EB 033

Chelmsford Traffic and Access Strategy

Essex County Council

Variable Demand Model – Technical Note

Variable Demand Model | Final

April 2017

Essex County Council

Chelmsford Traffic and Access Strategy

Project no:	B3553T37
Document title:	Variable Demand Model – Technical Note
Document No.:	VDM Technical Note
Revision:	Final
Date:	23 August 2017
Client name:	Essex County Council
Client no:	Essex County Council
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File name:	O:\Projects\B3553F26 Chelmsford Modelling\1.Project Management\Deliverables\!Final Delivery 04042017\Variable Demand Model Final.docx

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Document history and status

Revision	Date	Description	By	Review	Approved
Draft	19/12/2016	Variable Demand Model Technical Note	Pablo Vilarino	Csaba Kelen	Csaba Kelen
Revised Draft	26/01/2017	Variable Demand Model Technical Note	Pablo Vilarino	Csaba Kelen	Csaba Kelen
Revised Draft	22/02/2017	Variable Demand Model Technical Note	Pablo Vilarino	Csaba Kelen	Csaba Kelen
Final	04/04/2017	Variable Demand Model Technical Note	Pablo Vilarino	Csaba Kelen	Csaba Kelen

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Executive Summary

This technical note summarises the development and performance of the Variable Demand Model (VDM) against WebTAG criteria, providing reassurance that the model meets guidance and is suitable for testing impacts of local developments. Standard technical reports about the Chelmsford Multi-modal Strategic Transport Model have been previously issued, such as the Model Specification Report (MSR), the Local Model Validation Report (LMVR) and the Travel Forecast Report (TFR). Due to the timing of the Variable Demand Model development within the project programme, this note is issued separately.

The VDM has been developed and validated according to the WebTAG guidance. The model consists of private transport (car) and public transport (rail and bus) modes. Trips have been further divided into three separate trip purposes (commute, business and other), in keeping with the guidance and allowing model outputs to be used for Economic Assessments. The model was developed for AM peak, average inter-peak and PM peak periods.

Chapters 2 and 3 briefly introduce the most important characteristics of the transport supply and demand models. Further details on these can be found in the LMVR.

Chapter 4 contains a detailed description of how the VDM procedure was implemented and the theoretical basis behind each decision or assumption made. Based on WebTAG recommendation, an incremental hierarchic mode and destination choice model was identified as the most suitable approach. (Time-of-day choice was excluded due to the characteristics of the demand.) The model calculates new generalised travel costs in each iteration, which are then compared against the base year in order to estimate the changes in travel patterns. Chapter 4, in addition, also contains intensive detailed explanation of the generalised cost formulation used, for Public and Private Transport, as well as the implemented convergence criteria.

For the purpose of demonstrating that the model produces plausible outputs, a series of realism tests were undertaken (and reported in Chapter 5) to validate the response of the VDM against the following scenarios: 10% Fuel Increase, 10% Public Transport Fare Increase and 10% Increase in Car Journey Times. Overall, the model has succeeded in converging to standard WebTAG criteria within the recommended advised boundaries.

Chapter 6 contains the Reference Case Growth Forecasts for year 2021 and 2036. The impact of the VDM model in forecasting future car and public transport demand has been calculated and is shown in detail. Finally, the VDM has been verified against a series of sensitivity tests in Chapter 7, demonstrating that the impact of uncertainty in calibrated sensitivity parameters was realistic and within the required limits.

1. Introduction

Chelmsford City is facing the challenge of meeting increasing travel demands while actively encouraging economic growth. Jacobs was commissioned to build a multi-modal transport model for the city of Chelmsford to understand the current and future transport issues in Chelmsford and successfully bid for funding that will be made available via the Local Enterprise Partnership (LEP) and national funding sources.

Further background to the study is provided in Essex County Council's "Essex County Growth Deal" which forms part of the South East Local Enterprise Partnership's (SELEP) £1.2 Billion bid to Government to leverage £10 Billion of investment into the South East. The Essex County Growth Deal identifies a number of transport schemes and initiatives to help realise and promote the growth planned for the city of Chelmsford.

The scale of the potential proposals is such that the funding approval process will require the development of WebTAG compliant transport models. To this end, a strategic multi-modal model was developed to assess the strategic transport impacts of the various transport schemes in the city. The model was needed to evaluate the following infrastructure and policy interventions, to be implemented in Chelmsford:

- Residential, industrial and commercial land use developments,
- Road infrastructure improvements (roadways, junctions),
- Public transport service improvements (stations/stops, routes, timetables),
- Public transport policy (fares, information),
- Parking infrastructure and policy (car parks, parking costs),
- Cycling infrastructure and policy (bicycle lanes, parking).

The VDM is a standard model component of strategic transport models. The Chelmsford model VDM is composed of mode and destination choice components for three demand purposes (commute, business and other trips) and two modes of transport (car and public transport). The VDM model provides the basis for robust assessment of future changes in demand due to new infrastructure development or changes in transport policies.

PTV's VISUM14 software package was used for the VDM modelling, in order to retain consistency with the rest of the Chelmsford Strategic Model. The model was built with detailed network coverage of the whole Chelmsford Administrative and the Urban Area extending beyond its boundaries to ensure detailed representation of the key adjacent areas.

In summary, the final model was built to support the delivery of Major Scheme Business Cases (MSBCs) and an Economic Strategy of Chelmsford. The model is also able to estimate the local impact of infrastructure and policy schemes in rural Essex. However, the level of detail of the Chelmsford Model in rural Essex is such that the model cannot support MSBC analyses of rural schemes, where the impact area stretches beyond Chelmsford.

2. Transport Supply Model

2.1 Purpose of the Model

The VDM represents an additional model component to the previously developed Strategic Multi-Modal Transport Model, described in the LMVR submitted in August 2016.

This additional component represents an attempt to achieve a better understanding of future transport problems within Chelmsford Administrative Area and provide relevant forecasts to be used when bidding for funding via the Local Enterprise Partnership (LEP) and national funding sources.

The VDM component has been designed to predict changes in travellers' behaviour, such as mode and destination choice, in response to alterations to the travel conditions, such as trip time and out of cost. Therefore, the VDM model provides a better representation of future travel patterns.

2.2 Fully Modelled and External Area

The extent of the detailed modelling area was defined by the region where the level of impact, of the anticipated schemes, is expected to be significant, and, therefore, the granularity of the network and demand matrices needs to be at its greatest.

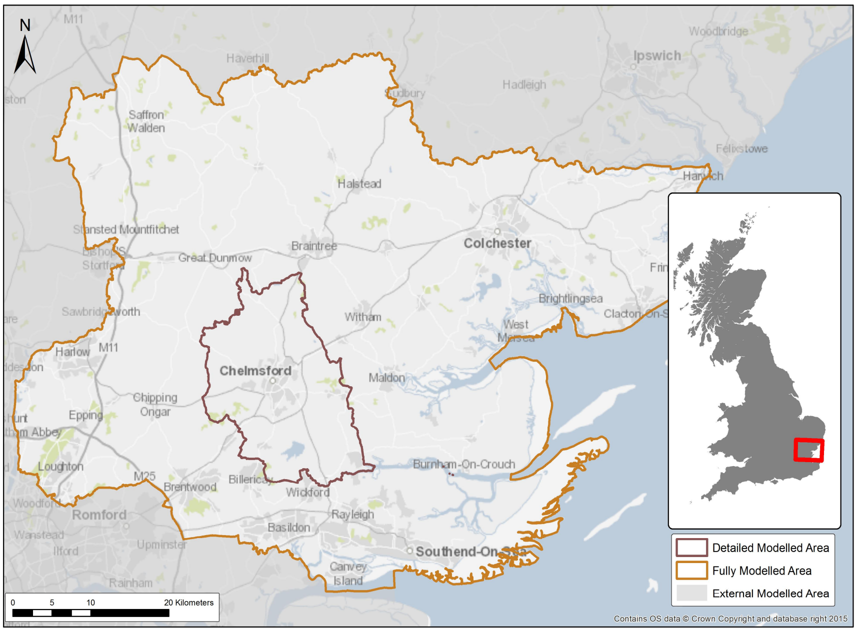

Figure 1 Detail of modelled areas

2.3 Transport Supply Model

This section describes the process and methodologies used to build the modelled network. In creating the network, consideration was given to the level of spatial detail required at different locations within and outside the study area. For further details on this, please refer to Chapters 2 and 4 of the previously submitted LMVR.

