	2.12	3.9%	Pass
20	First Essex	Southend - Hullbridge	16.36	17.99	58.09	59.06	0.97	1.7%	Pass
20	First Essex	Southend - Hullbridge	180	5.14	11	11.32	0.32	2.9%	Pass
21	First Essex	Canvey - Southend	36	31.43	93.6	96.22	2.62	2.8%	Pass
21	First Essex	Canvey - Southend	36	20.52	48.8	49.6	0.8	1.6%	Pass
21	First Essex	Southend - Canvey	25.71	33.54	96.43	98.82	2.39	2.5%	Pass
822	First Essex	Southend - Canvey Island	180	23.61	73	77.68	4.68	6.4%	Pass
21	NIBSbuses	Basildon - North Benfleet	90	11.03	22	23.75	1.75	8.0%	Pass
21	NIBSbuses	North Benfleet - Basildon	90	10.78	23	24.44	1.44	6.3%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
21	NIBSbuses	Ongar - Brentwood	60	13.38	26	26.44	0.44	1.7%	Pass
21	NIBSbuses	Brentwood - Ongar	60	13.53	25	26.83	1.83	7.3%	Pass
22	First Essex	Basildon - Canvey	16.36	18.95	55.73	56.31	0.58	1.0%	Pass
22	First Essex	Canvey - Basildon	18	19.01	54.7	55.05	0.35	0.6%	Pass
24	Stephensons of Essex	Southend Travel Centre - Southchurch	22.5	3.11	14	14	0	0.0%	Pass
24	Stephensons of Essex	Southchurch - Southend Travel Centre	25.71	4.98	17	17.01	0.01	0.1%	Pass
25	First Essex	Basildon - Southend	15	28.97	91.75	94.29	2.54	2.8%	Pass
25	First Essex	Basildon - Southend	180	17.04	45	46.09	1.09	2.4%	Pass
25	First Essex	Southend - Basildon	16.36	30.53	90.45	95.18	4.73	5.2%	Pass
825	First Essex	Southend - Westcliff - Basildon	180	30.8	95	99.01	4.01	4.2%	Pass
26	First Essex	Hadleigh - Southend - Southchurch	25.71	14.39	54	56.53	2.53	4.7%	Pass
26	First Essex	Southchurch - Southend - Hadleigh	20	14.71	56	60.64	4.64	8.3%	Pass
269	NIBSbuses	Grays - Brentwood	180	26.65	57	61.7	4.7	8.2%	Pass
269	NIBSbuses	Brentwood - Grays	180	27.52	74	80.23	6.23	8.4%	Pass
269	NIBSbuses	Brentwood - Grays	180	16.14	31	34.71	3.71	12.0%	Pass
27	First Essex	Canvey - Southend	12.86	22.53	73.36	75.86	2.5	3.4%	Pass
27	First Essex	Canvey - Southend	180	13.43	30	32.1	2.1	7.0%	Pass
27	First Essex	Southend - Canvey	12.86	23	80.07	81.64	1.57	2.0%	Pass
27X	First Essex	Benfleet - Canvey - (Hadleigh)	180	11.44	31	31.36	0.36	1.2%	Pass
27X	First Essex	Benfleet - Canvey - (Hadleigh)	20	5.55	14.78	14.78	0	0.0%	Pass
827	First Essex	Hadleigh - Canvey	180	19.63	65	65.25	0.25	0.4%	Pass
28	First Essex	Basildon - Southend	15	20.22	70.67	72.37	1.7	2.4%	Pass
28	First Essex	Southend - Basildon	16.36	20.87	71.18	72.99	1.81	2.5%	Pass
28	First Essex	Southend - Basildon	180	24.29	81	83.05	2.05	2.5%	Pass
29	Arriva	Temple Sutton - Belfairs	22.5	8.44	34.75	34.75	0	0.0%	Pass
29	Arriva	Belfairs - Temple Sutton	22.5	7.9	33.38	35.67	2.29	6.9%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
29	Arriva	Belfairs - Temple Sutton	180	4.69	25	27.15	2.15	8.6%	Pass
31B	First Essex	Burnham - Chelmsford	60	39.47	72.33	74.07	1.74	2.4%	Pass
31C	First Essex	Chelmsford - Maldon - Steeple - (Burnham)	180	35	71	71.85	0.85	1.2%	Pass
31C	First Essex	Chelmsford - Maldon - Steeple - (Burnham)	180	45.25	91	91.85	0.85	0.9%	Pass
31X	First Essex	Burnham - Maldon - Chelmsford	60	41.08	72.67	74.4	1.73	2.4%	Pass
31X	First Essex	Chelmsford - Maldon - Burnham	36	40.88	78	80.2	2.2	2.8%	Pass
31X	First Essex	Chelmsford - Maldon - Burnham	180	18.94	36	36.61	0.61	1.7%	Pass
31	NIBSbuses	Endeavour Way - Basildon Bus Station	90	2.97	10	10	0	0.0%	Pass
31	NIBSbuses	Brentwood Circular (via Pilgrims Hatch)	20	9.34	32	32.26	0.26	0.8%	Pass
339	The London Bus Company	Shenfield - Epping	180	26.62	62	68.25	6.25	10.1%	Pass
339	The London Bus Company	Shenfield - Epping	180	14.01	23	25.51	2.51	10.9%	Pass
339	The London Bus Company	Epping - Shenfield	180	26.68	61	66.1	5.1	8.4%	Pass
351	First Essex	(Warley) - Brentwood - Chelmsford	180	23.47	58	62.09	4.09	7.1%	Pass
351	First Essex	(Warley) - Brentwood - Chelmsford	45	21.96	51.75	56.02	4.27	8.3%	Pass
351	First Essex	Chelmsford - Brentwood - (Warley)	45	20.12	51.75	52.31	0.56	1.1%	Pass
351	First Essex	Chelmsford - Brentwood - (Warley)	180	21.72	51	52.93	1.93	3.8%	Pass
36	First Essex	Chelmsford - South Woodham	36	21.59	47.6	48.42	0.82	1.7%	Pass
36	First Essex	South Woodham - Chelmsford	90	21.59	49	50.13	1.13	2.3%	Pass
36	First Essex	South Woodham - Chelmsford	60	19.7	45.33	46.68	1.35	3.0%	Pass
36B	First Essex	South Woodham - Chelmsford	180	19.7	36	37.16	1.16	3.2%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	90	10.95	41.5	42.33	0.83	2.0%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	22.5	12.46	46.5	47.4	0.9	1.9%	Pass
37	First Essex	Brentwood (circular via Pilgrims Hatch)	180	10.86	39	39.87	0.87	2.2%	Pass
374	NIBSbuses	Basildon - Grays	90	29.88	73	74.95	1.95	2.7%	Pass
374	NIBSbuses	Grays - Basildon	180	29.58	71	71.61	0.61	0.9%	Pass
42	First Essex	Galleywood - Broomfield - (Howe Street)	22.5	12.6	42.75	42.75	0	0.0%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
42	First Essex	(Howe Street) - Broomfield - Galleywood	20	12.63	43.56	43.56	0	0.0%	Pass
42A	First Essex	Galleywood - Broomfield - Stansted Airport	90	39.73	90	91.93	1.93	2.1%	Pass
42A	First Essex	Stansted Airport - Broomfield - Galleywood	90	39	93	94.67	1.67	1.8%	Pass
42A	First Essex	Stansted Airport - Broomfield - Galleywood	180	39.4	86	87.56	1.56	1.8%	Pass
42B	First Essex	Galleywood - Broomfield - Braintree	60	27.75	79.67	79.96	0.29	0.4%	Pass
42B	First Essex	Galleywood - Broomfield - Braintree	90	29.05	76.5	78.1	1.6	2.1%	Pass
42B	First Essex	Braintree - Broomfield - Galleywood	90	26.62	77.5	78.2	0.7	0.9%	Pass
42B	First Essex	Braintree - Broomfield - Galleywood	60	27.02	72.67	73.43	0.76	1.0%	Pass
43	NIBSbuses	Billericay - Wickford	180	27.21	53	63.19	10.19	19.2%	Fail
45	NIBSbuses	Billericay - Wickford	180	38.59	74	88.05	14.05	19.0%	Fail
46	NIBSbuses	Billericay - Wickford	180	29.25	57	63.39	6.39	11.2%	Pass
50	NIBSbuses	Ingatestone - Billericay - Wickford	180	34.32	69	78.72	9.72	14.1%	Pass
45	First Essex	Oxney Green - Chelmsford - Moulsham Lodge	16.36	10.74	39.09	39.09	0	0.0%	Pass
45	First Essex	Moulsham Lodge - Chelmsford - Oxney Green	18	10.95	40.6	40.6	0	0.0%	Pass
45	First Essex	Moulsham Lodge - Chelmsford - Oxney Green	180	11.82	37	37.17	0.17	0.5%	Pass
473	NIBSbuses	Brentwood - Kelvedon - Ongar - Fyfield	180	16.85	35	36.21	1.21	3.5%	Pass
474	NIBSbuses	Brentwood - Doddinghurst - Blackmore - High Ongar	180	24.41	50	52.12	2.12	4.2%	Pass
475	NIBSbuses	Brentwood - Grays - Tilbury - Stanford	180	35.36	50	58.25	8.25	16.5%	Fail
484	National Express	London Victoria - Clacton	180	119.2	235	241.77	6.77	2.9%	Pass
484	NIBSbuses	St. Martins School - Kelvedon Hatch - Ongar	180	16.53	42	42.9	0.9	2.1%	Pass
49	NIBSbuses	Brentwood - Basildon	180	29.59	48	57.62	9.62	20.0%	Fail
498	Stagecoach London	Romford - Brentwood	20	11.89	47	47.23	0.23	0.5%	Pass
