North Yorkshire County Council and Selby District Council

SELBY DISTRICT TRAFFIC MODEL

Demand Model Report

DEMAND MODEL REPORT
MARCH 2022

CONFIDENTIAL

North Yorkshire County Council and Selby District Council

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North Yorkshire County Council and Selby District Council

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INTRODUCTION

1 INTRODUCTION

1.1 OVERVIEW

1.1.1. Selby District Council (SDC) is the local district authority within the North Yorkshire that consists of a number of wards within Selby district, including Selby East, Selby West, Tadcaster, Sherburn in Elmet and Eggborough. It is the southernmost district of North Yorkshire, bound by the unitary authority of City of York to its north, East Riding of Yorkshire to its east, Wakefield council to its south and City of Leeds to its west. Selby district has a population of around 84,000 based on 2011 Census information.

1.1.2. In 2016, a Selby Town Traffic highway model, primarily covering Selby town centre, extending to Cawood to the northwest of the town and Hemingbrough to the southeast, was developed by Mouchel with a base year of 2016 to help the assessment of the transport impacts of potential development sites and infrastructure improvements included in the local plan set out by the council.

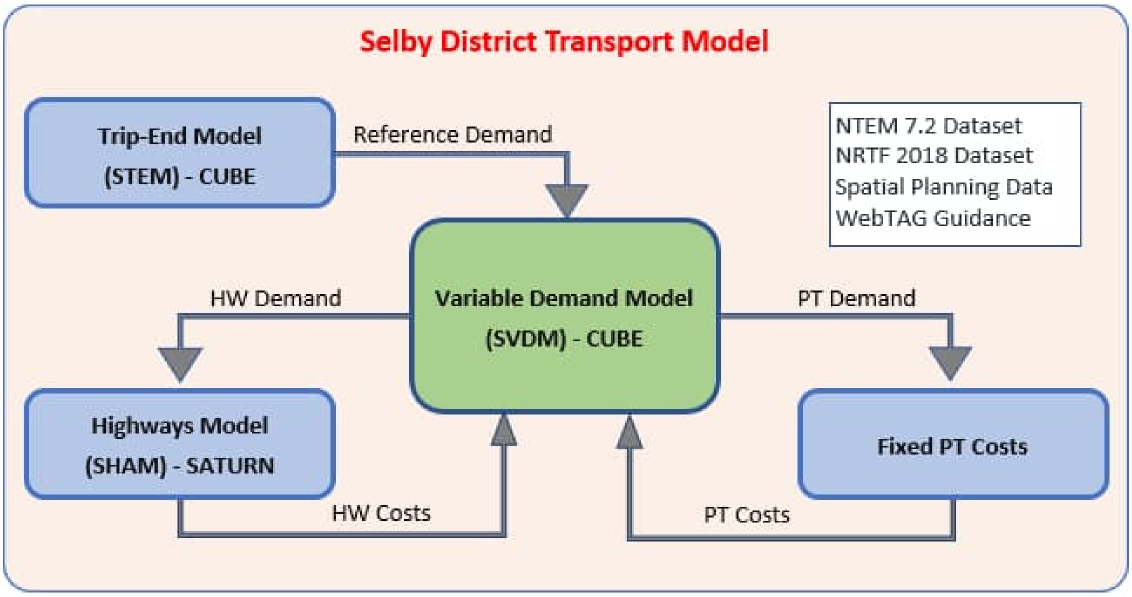
1.1.3. Since then, there have been number of land-use changes along with changes to the road network within Selby. To provide an up-to-date modelling platform required for testing those changes, as a result, WSP has been commissioned by North Yorkshire County Council (NYCC) and SDC to develop the updated Selby District Strategic Transport Model (SDSTM) for a 2019 base year. This will provide NYCC a robust modelling tool to support and test the proposed Selby District Local Plan.