2.3.1 Highway Network Data

The purpose of the supply model is to represent the network topology and the physical properties of the highway network that provide accessibility to the city of Chelmsford.

The highway network inside the Chelmsford Urban Area includes all streets and roads that are used by vehicles. The remainder of the Chelmsford Administrative Area also includes all major and minor roads, but only proportional treatment of local roads. Outside of the Chelmsford Administrative Area major and minor roads are coded while the model gradually reduces its resolution as further away from the Essex County boundaries. Figure 2 below shows a schematic map of the different areas.

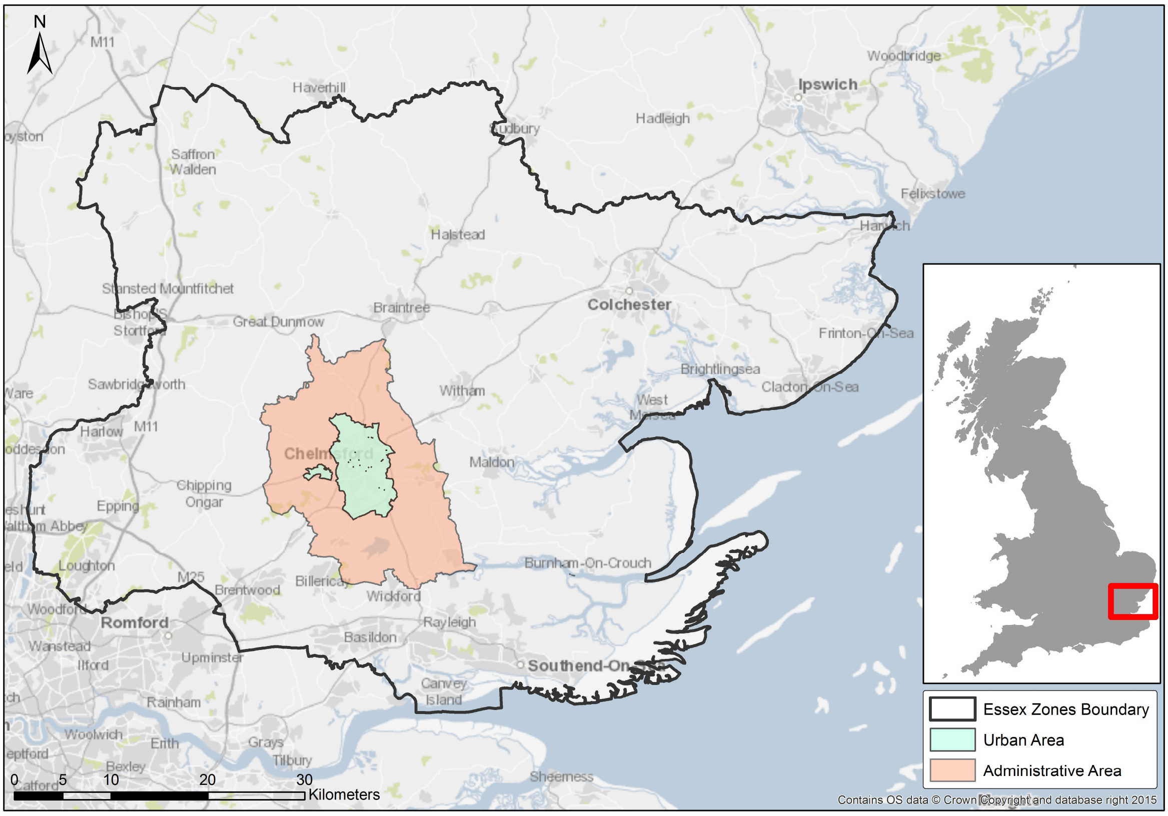

Figure 2 Administrative and Urban Areas

A total of 96 different highways classes or types were coded into the VISUM software, classifying roads based characteristics such as: road class, number of lanes, speeds, and modes allowed, etc. A full list of all the defined link types can be found on Appendix A of the LMVR.

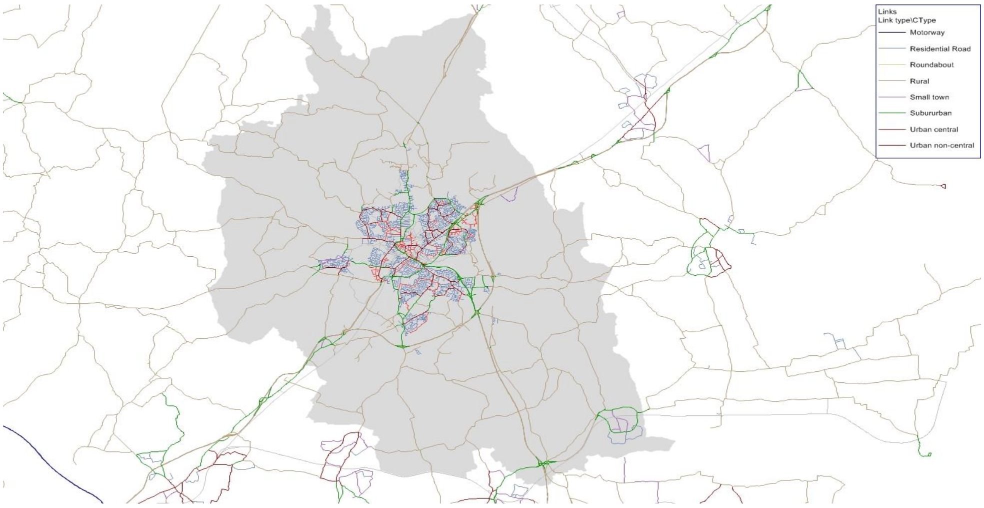

Figure 3 Summary of link types used

In the external model area, only major highways (selected Motorways, A roads and B roads) were coded in order to provide good levels of accessibility to the Essex and Chelmsford Administrative areas.

In order to ensure that delays are fully represented in the model, it was necessary to code all junctions which have the potential to generate traffic delays. In the detailed model area, (Administrative Area), all junctions have been modelled explicitly while the remaining junctions use the default VISUM control type, (uncontrolled). For those junctions within the Chelmsford's Administrative Area junction modelling was calculated within VISUM as explained in Chapter 4 of the LMVR.

2.3.2 Zone Connectors

Centroid connectors were designed, where possible, to represent actual means of access to and egress from the modelled network, while making sure they did not cross real existing barriers to vehicles.

Following WebTAG guidance, direct connection of centroids into main links and modelled junctions was avoided for the Detailed Model Area and, where needed, specific arms were coded into the junction in order to accommodate the movements.

For further details on the system of connectors please refer to the LMVR Chapter 4.1.41 to 49.

2.4 Public Transport Network

The model includes every Public Transport service (rail, coach and local bus), which serves the modelled area (Chelmsford Administrative Area). Individual lines and timetables were coded separately for each different variation.

Services that are either partially inside of the Chelmsford Administrative Area or within the Essex County boundaries are also fully represented. More detail about the selection of services that were coded can be seen in the LMVR Chapter 4.2.

Beyond the strategic model area, the following Public Transport services were coded*:*

- National railway lines
- London Underground lines
- Interurban bus services

- Local bus services

The following auxiliary network components were also coded in the model, at differing levels of detail depending on their proximity to the internal model area:

- Walk access/egress connectors and links
- Drive access/egress connectors and links

For more details please refer to LMVR Chapter 4.2.

3. Transportation Demand Model

3.1 Model Characteristics

3.1.1 Zonal Structure

The model uses geographic zones to represent locations of trip origins and destinations. The level of zonal detail in the model will vary, losing granularity, away from the detailed model area according to the illustration below.