498	Stagecoach London	Brentwood - Romford	18	11.89	41.5	42.29	0.79	1.9%	Pass
5	First Essex	Langdon Hills - Basildon - Pitsea	30	14.38	50	50.93	0.93	1.9%	Pass
5	First Essex	Pitsea - Basildon - Langdon Hills	30	15.93	51	55.47	4.47	8.8%	Pass
5	First Essex	Pitsea - Basildon - Langdon Hills	180	10.24	38	39.52	1.52	4.0%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
5A	First Essex	Grays - Basildon - Pitsea	60	27.99	77	78.66	1.66	2.2%	Pass
5A	First Essex	Pitsea - Basildon - Grays	90	28.23	77	79.52	2.52	3.3%	Pass
5B	First Essex	Grays - Orsett - Basildon - Pitsea	60	41.02	84	94.53	10.53	12.5%	Pass
5B	First Essex	Pitsea - Basildon - Orsett - Grays	60	41.07	84	97.31	13.31	15.8%	Fail
5B	First Essex	Pitsea - Basildon - Orsett - Grays	180	22.93	64	66.67	2.67	4.2%	Pass
503	Stephensons of Essex	Southend - South Woodham Ferrers	180	26.3	48	53.54	5.54	11.5%	Pass
503	Stephensons of Essex	Southend - South Woodham Ferrers	180	26.3	50	52.66	2.66	5.3%	Pass
504	Stephensons of Essex	Southend - Wickham Bishops	180	47.33	86	89.99	3.99	4.6%	Pass
560	Stephensons of Essex	Westcliff-on-Sea - Southchurch	180	16.16	38	46.15	8.15	21.4%	Fail
51	NIBSbuses	Southend High School - Pitsea - Chafford Hundred	180	53.87	90	109.28	19.28	21.4%	Fail
513	Stephensons of Essex	Southend - Chelmsford	180	45.72	89	109.27	20.27	22.8%	Fail
514	Stephensons of Essex	Westcliff - South Woodham	180	23.45	37	42.95	5.95	16.1%	Fail
552	NIBSbuses	Billericay - Ramsden Heath	90	7.01	15	15.84	0.84	5.6%	Pass
561	First Essex	Chelmsford - Basildon	180	30.64	72	75.24	3.24	4.5%	Pass
561A	First Essex	Chelmsford - Billericay	180	17.86	46	47.07	1.07	2.3%	Pass
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	180	25.53	69	72.07	3.07	4.4%	Pass
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	180	5.67	15	17.73	2.73	18.2%	Fail
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	180	5.57	18	18.51	0.51	2.8%	Pass
565	First Essex	Brentwood - Bulphan & West Horndon (circular)	180	26.17	58	62.44	4.44	7.7%	Pass
57	First Essex	Beaulieu - Galleywood	22.5	12.66	48.13	48.12	-0.01	0.0%	Pass
57	First Essex	Galleywood - Beaulieu	60	15.33	48.33	48.43	0.1	0.2%	Pass
57	First Essex	Galleywood - Beaulieu	45	14.94	49	49.08	0.08	0.2%	Pass
57	First Essex	Galleywood - Beaulieu	90	15.83	51	51.1	0.1	0.2%	Pass
57	First Essex	Galleywood - Beaulieu	180	16.22	48	48.08	0.08	0.2%	Pass
594	Stephensons of Essex	South Woodham - Witham	180	26.35	39	42.98	3.98	10.2%	Pass
6	Arriva	Southend - Southchurch	20	3.71	15.78	15.78	0	0.0%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
6	Arriva	Southchurch - Southend	20	3.72	15.67	15.67	0	0.0%	Pass
60	Stephensons of Essex	Southend (circular via Canewdon)	180	23.06	40	43.92	3.92	9.8%	Pass
60A	Stephensons of Essex	Southend - Canewdon - Paglesham	180	23.94	51	54.51	3.51	6.9%	Pass
60A	Stephensons of Essex	Southend - Canewdon - Paglesham	180	28.47	39	50.02	11.02	28.3%	Fail
608	Go-Ahead London	Shenfield High School - Gallows Corner	180	11.44	34	41.32	7.32	21.5%	Fail
608	Go-Ahead London	Shenfield High School - Gallows Corner	180	8.94	24	31.32	7.32	30.5%	Fail
61	Swallow Coach Company	Brentwood - Blackmore	180	12.55	25	25.78	0.78	3.1%	Pass
61	Swallow Coach Company	Brentwood - Blackmore	180	13.31	28	28.87	0.87	3.1%	Pass
61	Swallow Coach Company	Blackmore - Brentwood	180	13.11	26	26.32	0.32	1.2%	Pass
61	Swallow Coach Company	Blackmore - Brentwood	90	13.07	28	28.46	0.46	1.6%	Pass
625	First Essex	Southend High School for Boys - Chelmsford	180	43.32	89	96.5	7.5	8.4%	Pass
6A	Stephensons of Essex	Leigh-on-Sea - Belfairs	60	3.73	10	10.11	0.11	1.1%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	30	28.39	96.33	97.18	0.85	0.9%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	180	27.3	98	98.68	0.68	0.7%	Pass
7	Arriva	Gt. Wakering - Hockley/Rayleigh	180	7.53	19	19.14	0.14	0.7%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	180	30.7	112	114.34	2.34	2.1%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	180	21.75	82	83.84	1.84	2.2%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	60	26.54	98	100.39	2.39	2.4%	Pass
7	Arriva	Hockley/Rayleigh - Gt. Wakering	180	25.91	94	95.84	1.84	2.0%	Pass
8	Arriva	Southend- Rayleigh	25.71	27.13	94	94.25	0.25	0.3%	Pass
8	Arriva	Rayleigh - Southend	90	30.53	111	114.22	3.22	2.9%	Pass
8	Arriva	Rayleigh - Southend	180	26.38	97	100.27	3.27	3.4%	Pass
8	Arriva	Rayleigh - Southend	180	25.74	92.5	94.23	1.73	1.9%	Pass
700	First Essex	Sandon Circular P&R	90	5.1	14.5	14.5	0	0.0%	Pass
700	First Essex	Sandon Circular P&R	16.36	9.98	24.55	24.55	0	0.0%	Pass
701	First Essex	Chelmer Valley P&R - Sandon P&R	10.59	10.81	25.12	25.12	0	0.0%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
701	First Essex	Sandon P&R - Chelmer Valley P&R	11.25	10.96	24.06	24.06	0	0.0%	Pass
71	Stephensons of Essex	Stondon Massey (circular via Brentwood)	180	15.4	51	53.07	2.07	4.1%	Pass
71	Stephensons of Essex	Stondon Massey (circular via Brentwood)	180	11.45	24	25.88	1.88	7.8%	Pass
71C	Stephensons of Essex	Brentwood Circular	60	2.99	13	13.16	0.16	1.2%	Pass
71C	Stephensons of Essex	Brentwood Circular	90	6.02	28	28.41	0.41	1.5%	Pass
71C	Stephensons of Essex	Brentwood Circular	90	2.94	11	11.36	0.36	3.3%	Pass
725	First Essex	Southend High School for Boys - Basildon	180	36.29	80	86.05	6.05	7.6%	Pass
8	First Essex	Laindon - Pitsea	20	10.9	40	40.13	0.13	0.3%	Pass
8	First Essex	Pitsea - Laindon	20	11.86	35	35.26	0.26	0.7%	Pass
8A	First Essex	Laindon - Pitsea	20	12.95	40	41.8	1.8	4.5%	Pass
8A	First Essex	Pitsea - Laindon	20	11.02	35.89	36.89	1	2.8%	Pass
808	Brentwood CT	Brentwood Community Hospital (circular)	180	15.66	60	61.39	1.39	2.3%	Pass
81	NIBSbuses	(Warley) - Brentwood - Hutton	36	6.45	22	23.04	1.04	4.7%	Pass
81	NIBSbuses	(Warley) - Brentwood - Hutton	45	7.96	27	27.93	0.93	3.4%	Pass
81	NIBSbuses	Hutton - Brentwood - (Warley)	36	6.28	25	25.29	0.29	1.2%	Pass
81	NIBSbuses	Hutton - Brentwood - (Warley)	60	7.88	29.67	30.02	0.35	1.2%	Pass
814	Stephensons of Essex	Westcliff - Southchurch	180	23.78	55	59.45	4.45	8.1%	Pass
815	Stephensons of Essex	Westcliff - Rochford	180	17.33	39	44.92	5.92	15.2%	Pass
816	Stephensons of Essex	Leigh-on-Sea - Rochford	180	27.94	64	73.46	9.46	14.8%	Pass
9	Arriva	Shoeburyness - Rayleigh	12.86	24.19	77	78.82	1.82	2.4%	Pass
9	Arriva	Rayleigh - Shoeburyness	13.85	24.1	79.77	81.5	1.73	2.2%	Pass
9	Arriva	Rayleigh - Shoeburyness	90	13.62	38	39.22	1.22	3.2%	Pass
9	First Essex	Brentwood - Basildon	36	26.56	76.6	79.12	2.52	3.3%	Pass
9	First Essex	Basildon - Brentwood	30	27.48	74.5	78.56	4.06	5.4%	Pass
9A	First Essex	Shenfield - Hutton	45	4.22	11	11.2	0.2	1.8%	Pass
94	First Essex	Basildon - South Woodham	180	28.85	69	71.23	2.23	3.2%	Pass