1.1.4. The Selby District Model has therefore been developed and is comprised of three distinct components:

- A CUBE/Voyager forecast trip-end model produces a forecast demand, unconstrained by network capacity, that represents future growth in both highway and public transport using growth assumptions from the National Trip-End Model (NTEM), National Road Transport Forecast (NRTF) and explicit planning assumptions across the modelled hours for the study area;
- A CUBE/Voyager multi-modal incremental demand model that considers the impact of frequency choice, main mode choice, macro-time choice and destination choice on reference demand produced from the trip-end model in response to changes in travel costs across the 24-hour period;
- A SATURN highways assignment model representing vehicle-based movements across the Selby district area of a typical 2019 morning peak hour (08:00-09:00), an average inter-peak hour (10:00-16:00) and an evening peak hour (17:00-18:00); and
- A passive Public transport model with fixed Public transport costs (derived from the Highway costs) that were used to allow for mode choice response to be undertaken within the demand model.

1.1.5. A model suite has been developed within the CUBE environment that seamlessly links the forecast trip-end model, the variable demand model (VDM) and the SATURN highways assignment model as illustrated in Figure 1-1 below.

Figure 1-1 Selby District Transport Model



1.2 THE NEED FOR VARIABLE DEMAND MODELLING (VDM)

1.2.1. TAG M2, section 1.1 states that any change to transport conditions will, in principle, cause a change in demand for travel and the purpose of VDM is to predict and quantify these changes. It is of key importance to establish a realistic scenario in the absence of, and with the inclusion of the proposed scheme or strategy and for schemes that may affect traveller behaviour such as choice of mode, realistic levels of demand across the modes needs to be established.

1.2.2. Since both demand changes and benefits tend to scale with the size of the scheme, changes in demand can have fundamental implications for the justification of a scheme of any size, in terms of economic, environmental and social impacts.

1.2.3. TAG M2, section 2.2 also suggests that ‘fixed demand’ approach assessments may be acceptable in a limited number of circumstances. However, the context of the assessment of the Western Distributor Road indicates the need for the VDM as:

- The scheme is likely to have considerable effects on travel costs and capital costs for the scheme are likely to be significantly larger than £5 million; and
- The current base year networks experience significant traffic congestions (particularly within Selby town centre) and are very likely to become worse in the forecast years.

1.2.4. As agreed with the client, the Selby District Transport Model has been developed to be fully compliant with the TAG M2 which allows assessments of potential transport interventions within the study area to be undertaken.

1.3 PURPOSE AND REPORT STRUCTURE

1.3.1. This report describes the development of the demand model elements for The Selby District Transport Model, which is fully compliant with the TAG M2 guidance aimed to assess potential transport interventions in the Selby local authority area. The interventions include demand management (and supporting complementary measures) and new highways schemes.

1.3.2. Following this introduction, the structure of the Demand Model Development report includes 5 sections as below:

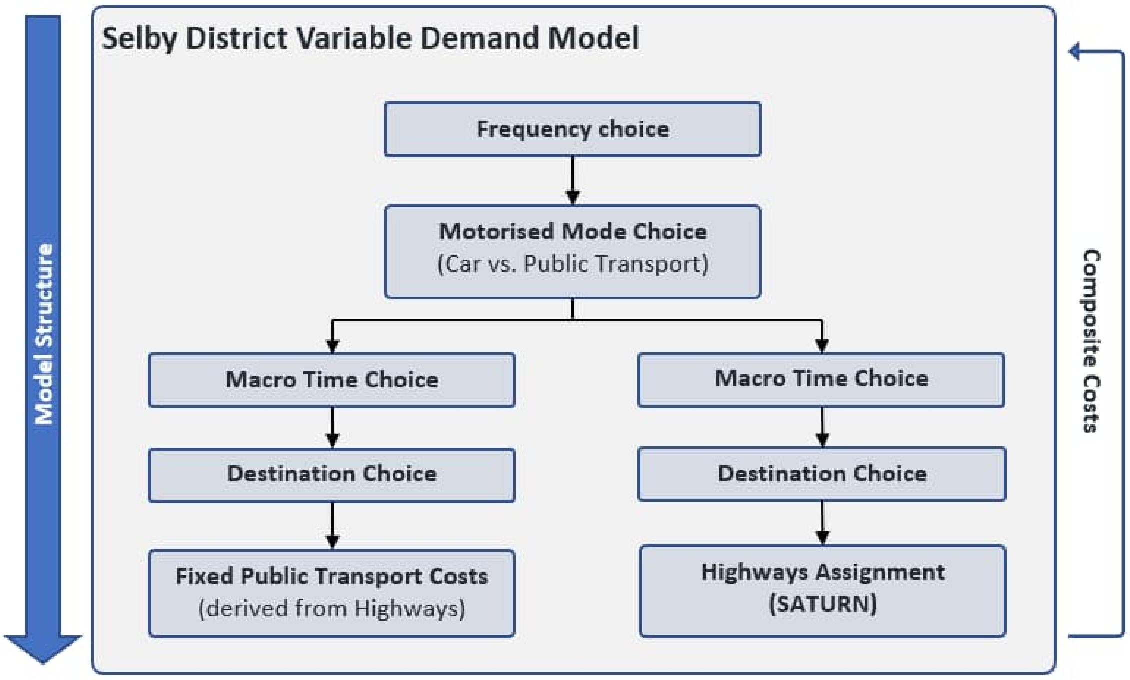
- **Chapter 2** – Demand Model System;
- **Chapter 3** – Demand Model Parameters;
- **Chapter 4** – Demand Model Calibration; and
- **Chapter 5** – Summary.