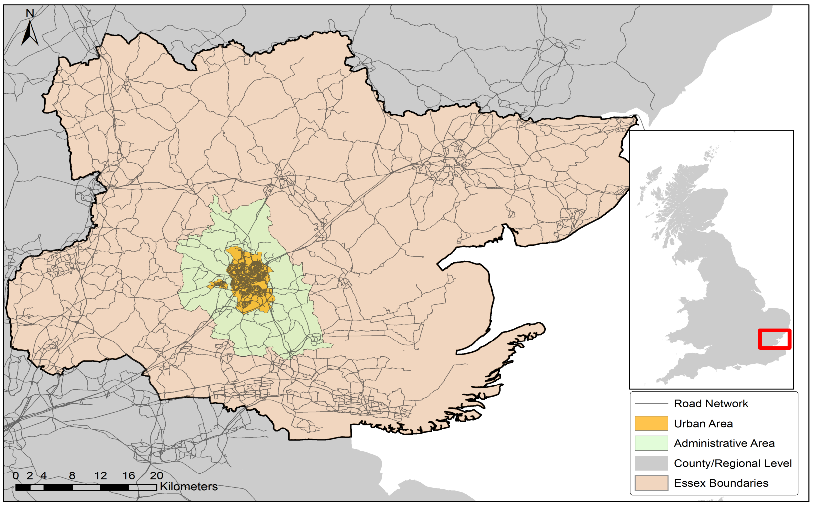

Figure 4 Zonal structure level of detail

The zone structure by geographic area is summarised in the table below. For further details please refer to Chapter 2.4 of the LMVR.

Table 1 Zonal Structure summary table

Geographic Area	Zone ID	Number of Zones
Chelmsford Admin Area	1-146 (excluding 115)	143
Essex Area	147-269 (including 115)	122
Rest of mainland UK	301-321	21
Total		**286**

3.1.2 Journey purpose, vehicle class and user class segmentation

Due to the different trip patterns that different trip purposes are known to have, the model was designed to distinguish between different trip purposes, Table 2.

Physical attributes of vehicles are also known to influence and affect the usage and capacity of the physical existing network. For these reasons, different vehicle classes were also introduced in the calculations.

User classes and a combination of modes and purposes were used to define the parameter values in the Assignment Model. The relationships between purpose, vehicle class and user class are summarised in Table 2 below.

Table 2 Purpose, user class and vehicle class correspondence

Purpose	User Class (UC)	Vehicle Class (VC)
Home Based Work (HBW)	UC1: Commute	VC1:Car
Home Based Employer's Business (HBEB)	UC2: Business	
Non-Home Based Employer's Business (NHBEB)		
Home Based Other (HBO)	UC3: Other	
Non-Home Based Other (NHBO)		
Light Goods Vehicles (LGVs) (All Trips)	UC4: LGV	VC2: LGV
Heavy Goods Vehicles (HGVs) (All Trips)	UC5: HGV	VC3: HGV
Cycles (All Purposes)	UC6: Cycle	VC3: Cycle

In line with WebTAG Unit 2.6, user classes were defined to differentiate between travellers with various perceptions of travel cost, such as commute, business and other trips. Light and Heavy Goods Vehicles on employers' business are kept separate from cars on employers' business as their origins, destinations and trip distribution are likely to be substantially different.

All user classes have a Passenger Car Unit (PCU) factor of 1 with the exception of User Class 5 (HGV), which has an average PCU factor of 2.5. This reflects the greater size of HGVs in comparison with cars.

Buses were loaded onto the network as fixed pre-loads based on the coded timetables, therefore, they do not form part of a discrete assignment user class.

3.1.3 Modelled Time Periods

The highway assignment model was built to represent three modelled time periods due to a need to provide assessment and forecasting capability of morning peak, evening peak and inter-peak periods traffic conditions, to allow policy makers to understand both strategic and local impacts of developments, infrastructure improvements and policy measures. In line with WebTAG M3.1 section 2.5, the demand matrices were developed to provide information for the following standard time periods:

- Morning peak (07:00-10:00)
- Inter-peak period (10:00-16:00)
- Evening peak (16:00-19:00)

The assignment models were developed for the peak hours in order model the most critical traffic conditions. The following standard time periods were used:

- Morning peak hour (08:00-09:00)
- Average inter-peak hour (average hour, 12:00-13:00)
- Evening peak hour (17:00-18:00)

The exact times over which the morning and evening peak hours occurred were confirmed by using local traffic and passenger count data, please refer to LMVR Chapter 2.6 for further details.

3.1.3.1.1 Modelled time horizons

This study uses mobile phone data as its primary data source for building travel demand matrices for the base year. The methods used in the development of travel matrices for this study are described in detail within Chapter 5 of the LMVR.

The client requested that the forecast year model be developed for years 2021 and 2036 to be consistent with the council planning horizon. Local planning data was used to inform the forecast year models. Please refer to the Traffic Forecast Report submitted in August 2016 for further details of the forecasting.

Both current and future planning data were supplied by Essex County Council and Chelmsford City Council.

3.2 Base Year Model (2014)

3.2.1 Base year demand model

Base year demand matrices were developed from mobile phone data, and were verified and adjusted by using third party data sources. Subsequently, the prior matrices were calibrated in order to achieve an acceptable match with existing calibration count sites. Finally, the highway matrices were validated according to the WebTAG model validation methodology.

Similarly, the public transport matrices were calibrated and validated against available passenger count data.

Please refer to the Chapter 5.6 in the LMVR for further details on the post-processing of demand matrices, and Chapter 7 of the same document for further details on the Calibration and Validation.

3.3 Highway Assignment Methodology

The demand assignment on the highway network is based on Wardrop's principle of traffic equilibrium, as described in WebTAG M1.1 Section 4.4.

The calculation of the costs, for each route, is based on that calculated after all demand is loaded onto the network, taking into account delays due to the coded speed-flow relationships and modelled junction.

The assignment methodology used within the VISUM model was "Assignment with ICA". For further details on this refer to Chapter 2.9 of the LMVR.

3.4 Public Transport Assignment Methodology

Public Transport Assignment is timetable-based, which is the usual choice for public transport networks with long headways.

More details about the Public Transport Assignment Methodology and cost calculation can be found at LMVR Chapter 6.3.

4. Variable Demand Model

4.1 Introduction

In order to establish model responsiveness to travel demand, an incremental choice model was built with destination and mode choice components and calibrated following WebTAG guidance.

The choice model is formulated as a hierarchic choice model, as illustrated in Figure 5.

Initial model parameter values of the destination and mode choice models were obtained from comparative UK studies from WebTAG Unit M-2 Section 5.6. These values, as advised by WebTAG Unit M2 Chapter 6, were adjusted throughout the calibration of the VDM to improve model elasticities in order to fit to the provided advised values. This is further explained within Chapter 5 of this report.

The VDM calculates new travelling costs, on each iteration, for each demand segment and mode, and compares these against base year values. These changes in cost are then fed into the choice model, which estimates the following:

- Changes in mode choice between the car and public transport
- Changes to trip distribution