Route ID	Operator Description	Bus Line Description	Headway [min]	Length [km]	Observed JT [min]	Modelled JT [min]	Diff [min]	Diff [%]	Pass / Fail
94	First Essex	South Woodham - Basildon	90	27.02	58	59.42	1.42	2.4%	Pass
94A	First Essex	Basildon - South Woodham	180	25.59	54	57.58	3.58	6.6%	Pass
94A	First Essex	South Woodham - Basildon	180	5.04	10	10.11	0.11	1.1%	Pass
X10	First Essex	Chelmsford - Basildon	60	26.22	43.33	44.23	0.9	2.1%	Pass
X10	First Essex	Basildon - Chelmsford	60	26.36	47	48.03	1.03	2.2%	Pass
X30	First Essex	Southend - Chelmsford	60	35.15	65.33	66.23	0.9	1.4%	Pass
X30	First Essex	Chelmsford - Southend	60	35.13	63.33	68.32	4.99	7.9%	Pass
Z4	Ensignbus	Pitsea - Basildon - Tilbury (Amazon)	90	24.36	45	47.84	2.84	6.3%	Pass

Appendix C - PT Assignment Parameters

This appendix summarises the method and parameters utilised in the south Essex public transport model demand assignments.

Software: EMME version 4.4.4.2

Methodology: Public transport assignment model - Multiclass Frequency-based, Optimal Strategies algorithm, without in-vehicle capacity crowding functionality.

The generalised cost components are:

- In-vehicle time.
- Wait time (time spent waiting for services).
- Walk time (time spent walking on-street, PT and zone access and egress).
- Boarding penalty (penalty associate with inconvenience of interchanging.