2 DEMAND MODEL SYSTEM

2.1 INTRODUCTION

2.1.1. The variable demand model which forms part of the Selby District Transport Model is an incremental PA model that represents travel choice across a typical 24-hour weekday period, pivoting off the validated 2019 Base year models and estimating change in demand between travel alternatives using the TAG choice response mechanisms (frequency choice, mode choice, time choice and destination choice), depending on the change in travel costs or disutility from the base year costs. The demand model structure is illustrated in Figure 2-1 below.

Figure 2-1 Variable Demand Model Structure



2.1.2. The demand model has been developed using a combination of two software platforms, SATURN for the Highways assignment models and CUBE/Voyager for the bespoke Variable demand model. This is specified as an incremental Production-Attraction (PA) model for Home Based (HB) trip purposes and Origin-Destination (OD) model for Non-Home Based (NHB) trip purposes, being pivoted from the validated Base Year costs, in accordance with TAG M2 guidance.

2.1.3. The function of the respective software platforms are as follows.

- SATURN provides highways assignment functionality where trips matrices are assigned to a congested highway network;
- Fixed costs derived from the highway's assignment models were used to represent the Public transport costs;
- The cost skims from the SATURN highways assignments and the fixed PT costs are then produced and fed to the demand model in an appropriate format (PA or OD) to allow choice responses to be undertaken such as frequency choice, mode choice, time choice and destination choice;

- The resultant demand from the choice responses above are converted to OD format and fed back to allow SATURN highway assignments; and
- The process is iterated until a stable convergence solution is reached.

2.1.4. Freight trips (LGV and HGV) are not subject to VDM as it is often sufficient to assume that total freight traffic is fixed and only susceptible to route choice modelling (i.e. traffic assignment).