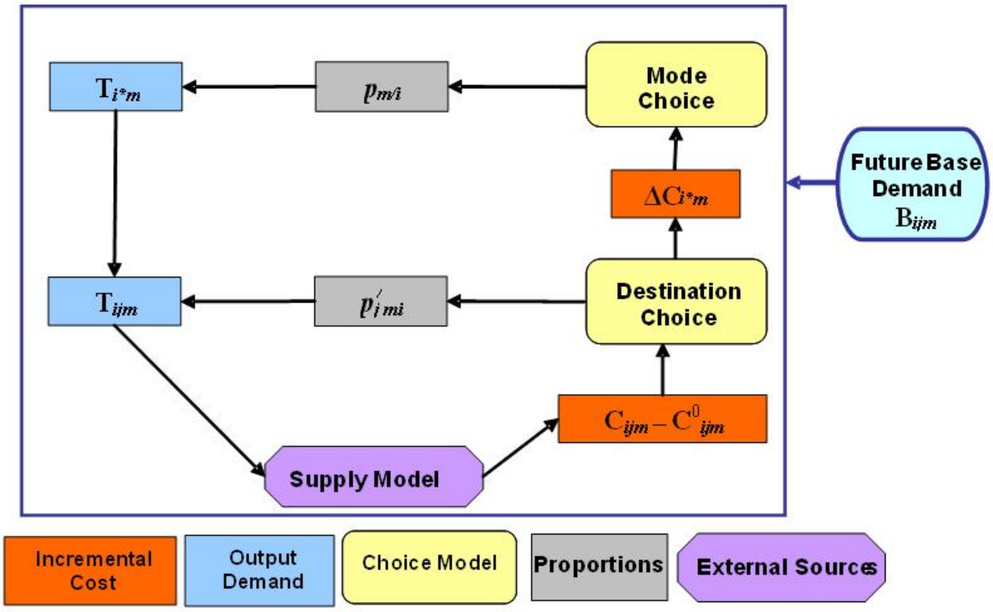

Figure 5 Hierarchic choice model summary

Following advice from WebTAG U2 Chapter 4.9.10, 11 and 13, an incremental destination choice model was selected with doubly constrained process for business and commuting trips. This allows the number of trips that are allocated to each attraction to change while keeping total number of attractions to the number of trips produced. Other purpose trips were run as a singly constrained process, allowing in this case a bigger degree of change.

4.2 Generalised cost functions

WebTAG Unit 2 on its Chapter 3 states that: "All transport modelling should recognise that people's travel choices depend upon the cost, in both time and money". It is for this reason that it becomes critical to combine both of these elements into a single formula so that demand can respond to changes in either of them. It is for this purpose that a Generalised Cost Function, with appropriate weights, must be introduced so that travellers can trade money for time when deciding on the mode and destination.

WebTAG also advices that different types of users will trade time and money in different ways, depending on the purpose of the trip or mode chosen, becoming therefore necessary to define different equations for the different user classes within the model. For this purpose different VOC, VOT, occupancy and α values are used in the Generalised Cost Functions described below.

4.2.1 Highway Generalised Cost Function

The highway generalised cost of the VDM model combines in-vehicle journey times, trip-end walk times, trip distances and any out of pocket costs (parking) into a standard unit of generalised time, using standard WebTAG based VOC (pence per minute) and VOT (pence per kilometre) parameters. The formulation is summarized below.

$$GC_{Car} = t_{walk} * \vartheta_{walktime} + t_{ride} + \frac{d * VOC}{(occ * VOT)} + \frac{C_{park} * \alpha}{(occ * VOT)}$$

Where:

t_{walk} : Walking access and egress time,

$\vartheta_{walktime}$: Walking access and egress time penalty ($\vartheta_{walktime} = 2$),

t_{ride} : Ride time (In-vehicle time),

d: Distance,

VOC: Vehicle operating costs (WebTAG Databook M2.1 / M2.2 / A1.3.2),

VOT: Value of time (WebTAG Databook A1.3.4),

occ: Vehicle occupancy (WebTAG Databook A1.3.3),

C_{park} : Parking cost,

α: Car park factor by trip purpose (2 for commute/business, 1 for other trips).

The components within the equation above, with the exception of t_{walk} and C_{park} explained below, are all either purpose, time period or mode specific constants, selected based on guidance from WebTAG Unit M2, or skim matrices from the calibrated and assigned model network.

Parking cost, C_{park} , was calculated based on a series of assumptions, depending on each trip origin and destination. By default every trip was charged with a flat base value depending on the trip's origin and destination location, see figure below for a spatial representation of the areas mentioned.

- Central Zone (Orange Zone) £2.20
- Buffer of Central Zone (Blue Zone) £1.50
- London £2.50

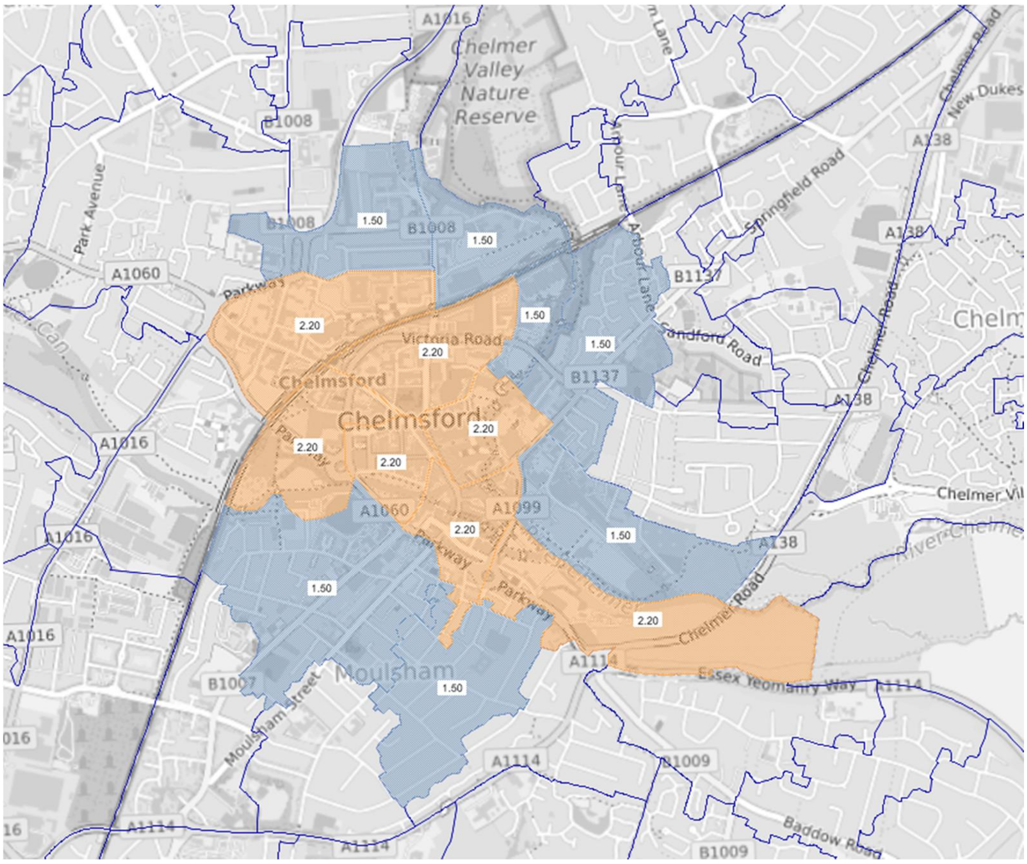

Figure 6 Location of central and buffer zones of Chelmsford

Walking access and egress time, t_{walk} , was calculated based on a series of assumptions, depending on each trip origin and destination. By default every trip was charged with a flat base value of 1 minute for each trip end inside the Chelmsford Administrative Area. In addition the following supplements were added depending on the trip's origin and destination location:

- Central Zone (Orange Zone)
  - Trips with their origin inside the Central Zone of Chelmsford +2 minutes
  - Trips with their destination inside the Central Zone of Chelmsford +3 minutes
- Buffer of Central Zone (Blue Zone)
  - Trips with their origin inside the Buffer of Central Zone of Chelmsford +1 minutes
  - Trips with their destination inside the Buffer of Central Zone of Chelmsford +2 minutes
- London
  - Trips with their origin inside London +2 minutes
  - Trips with their destination inside London +4 minutes
- Rest of external zones
  - Trips with their origin inside rest of external zones +1 minutes
  - Trips with their destination inside of external zones +2 minutes

4.2.2 Public Transport Generalised Cost Function

The public transport generalised cost combines journey times and out of pocket cost such as fares into a standard unit of generalised time, using standard VOT (pence per kilometre) parameters. Fares are calculated on the bases of in vehicle distance for interurban services, and by flat fare for urban services.

$$GC_{PuT} = t_{walk} * \vartheta_{walk} + t_{wait} * \vartheta_{wait} + t_{ride} + \frac{C_{fare}}{VOT} + C_{transfer} * n_{transfer}$$

Where:

- t_{walk} : Walking access and egress time
- ϑ_{walk} : Walking access and egress time penalty ($\vartheta_{walktime}$ = 2)
- t_{wait} : Initial wait time
- ϑ_{wait} : Initial wait time penalty ($\vartheta_{waittime}$ = 2)
- t_{ride} : Ride time (In-vehicle time)
- C_{fare}: Fare
- VOT: Value of time (WebTAG Databook A1.3.4)
- $C_{transfer}$: transfer penalty ($C_{transfer}$ = 10)
- $n_{transfer}$: Number of interchanges

The components within the previous equation are all purpose, time period or mode specific constants, selected based on guidance from WebTAG Unit M2, or skim matrices from the calibrated and assigned model network.