Table below shows the generalised cost component and respective coefficient:

Table C1: Generalised cost component and coefficients

Generalised Cost Component	Coefficient (weighting)
In-vehicle time	1.0
Walk time	2.0
Wait time	2.5
Boarding Penalty	1.0

Appendix D – Bus Loading Factors Plots

This appendix summarises the bus and coach average and maxium loading factor plots used to sense check the bus loadings against the available seated capacity accros the AoDM in all time periods in south essex public transport model, AM, IP and PM.

AM Bus Loading Factors

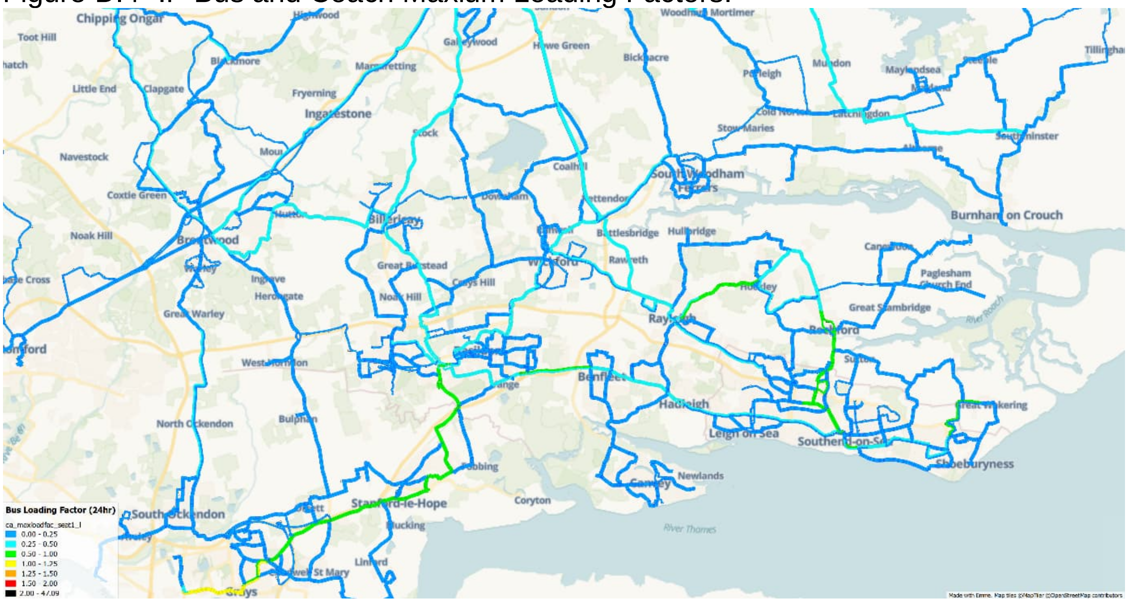
Figure D.1- AM Bus and Coach Average Loading Factors.

Figure D.2- AM Bus and Coach Maxium Loading Factors.

IP Bus Loading Factors

Figure D.3- IP Bus and Coach Average Loading Factors.

Figure D.4- IP Bus and Coach Maxium Loading Factors.



PM Bus Loading Factors

Figure D.5- PM Bus and Coach Average Loading Factors.

Figure D.6- PM Bus and Coach Maxium Loading Factors.

Appendix E – Prior and Adjusted Prior vs Post ME Matrices

Figure E.1 - Commute AM – comparison between Prior vs Post ME and Adjusted Prior vs Post ME

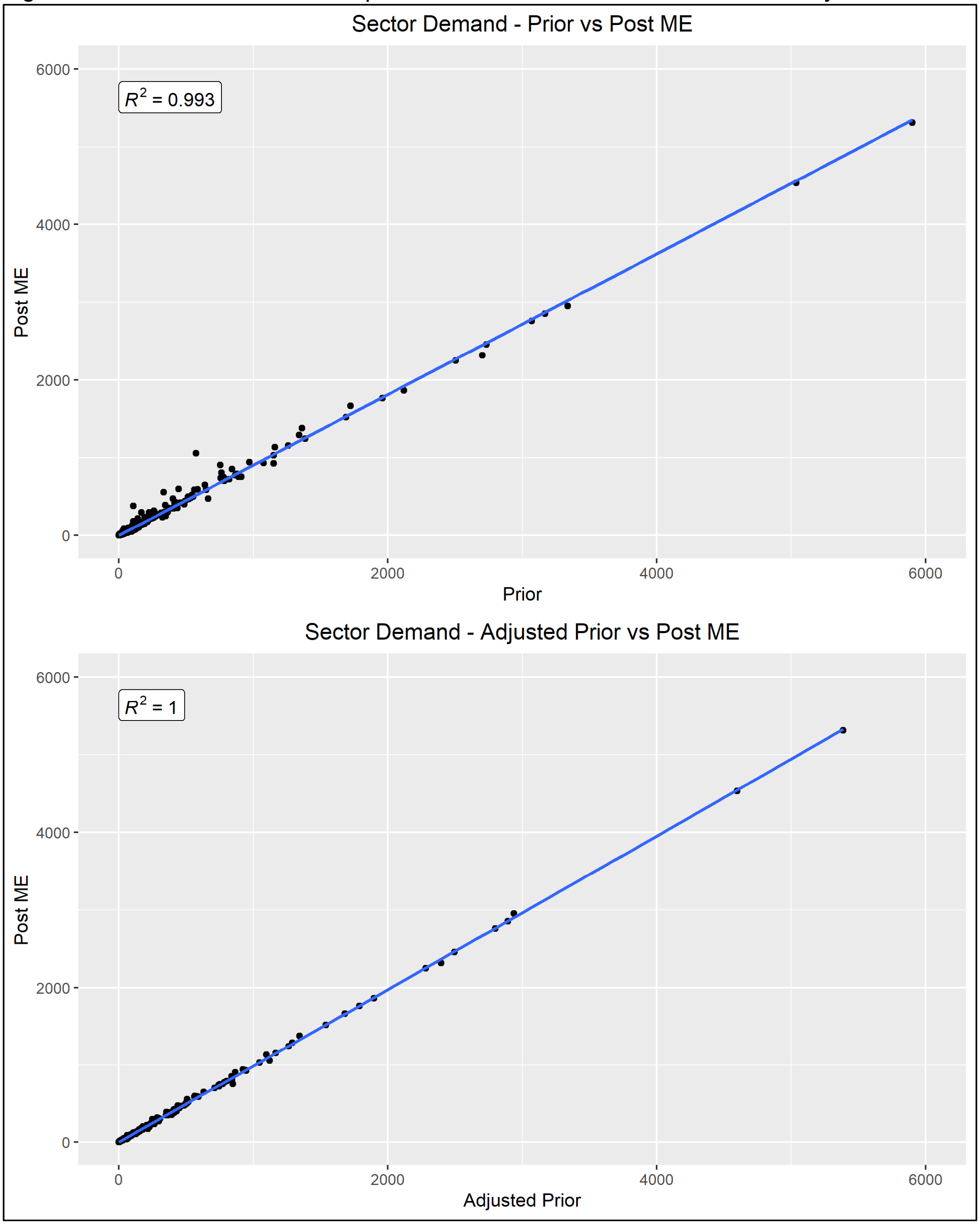


Figure E.2 - Commute IP – comparison between Prior vs Post ME and Adjusted Prior vs Post ME