Fares were calculated for the four types of service available in the modelled area: rail, underground, long distance bus and local bus. Fares are represented in the form of a flat component, and a distance based component. Values of the flat and distance-based components were determined by collecting fare data and fare policy information from the websites of Transport for London, Network Rail and First, the main bus operator in Essex. The fare structure used in the model is summarised below:

- Rail
  - £2.00 flat supplement
  - 0.20 £/km with a maximum fee of £200
- London underground and DLR
  - £2.00 flat supplement
  - 0.35 £/km with a maximum fee of £8.50
- Long distance bus
  - £2.00 flat supplement

   - o 0.15 £/km with a maximum fee of £6.00
- · Local bus
   - o £2.00 flat supplement only

4.3 Selection of lambda sensitivity parameters

Following advice from WebTAG Unit M2 chapter 6.5.5, median lambdas and thetas were adopted as a starting point for the calibration of the VDM. This is the standard approach recommended for those cases were no locally calibrated data is available. These median values are the result of a study undertaken by the Department for Transport for a number of UK transport models. These values were revised and modified accordingly during the realism testing of the model, as explained later on this report.

The initial sensitivity parameters of the VDM model are shown below:

Table 3 Sensitivity Parameters AM

Purpose	Sensitivity Parameters AM		
	Destination Highway (lambda-hw)	Destination PT (lambda-pt)	Mode (Lambda)
Commute	0.065	0.033	0.023
Business	0.069	0.037	0.018
Other	0.088	0.036	0.022

Table 4 Sensitivity Parameters IP

Purpose	Sensitivity Parameters IP		
	Destination Highway (lambda-hw)	Destination PT (lambda-pt)	Mode (Lambda)
Commute	0.065	0.033	0.033
Business	0.070	0.038	0.039
Other	0.087	0.035	0.035

Table 5 Sensitivity Parameters PM

Purpose	Sensitivity Parameters PM		
	Destination Highway (lambda-hw)	Destination PT (lambda-pt)	Mode (Lambda)
Commute	0.065	0.033	0.023
Business	0.070	0.039	0.020
Other	0.088	0.035	0.023

4.4 Convergence

In order to have enough confidence that the model is robust and the results as unbiased and free from error as possible, it is of crucial importance to demonstrate that the model converges to a satisfactory degree.

WebTAG U2 6.3.4 recommends convergence within the VDM to be measured through the relative gap between the demand and assignment models, as expressed below:

$$\frac{\sum_{ijctm} C(X_{ijctm})\,|D(C(X_{ijctm})) - X_{ijctm}|}{\sum_{ijctm} C(X_{ijctm})X_{ijctm}} * 100$$

where:

- X_{ijctm}: is the matrix from the model;
- $C(D_{ijctm})$: is the cost matrix derived from the current matrix;
- $D(C(D_{ijctm}))$: is the matrix output by the demand model using the above cost as input; and
- $ijctm$: represents the origin i, destination j, user class c, time period t and mode m.

This unit represents a measure of how far the current flow is from the equilibrium point and would, therefore, in a perfectly converged model be 0. However, WebTAG Unit M2 Paragraph 6.3.8 suggests that a relative gap under 0.2% is recommended.

5. Realism testing

5.1 Introduction

It is essential for any model to demonstrate its plausibility by ensuring it behaves realistically. For this purpose and following guidance from WebTAG Unit 2 Chapter 6.4, a series of realism tests were undertaken by changing various components of travel costs and times and checking the overall demand response.

The acceptability of the model's responses to changes in costs and journey times is determined by its demand elasticities. Specifically, the model tests are expected to demonstrate the VDM responsiveness to changes in car fuel cost, public transport fare and car journey times. The realism tests, required by WebTAG M2, Section 6.4, are the following:

- Fuel Cost increase impact on Vehicle kilometres (10% or 20%)
- General PT Fare increase impact on Trips (10% or 20%)
- Change in car journey time impact on Trips (due to congestion)

The acceptability of how a demand model responds to changes in costs is through the demand elasticity of the base year model. The demand elasticity calculates the proportional change in demand of changes in costs or time within the calibrated base year model and is calculated using the formula below:

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

Where:

- T0 and T1 are the trips before and after the changes in cost
- C0 to C1 are journey costs before and after the changes
- e is the elasticity of demand

WebTAG Unit M2 paragraph 6.4.14, based on a number of UK studies on car travel and fuel prices and costs, suggests that car use elasticity with respect to fuel cost increments should report to be around -0.3. In addition, the Department's view is that:

- Annual average fuel cost elasticity should lie within -0.25 and -0.35

The guidance, paragraph 6.4.17, also suggests that elasticities may be regarded as more plausible if:

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

Elasticities of Public Transport trips with respect to increases in fares are advised to lie between a range from -0.2 to -0.9, considering values close to the -0.2 extreme to be unlikely and considering the elasticities also to be more plausible if:

- The pattern of average public transport fare elasticities show peak values for non-discretionary purposes which are lower than those for discretionary trips; and
- The pattern of all-purpose elasticities shows peak period elasticities which are lower than those for the inter-peak.

With regard to journey time elasticities WebTAG U2 6.4.28 suggests that output elasticities should be checked to ensure that values are not stronger than 2.00.

Table 6 below summarises the recommended elasticities that should be achieved during the realism testing as outlined by WebTAG.

Table 6 Summary of WebTAG required elasticities for realism testing

Realism Test	High	Low
Average Fuel Cost (veh km)	-0.35	-0.25
PT Main Mode Fare (trips)	-0.90	-0.20
Car Journey Time (trips)	No stronger than -2.0	

5.2 Model adjustments

Due to the uncertainty around the sensitivity parameters, lambdas, and following WebTAG advice, the VDM realism testing starting point was using median lambdas and thetas while implementing a cautious and systematic process of modifying these parameters.

WebTAG Unit 2 paragraph 6.5.6 suggests that revised lambdas and thetas which are within ±25%of the median illustrative values would be regarded as acceptable.

During the process of calibrating the model a series of lambdas and thetas were used, always within the ranges specified by WebTAG. The tables below contain the final set of values used. Please refer to **Error! Reference source not found.**for a full record of all the changes made to the sensitivity parameter during the calibration process.

Table 7 Calibrated sensitivity parameters AM

Purpose	Sensitivity Parameters AM		
	Destination Highway (lambda-hw)	Destination PT (lambda-pt)	Mode (Lambda)
Commute	0.052	0.033	0.023
Business	0.062	0.037	0.018
Other	0.070	0.036	0.020

Table 8 Calibrated sensitivity parameters IP

Purpose	Sensitivity Parameters IP		
	Destination Highway (lambda-hw)	Destination PT (lambda-pt)	Mode (Lambda)
Commute	0.072	0.033	0.023
Business	0.077	0.038	0.019
Other	0.070	0.035	0.021

Table 9 Calibrated sensitivity parameters PM

Purpose	Sensitivity Parameters PM		
	Destination Highway (lambda-hw)	Destination PT (lambda-pt)	Mode (Lambda)
Commute	0.052	0.033	0.023
Business	0.070	0.039	0.020
Other	0.088	0.035	0.023

In addition to all the changes made to the sensitivity parameters, and based on WebTAG Unit M2 paragraph 6.5.2, a cost damping function was implemented.

WebTAG prescribes the application of cost damping in those instances where a model fails to yield elasticities within WebTAG specified ranges. In view of early analyses of outturn elasticities revealing the model's high sensitivity to cost changes as a result of longer distance trips, a decision was taken to employ generalised cost damping as a function of distance, see the formula below:

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

where:

- t, 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;
- G': is the damped generalised cost;
- d: is the trip length; and
- α and k: parameters that need to be calibrated.