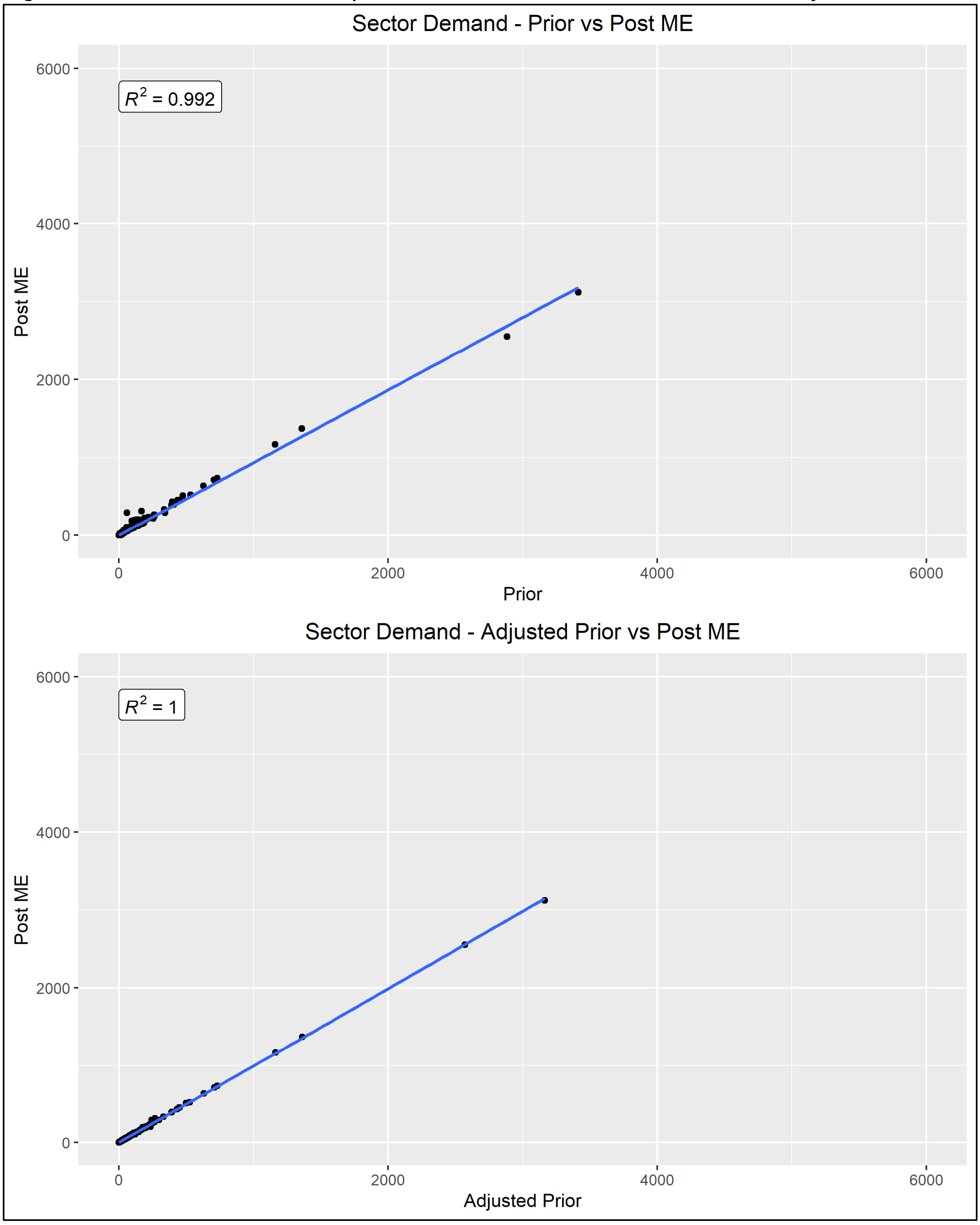


Figure E.3 - Commute PM – comparison between Prior vs Post ME and Adjusted Prior vs Post ME