Following advice from WebTAG Unit M2 Chapter 3.3.10 final values of $\alpha = 0.5$ and $k = 30\ km$ were employed.

5.3 Results of realism testing

Table 10 below summarise the elasticities achieved for the realism testing after the model calibration. Based on the WebTAG guidance and as explained above, the following realism tests were performed and their results compared against WebTAG criteria Table 6:

- 10% fuel cost increase impact on vehicle kilometres;
- 10% general PT fare increase impact on public transport trips; and
- 10% increase in car journey time impact number of car trips.

Table 10 Summary of elasticities after Realism Testing

Purpose	Fuel Cost Increase All Periods	Fare Cost Increase All Periods	Journey Time Increase All Periods
Business	-0.079	-0.317	-0.484
Other	-0.410	-0.772	-0.841
Commute	-0.212	-0.699	-0.353
All	-0.317	-0.727	-0.627

5.3.1 Fuel cost increase realism test results

Based on the elasticities in Table 10 and WebTAG requirements in Table 6 all the mentioned tests show that the elasticities lie within the required WebTAG intervals.

In addition, the guidance in paragraph 6.4.17 also suggests that elasticities may be regarded as more plausible if average elasticities show:

- Employers' business elasticities near to -0.1, in our case -0.08, other trips elasticities around -0.4, in our case -0.41, and for commuting purposes somewhere in between, in our case -0.21.
- Peak period elasticities to be weaker than inter-peak. In our case, the AM and PM peak periods are reported to be -0.298 and -0.225 against a stronger inter-peak elasticity of -0.40.

Table 11 Summary of elasticities after Realism Testing, 10% fuel cost increase

10% Fuel cost increase impact on vehicle kilometres				
Purpose	AM	IP	PM	12 hours
Business	-0.081	-0.091	-0.058	-0.079
Other	-0.395	-0.461	-0.284	-0.410
Commute	-0.219	-0.230	-0.200	-0.212
All	-0.298	-0.400	-0.225	-0.317

5.3.2 PT fare cost increase realism test results

As mentioned in Chapter 5.1 of this report, the elasticity of Public Transport trip kilometres with respect to fare cost increase should lie below -0.90. Table 10 and Table 12 both show an average elasticity for a 10% fare cost increase of -0.727, falling within the required boundaries.

Table 12 Summary of elasticities after Realism Testing, 10% fare cost increase

10% Fare increase impact on Public Transport Trips				
Purpose	AM	IP	PM	12 hours
Business	-0.381	-0.338	-0.251	-0.317
Other	-0.754	-0.790	-0.773	-0.772
Commute	-0.555	-0.928	-0.888	-0.699
All	-0.654	-0.794	-0.782	-0.727

In addition, the guidance in paragraph 6.4.22 also suggests that elasticities may be regarded as more plausible if average elasticities show:

- Business and Work to be lower, or weaker, than for Other trips. In our case this is true for every time period.
- AM and PM values to be weaker than inter-peak. In our case AM and PM are -0.654 and -0.782 against -0.794 for the inter-peak.

5.3.3 Car journey time increase realism test results

Car journey time elasticities were calculated using a single run of the demand model, as advised by WebTAG Unit 2 paragraph 6.4.27.

The elasticities calculated should in every case be weaker than -2. In our case the value was -0.627.

Table 13 Summary of elasticities after Realism Testing, 10% journey time increase

10% Journey time increase impact on vehicle kilometres				
Purpose	AM	IP	PM	12 hours
Business	-0.505	-0.547	-0.366	-0.484
Other	-0.769	-0.963	-0.584	-0.841
Commute	-0.362	-0.381	-0.334	-0.353
All	-0.570	-0.822	-0.422	-0.627

5.3.4 Network-based fuel cost increase realism test results

The network based fuel cost increase realism test produced overall elasticity values for AM, IP, PM and 12 hours of -0.26, -0.31, -0.24 and -0.28, respectively, when all links in the network were included in the elasticity calculations, and -0.15, -0.14, -0.13 and -0.14, when excluding the external links. As it can be observed from Table 14 and Table 15 below, and based on the WebTAG suggestion that this test tends to underestimate fuel cost elasticities when compared to matrix-based results (WebTAG Unit M2, 6.4.13), the values are considered to lie within the required boundaries and therefore WebTAG guidance is met.

Table 14 Summary of network based elasticities after Realism Testing, 10% fuel cost increase (With External Links)

10% Journey time increase impact on vehicle kilometres				
Purpose	AM	IP	PM	12 hours
Business	-0.06	-0.08	-0.05	-0.06
Other	-0.37	-0.46	-0.39	-0.42
Commute	-0.15	-0.10	-0.14	-0.13
All	-0.26	-0.31	-0.24	-0.28

Table 15 Summary of network based elasticities after Realism Testing, 10% fuel cost increase (Without External Links)

10% Journey time increase impact on vehicle kilometres				
Purpose	AM	IP	PM	12 hours
Business	-0.05	-0.04	-0.02	-0.04
Other	-0.21	-0.16	-0.20	-0.18
Commute	-0.11	-0.10	-0.08	-0.10
All	-0.15	-0.14	-0.13	-0.14

5.3.5 Convergence statistics summary

WebTAG M2 6.3.8 requires that the relative gap value, as defined earlier in chapter 4.4, is achieved below specified thresholds. In general, convergence of 0.1% is required, but, for "problematic systems", WebTAG accepts convergence value of 0.2%. Since Chelmsford model has relatively limited route choice alternatives and high demand, convergence value of 0.2% was used for this assessment. Table 16 summarizes the convergence values achieved in the various model runs for the realism testing. The table shows, that all model runs achieved the convergence criteria.

Table 16 Realism testing convergence statistics

Convergence (% relative GAP)		
10% Fuel Increase		
AM	IP	PM
0.104	0.054	0.093
10% PT Fare Increase		
0.136	0.031	0.126

6. Reference Case Growth Forecasts (2021, 2036)

6.1 Forecast network development

6.1.1 Highway Network

Table 17 provides a full list of the planned highway infrastructure developments considered. For more information please refer to Chapter 3.1 of the TFR.

Table 17 Planned highway infrastructure developments

Infrastructure Scheme	Description	Location	Delivery Date
Radial Distributor Road	Single carriageway distributor road including improvements to Boreham Interchange	Between Boreham Interchange J19 A12 to Belsteads Farm Junction on A130	2021
Chelmer Viaduct	Replacement of Viaduct. Single carriageway with footway/cycle way on western side	A138 Chelmer Road	Winter 2016
Colchester Road, Springfield	Widening to provide two lane approach to Sainsbury roundabout	A130 between J19 A12 northbound off slip at Drovers Way and Sainsbury roundabout	March 2017
Rectory Lane with Chelmer Valley Road	Widening of A1016 Chelmer Valley Road to extend two lane approach to Rectory Lane	Alan Cherry Drive to Rectory Lane	November 2017
NE Chelmsford by-pass	New strategic link dual carriageway	Between A12 J19 Boreham Interchange and Deres Bridge Junction on A131	2021-2036
Army and Navy Improvements	Two way flyover or other scheme yet to be determined	Army and Navy roundabout	2021-2036

6.1.2 Public Transport Network

Table 18 below, provides a full list of the planned public transport infrastructure developments considered. For more information please refer to Chapter 3.2 of the TFR.

Table 18 Planned public transport infrastructure developments

Infrastructure Scheme	Description	Location	Delivery Date
NE Chelmsford Rail Station (BP)	New rail station and passing loops and 1,450 car parking spaces	NE Chelmsford	2021
CHART: Greater Beaulieu Park bus	Liveried bus service from Greater Beaulieu Park to town center, 20 min service daytime 30 mins eve.	Between site and town center	2021
Channels Bus service	30 min service 6am to 11pm Mon to Fri and 7am to 11pm Sat	Channels to town center	2016
Crossrail system	Crossrail service between Shenfield and Reading	Shenfield-Reading	2018

6.2 Demand in the forecast year

Zonal data in the Chelmsford area of interest was prepared with consideration of the forecast years detailing households, population and jobs (by NTEM job category). These took account of anticipated developments between the base and forecast year, and were constrained to conform to NTEM levels of growth.

For external zones the NTEM levels of growth were used to provide the totals, and job type distribution assumed to remain constant over time.

These planning data were input to the trip end calculation processes. The trip ends were calculated by purpose, mode and car availability group. Growth factors were calculated dividing these by equivalent base year values. These growth factors were used to factor up the base year demand matrices.

The resulting matrices reflected changes in planning data and car ownership, and are the demand patterns expected if travel costs in the forecast year remained the same as in the base year.

LGV and OGV matrices for forecast years were obtained by applying standard annual growth figures (from DfT) to the base year matrices.

For further details on the methodology used in the development of the forecast year demand, please refer to Chapter 4 of the TFR.

6.3 Forecast year model run

The forecast model run takes the forecast demand matrices and assigns them to the forecast year (2021 / 2036) networks. Forecast networks include all infrastructure improvements, such as major scheme business case infrastructure developments (road, railway) and other infrastructure developments (road, railway). Estimated changes in costs (petrol, fare, and parking) were also taken into account.

7. Sensitivity Testing

7.1 Introduction

Rather than checking model responses against experience, the aim of the sensitivity testing is to verify the relative effect that using different parameters has on the outcome of the appraised scenario. WebTAG recommends a series of checks to be undertaken so that confidence can be invested in the model's conclusions.

WebTAG Unit M2 section 6.6.2 states that sensitivity testing should be undertaken for those parameters that are judged to:

- have a substantial effect on the model's prediction of changes
- be uncertain in their calibration

Following the previously mentioned guidance from the TAG document the following tests were undertaken to the Reference Case Growth Forecasts:

- Decrease sensitivity parameters by -25%
- Increase sensitivity parameters by +25%

Please note that mode and destination choice parameters where changed in the same direction and proportion for a given test, in order to maintain consistent graduation of parameters in the choice hierarchy.

7.2 Results of the reference case growth forecasts

Prior to undertaking any sensitivity testing of the model, 2021 and 2036 reference case scenarios were run, for the calibrated sensitivities, and results compared against starting no-VDM matrices. Table 20 and Table 22 summarise the changes in demand, in percentage terms, produced by the model for the 2021 and 2036 cases. In general we can observe a constant pattern of travellers swapping from Highways into Public Transport related modes. This swapping redoubles with time, so that percentage changes are higher for the 2036 case scenario than for 2021, due not only to an increase in demand and congestion, but also due to the improvements in the public transport related network (Beaulieu Park and CrossRail).

Table 19 2021 Demand after VDM – Matrix Totals

2021 Travel Demand (Trips)							
Mode	Purpose	Reference Case - No VDM			VDM - Calibrated Sensitivity Param.		
		AM	IP	PM	AM	IP	PM
Car	Commute	17,154	7,662	21,492	16,952	7,603	21,251
	Other	18,552	25,293	18,599	18,120	24,951	18,291
	Business	1,909	990	1,576	1,891	983	1,550
Public Transport	Commute	4,378	866	2,278	4,607	933	2,550
	Other	5,203	3,140	2,592	5,908	3,697	3,095
	Business	388	326	1,093	409	334	1,125

Table 20 2021 Demand after VDM - Percentage change

2021 Travel Demand				
Mode	Purpose	VDM - Calibrated Sensitivity Param.		
		AM	IP	PM
Car	Commute	-1%	-1%	-1%
	Other	-2%	-1%	-2%
	Business	-1%	-1%	-2%
Total		-2%	-1%	-1%

Table 21 2036 Demand after VDM – Matrix Totals

2036 Travel Demand (Trips)							
Mode	Purpose	Reference Case - No VDM			VDM - Calibrated Sensitivity Param.		
		AM	IP	PM	AM	IP	PM
Car	Commute	18,262	9,326	24,392	17,616	9,136	23,825
	Other	20,798	32,638	22,069	19,363	31,385	21,174
	Business	2,138	1,274	1,864	2,096	1,255	1,809
Public Transport	Commute	4,490	889	2,340	5,213	1,101	2,974
	Other	5,747	3,488	2,864	7,995	5,451	4,267
	Business	427	360	1,201	477	383	1,265

Table 22 2036 Demand after VDM - Percentage change

2036 Travel Demand				
Mode	Purpose	VDM - Calibrated Sensitivity Param.		
		AM	IP	PM
Car	Commute	-4%	-2%	-2%
	Other	-7%	-4%	-4%
	Business	-2%	-1%	-3%
Total		-5%	-3%	-3%

7.3 Results of the sensitivity testing

The results from the sensitivity tests outlined above, for the forecasted years: 2021 and 2036, are summarised on the next page along with the results from the calibrated version of the model. Total demand and vehicle-kilometre before and after VDM were selected as the main indicators of model output.

Table 23 and Table 24 below show a summary of how car demand changes for the different years and time periods by purpose, for each test and the calibrated scenario, against the reference case forecast matrices without VDM. Overall we can see the changes in demand, for the 2021 scenario, range between -0.8% to -2.3% for the calibrated version of the VDM, with higher percentage changes for discretionary trips and in the PM peak period. When testing the model against adjusted sensitivity parameters, the resulting values stay within a reasonable range suggesting that the model's uncertainty does not result in a big impact to the outputs. The results for the forecast year of 2036 show a similar pattern.

Convergence statistics for each of the sensitivity tests is summarised in Appendix B and Appendix C.

Table 23 Summary of sensitivity tests, 2021 changes in demand

2021 Travel Demand Change - Sensitivity Testing										
Mode	Purpose	VDM - Calibrated Sensitivity Param			VDM -25% Sensitivity Param			VDM +25% Sensitivity Param		
		AM	IP	PM	AM	IP	PM	AM	IP	PM
Car	Commute	-1.2%	-0.8%	-1.1%	-0.9%	-0.5%	-0.8%	-1.6%	-1.0%	-1.5%
	Other	-2.3%	-1.4%	-1.7%	-1.6%	-0.9%	-1.1%	-3.2%	-1.9%	-2.4%
	Business	-0.9%	-0.7%	-1.7%	-0.7%	-0.5%	-1.2%	-1.2%	-0.9%	-2.1%

Table 24 Summary of sensitivity tests, 2036 changes in demand

2036 Travel Demand Change - Sensitivity Testing										
Mode	Purpose	VDM - Calibrated Sensitivity Param			VDM -25% Sensitivity Param			VDM +25% Sensitivity Param		
		AM	IP	PM	AM	IP	PM	AM	IP	PM
Car	Commute	-3.5%	-2.0%	-2.3%	-2.6%	-1.5%	-1.7%	-4.5%	-2.5%	-3.1%
	Other	-6.9%	-3.8%	-4.1%	-4.9%	-2.8%	-2.8%	-9.3%	-5.1%	-5.7%
	Business	-2.0%	-1.5%	-2.9%	-1.4%	-1.1%	-2.2%	-2.6%	-1.9%	-3.7%

7.3.1 Sensitivity test results for forecast year 2021

Table 25 Sensitivity test results for forecast year 2021, changes in demand

2021 Travel Demand (Trips) - Sensitivity Testing													
Mode	Purpose	No VDM			VDM - Calibrated Sensitivity Param			VDM -25% Sensitivity Param			VDM +25% Sensitivity Param		
		AM	IP	PM	AM	IP	PM	AM	IP	PM	AM	IP	PM
Car	Commute	17,154	7,662	21,492	16,952	7,603	21,251	17,008	7,621	21,323	16,885	7,583	21,169
	Other	18,552	25,293	18,599	18,120	24,951	18,291	18,255	25,062	18,395	17,966	24,809	18,152
	Business	1,909	990	1,576	1,891	983	1,550	1,896	985	1,557	1,886	981	1,542
Public Transport	Commute	4,378	866	2,278	4,607	933	2,550	4,543	913	2,469	4,683	956	2,644
	Other	5,203	3,140	2,592	5,908	3,697	3,095	5,688	3,516	2,924	6,160	3,928	3,321
	Business	388	326	1,093	409	334	1,125	404	332	1,116	415	336	1,133