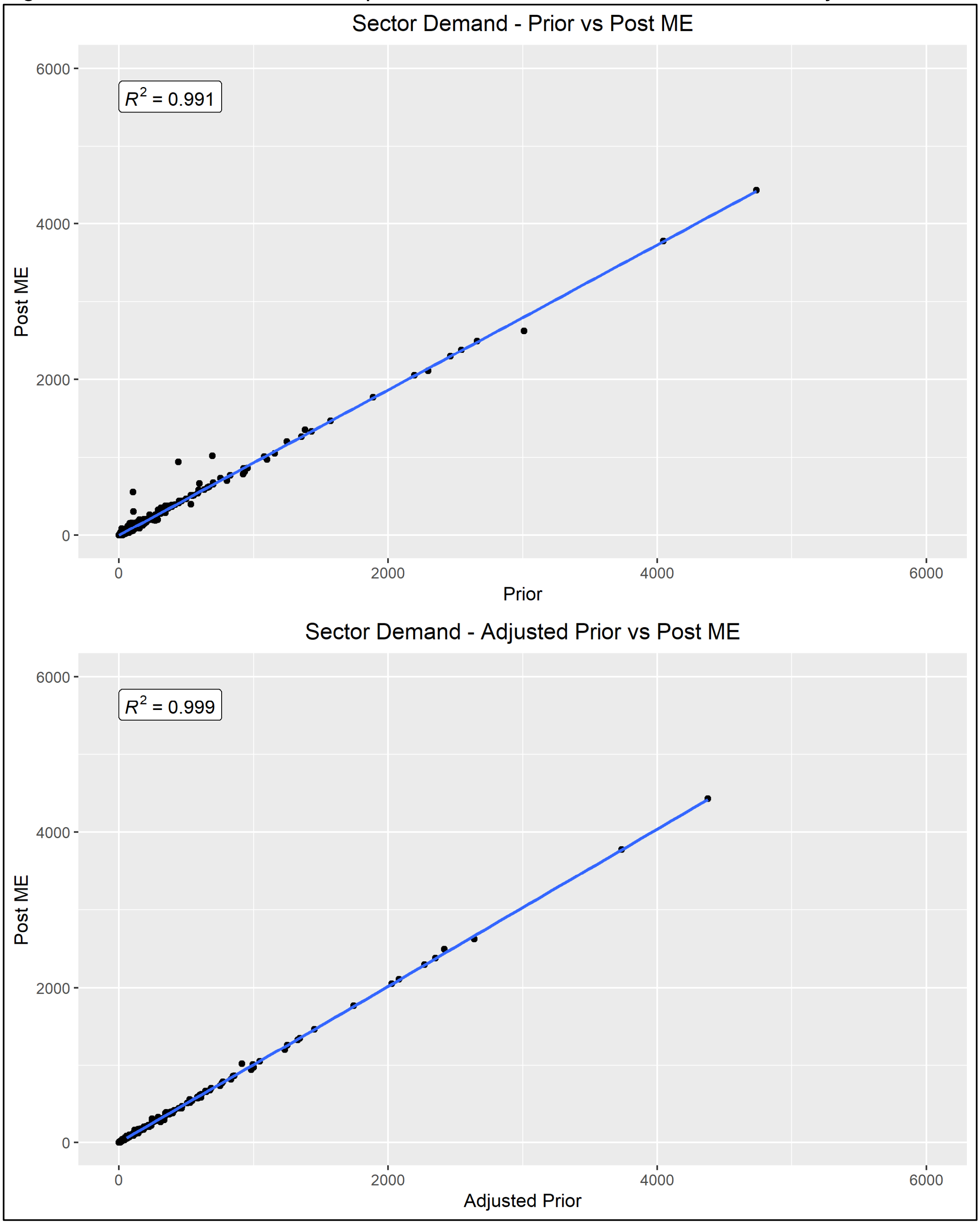


Figure E.4 – Employer's Business AM – comparison between Prior vs Post ME and Adjusted Prior vs Post ME

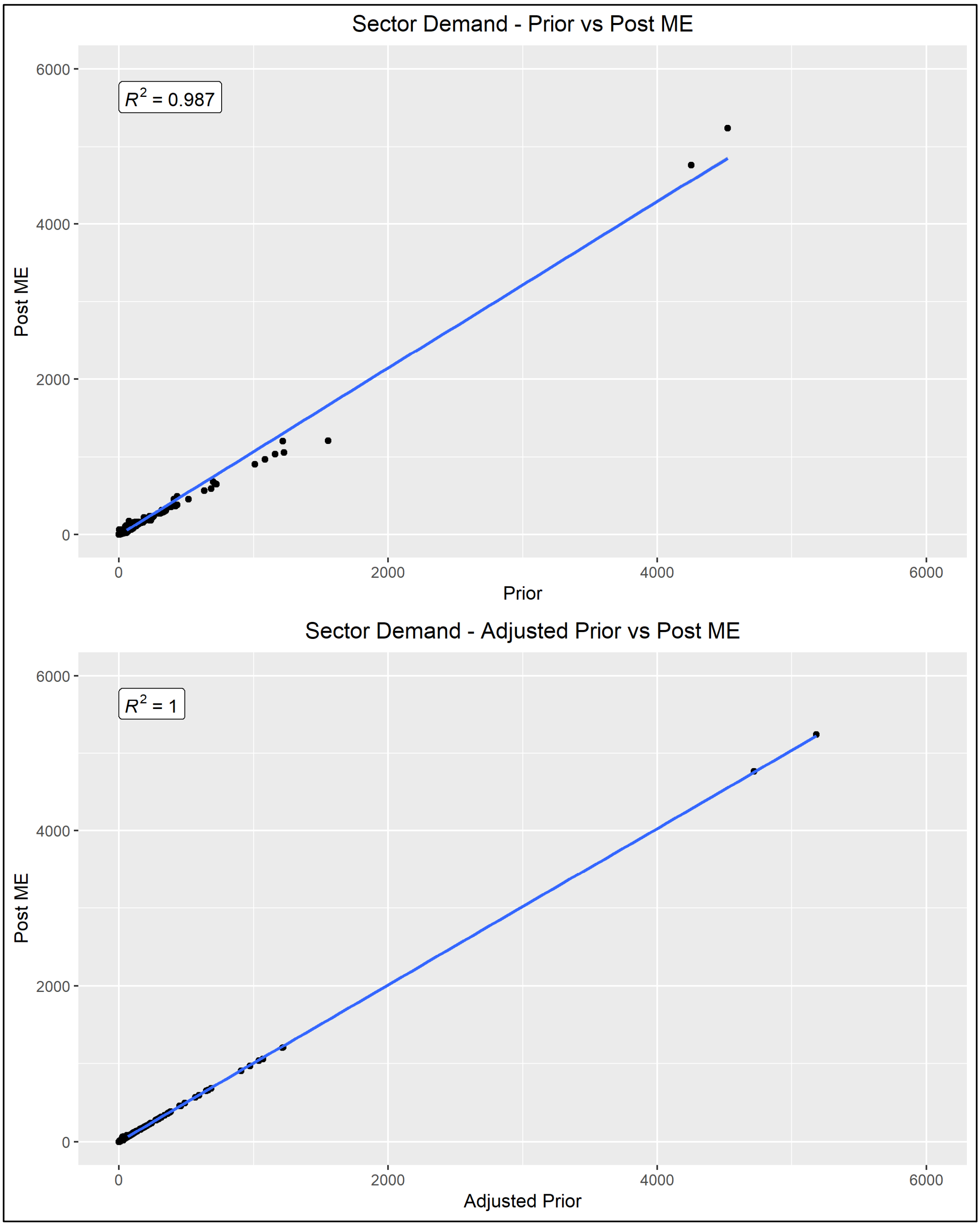


Figure E.5 – Employer's Business IP – comparison between Prior vs Post ME and Adjusted Prior vs Post ME

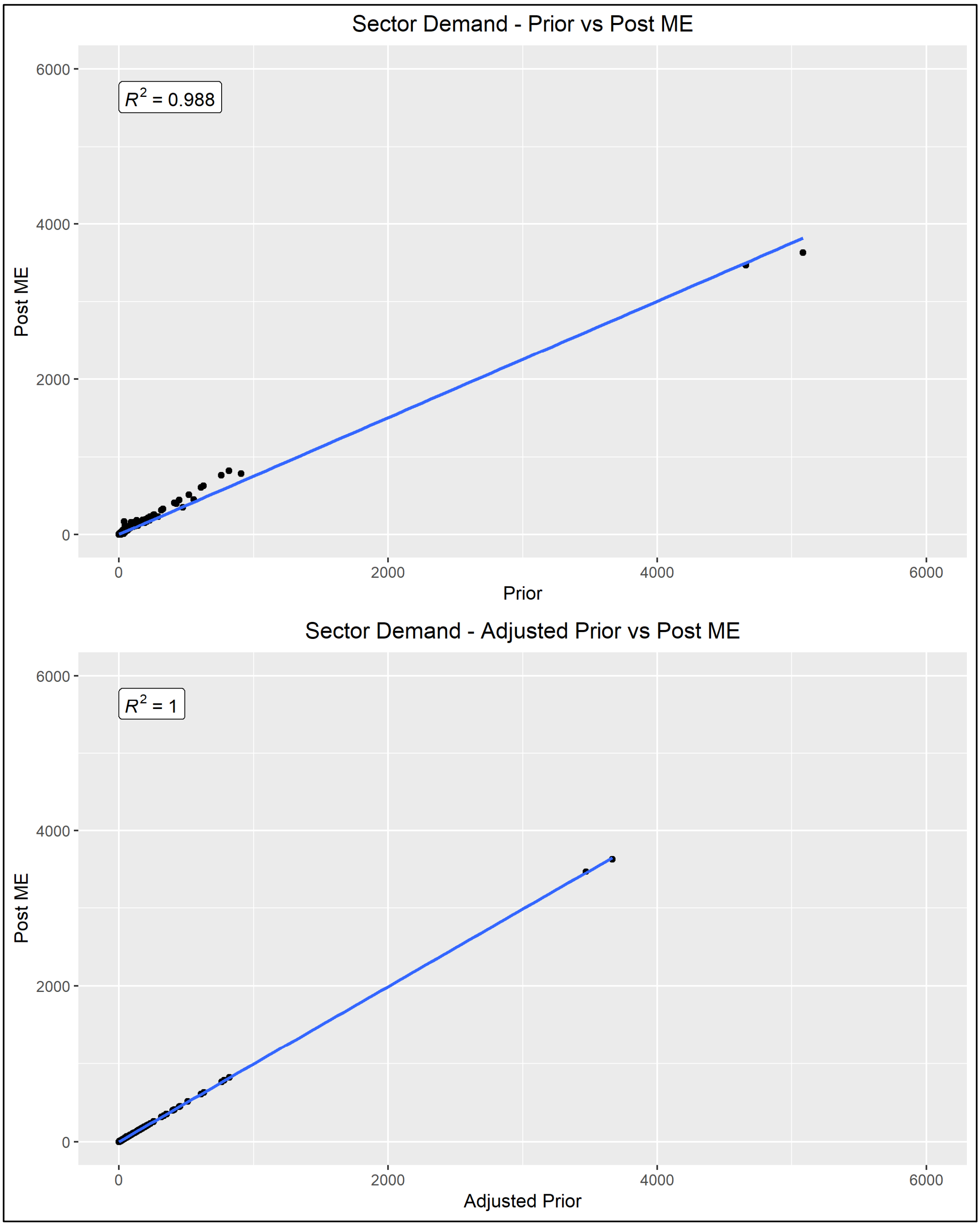


Figure E.6 – Employer's Business PM – comparison between Prior vs Post ME and Adjusted Prior vs Post ME

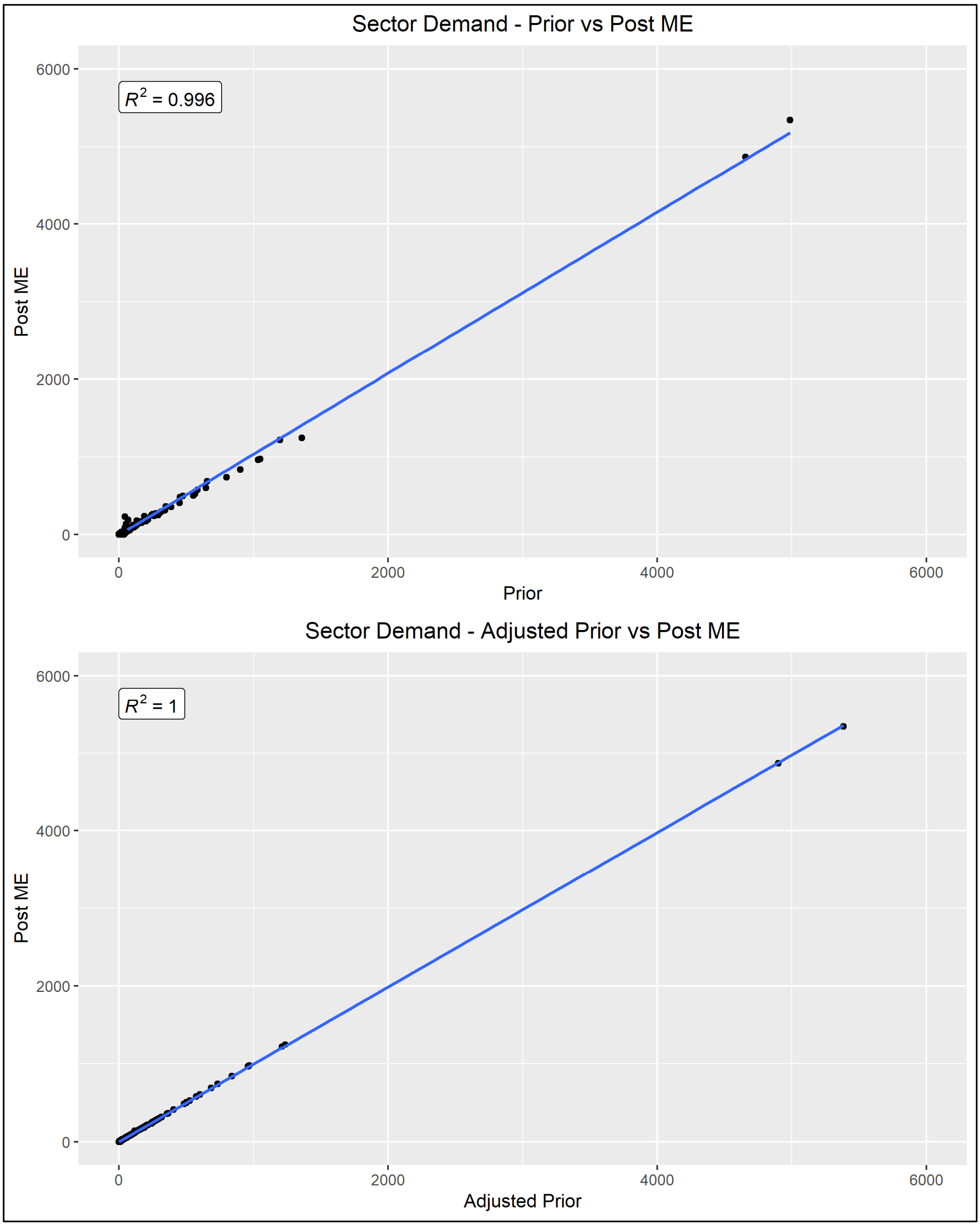


Figure E.7 – Other AM – comparison between Prior vs Post ME and Adjusted Prior vs Post ME