Table 26 Sensitivity test results for forecast year 2021, changes in Veh-Pass Kilometre

2021 Vehicle Kilometre / Passenger Kilometre - Sensitivity Testing													
Mode	Purpose	No VDM			VDM - Calibrated Sensitivity Param			VDM -25% Sensitivity Param			VDM +25% Sensitivity Param		
		AM	IP	PM	AM	IP	PM	AM	IP	PM	AM	IP	PM
Car	Commute	529,903	311,140	658,960	522,829	312,947	652,436	524,846	312,718	654,594	520,687	313,209	649,767
	Other	706,490	499,971	502,869	769,823	564,895	557,231	752,884	546,531	543,088	787,353	584,921	570,884
	Business	79,433	19,215	41,648	78,931	19,043	40,737	79,097	19,089	41,011	78,744	18,998	40,469
Public Transport	Commute	245,741	45,740	125,932	261,179	50,088	137,091	254,624	47,601	133,106	273,030	53,408	141,612
	Other	153,728	115,560	96,280	263,649	184,558	141,194	220,929	152,758	121,686	313,501	236,020	170,896
	Business	28,325	22,820	90,087	29,951	23,136	91,284	29,535	23,032	90,981	30,406	23,268	91,667

7.3.2 Sensitivity test results for forecast year 2036

Table 27 Sensitivity test results for forecast year 2036, changes in demand

2036 Travel Demand (Trips) - Sensitivity Testing													
Mode	Purpose	Base Year - No VDM			VDM - Calibrated Sensitivity Param			VDM -25% Sensitivity Param			VDM +25% Sensitivity Param		
		AM	IP	PM	AM	IP	PM	AM	IP	PM	AM	IP	PM
Car	Commute	18,262	9,326	24,392	17,616	9,136	23,825	17,780	9,186	23,986	17,448	9,089	23,644
	Other	20,798	32,638	22,069	19,363	31,385	21,174	19,787	31,735	21,449	18,866	30,989	20,820
	Business	2,138	1,274	1,864	2,096	1,255	1,809	2,107	1,259	1,823	2,083	1,250	1,795
Public Transport	Commute	4,490	889	2,340	5,213	1,101	2,974	5,029	1,045	2,794	5,400	1,153	3,177
	Other	5,747	3,488	2,864	7,995	5,451	4,267	7,330	4,903	3,835	8,775	6,071	4,822
	Business	427	360	1,201	477	383	1,265	463	377	1,249	492	388	1,282

Table 28 Sensitivity test results for forecast year 2036, changes in Veh-Pass Kilometre

2036 changes in Vehicle Kilometre / Passenger Kilometre - Sensitivity Testing													
Mode	Purpose	No VDM			VDM - Calibrated Sensitivity Param			VDM -25% Sensitivity Param			VDM +25% Sensitivity Param		
		AM	IP	PM	AM	IP	PM	AM	IP	PM	AM	IP	PM
Car	Commute	565,844	382,003	750,291	529,182	375,414	710,830	538,491	377,596	722,567	519,906	373,112	696,594
	Other	796,775	660,166	606,477	902,074	807,634	713,382	871,663	760,167	682,321	934,203	865,483	745,557
	Business	89,130	25,404	50,205	87,292	24,365	47,382	87,844	24,638	48,066	86,661	24,155	46,669
Public Transport	Commute	253,992	47,169	129,941	376,776	91,659	185,272	356,545	82,894	168,871	388,420	95,560	208,493
	Other	169,581	125,997	105,499	630,374	735,741	449,602	519,700	605,578	352,540	789,688	870,875	598,294
	Business	30,703	24,695	97,891	36,932	26,727	101,927	34,615	26,276	100,845	39,900	27,071	103,192

8. Conclusions

The objective of the Chelmsford VDM model is to provide robust future travel demand forecasts by estimating the impact of changing costs to destination and mode choice. This document has summarised the development and performance of the VDM against WebTAG criteria, providing reassurance that the model meets guidance and is suitable for testing impacts of local schemes and developments in the Chelmsford study area.

Based on WebTAG recommendation, an incremental hierarchic mode and destination choice model was identified as the most suitable approach and calibrated following the available guidance. Overall, the model has been calibrated to produce plausible results for the all matrix based realism tests.

In addition, the VDM's performance was verified against the Reference Case forecast scenarios, 2021 and 2036, demonstrating that the model responds as expected. Uncertainty in the model's parameters is not likely to generate significantly different outputs for the Reference case.

A limitation of the VDM model is that it does not include a time-of-day choice component. The VDM model incorporates mode and destination choice components only, primarily due to limitations of the mobile phone-based demand data, available for this work.

Overall, the model meets WebTAG guidance and therefore it can be used to assess the impact of future highway or public transport infrastructure schemes, as well as parking or fare policies.

Appendix A. Model Calibration Process Audit Trail (Realism Testing)

Test No	Cost Damping	Destination Lambdas HW	Destination Lambdas PT	Mode Choice Lambdas	Observation
1	No	Median	Median	Median	Values substantially far from WebTAG. Following guidance from WebTAG Unit M2 Chapter 3.3 Cost Damping was introduced.
2	α=0.5 K=30km	Median	Median	Median	Fare Increase elasticities for PT within required boundaries. Fuel Increase slightly high.
3	α=0.5 K=30km	AM: O -10% W -10% / IP: O -10% / PM: W -10% from the median value	Median	Median	All elasticities within boundaries. Adjustments to be done to achieve more plausibility on period and purpose specific elasticities. (WebTAG 6.4.17 and 6.4.22)
4	α=0.5 K=30km	AM: O -10% EB -10% W -20% / IP: O -10% EB 10% W 10%/ PM: W -20% from the median value	Median	Median	All elasticities within boundaries. Adjustments to be done to achieve more plausibility on period and purpose specific elasticities. (WebTAG 6.4.17 and 6.4.22)
5	α=0.5 K=30km	AM: O -20% EB -20% W -20% / IP: O -20% EB 10% W 10%/ PM: W -20% from the median value	Median	AM: O -10% / IP: O -10%	Values are within WebTAG boundaries and are plausible in terms of period and purpose-specific elasticities.

W: Commute trips, O: Other Trips, EB: Business Trips

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Appendix B. 2021 Forecast Sensitivity Testing Convergence Statistics

Iteration	VDM Calibrated ʎs			Sensitivity Tests					
				- 25% Sensitivity Parameters			+ 25% Sensitivity Parameters		
	2021			2021			2021		
	AM	IP	PM	AM	IP	PM	AM	IP	PM
Status:	Converged	Converged	Converged	Converged	Converged	Converged	Converged	Converged	Converged
1	0.450	1.162	1.454	0.258	0.760	0.926	0.652	1.539	2.163
2	0.142	0.485	0.593	0.048	0.171	0.378	0.285	0.394	0.548
3		0.376	0.769			0.534	0.232	0.223	0.350
4		0.128	0.364			0.172	0.168	0.171	0.094
5			0.121						

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Appendix C. 2036 Forecast Sensitivity Testing Convergence Statistics

Iteration	VDM Calibrated λs			Sensitivity Tests					
				- 25% Sensitivity Parameters			+ 25% Sensitivity Parameters		
	2036			2036			2036		
	AM	IP	PM	AM	IP	PM	AM	IP	PM
Status:	Converged	Converged	Converged	Converged	Converged	Converged	Converged	Converged	Converged
1	0.521	1.419	1.691	0.342	0.895	1.091	0.837	2.049	2.338
2	0.094	0.573	0.367	0.083	0.251	0.340	0.169	0.762	0.926
3		0.421	0.542		0.062	0.194		0.380	0.855
4		0.336	0.483					0.218	0.369
5		0.233	0.302					0.205	0.283
6		0.080	0.350					0.208	0.172
7			0.444					0.063	
8			0.448						
9			0.140						