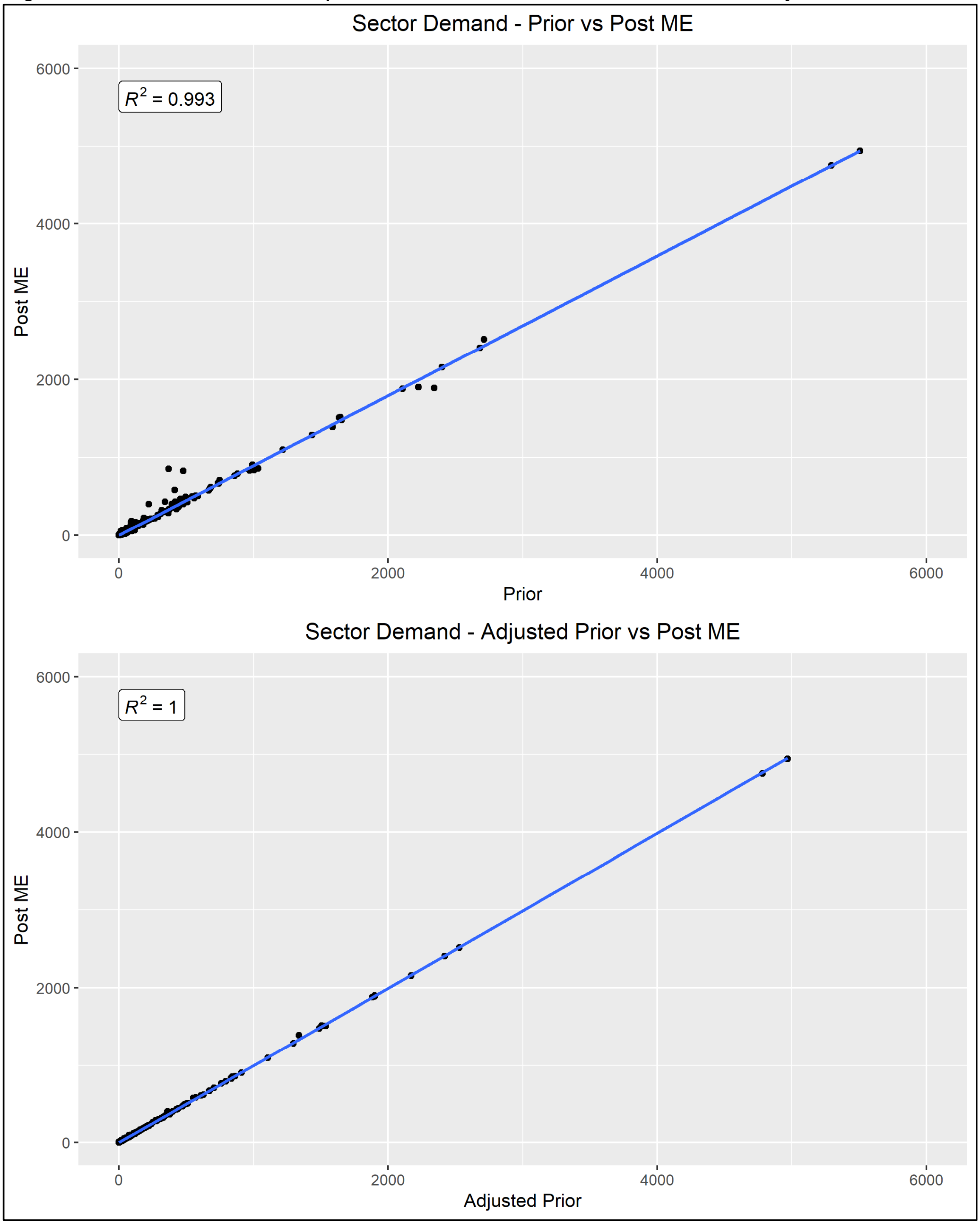


Figure E.8 – Other IP – comparison between Prior vs Post ME and Adjusted Prior vs Post ME

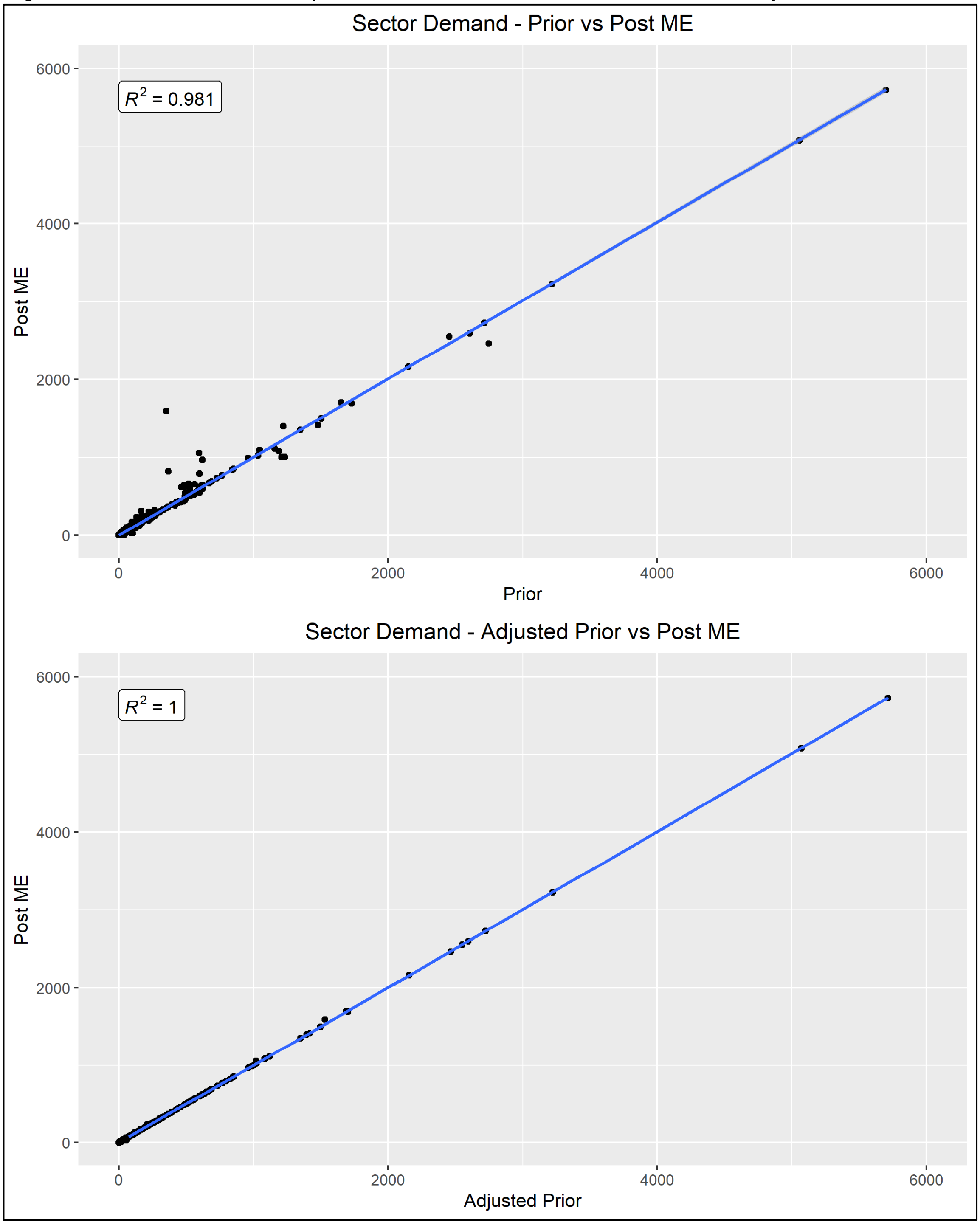


Figure E.9 – Other PM – comparison between Prior vs Post ME and Adjusted Prior vs Post ME