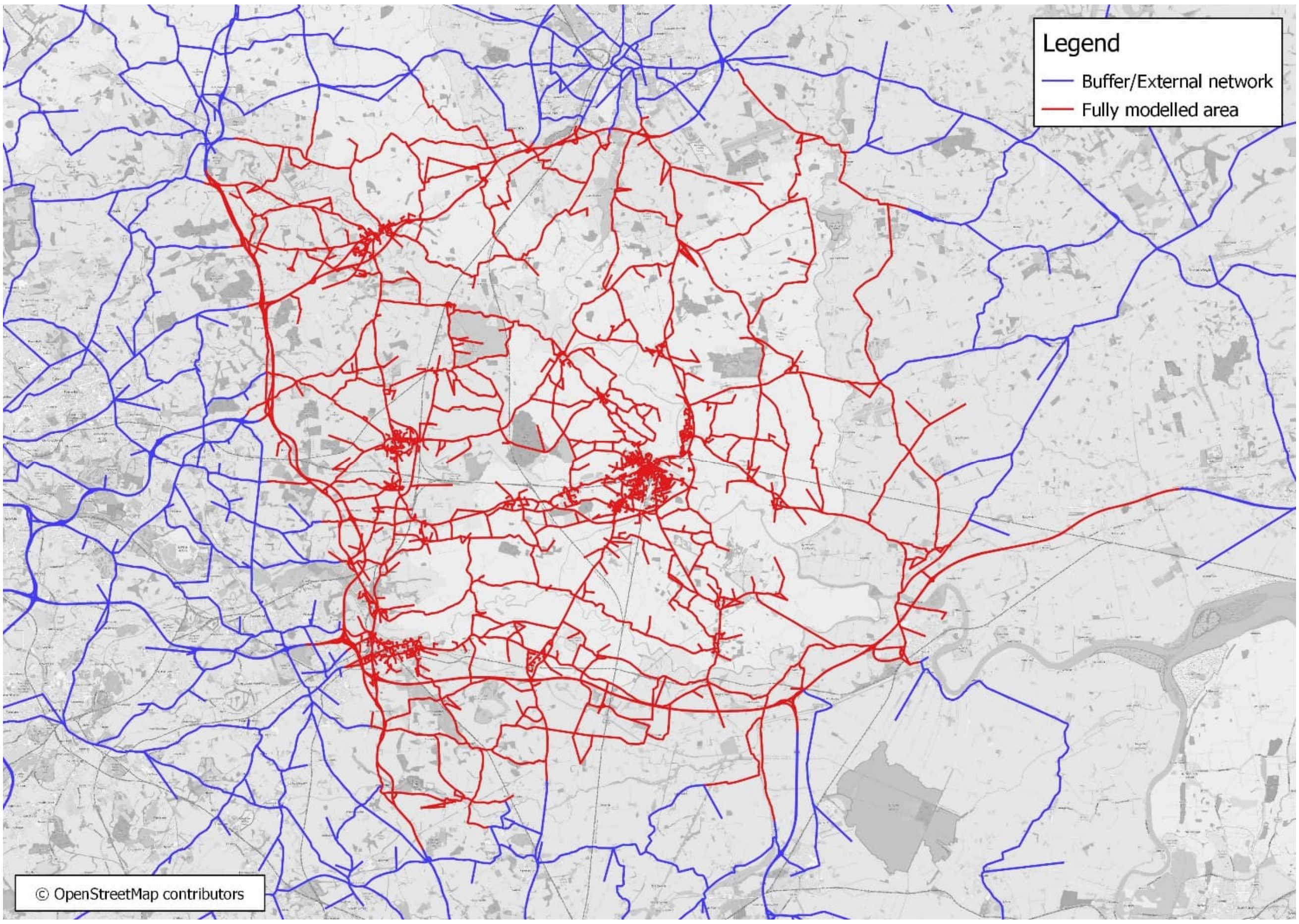
2.2 SELBY DISTRICFT TRANSPORT MODEL STUDY AREA

2.2.1. TAG guidance emphasises the importance of the size of the zone system for highways assignment models. Zone size needs to be optimised, sufficiently small to enable accurate routeing to be predicted but also sufficiently large to allow travel demand from/to be estimated with confidence.

2.2.2. The Model Specification Report states the primary intended use of the model to “support SDC and NYCC in managing the existing transport network, developing the future transport network that is consistent with its Transport Strategy aspirations, and assessing impacts of developments identified within the SDCLP”. To help with those objectives, it is required that an appropriate geographical extent of the main model area to be identified to allow a robust modelling and appraisal system can be achieved. The extent of the geographical area of the modelling system is shown in Figure 2-2 below.

2.2.3. The base year highway models therefore cover the geographical area as highlighted below. The zone system is described further in the LMVR report.

Figure 2-2 Selby District Study Area



2.3 MODEL FORMS & RESPONSE HIERARCHY

2.3.1. According to TAG M2, there are a number of model forms that can be employed for a variable demand model, as below:

- Absolute model – use a direct estimate of the number of trips in each category;
- Absolute model applied incrementally – use absolute model estimates to apply changes to a base year demand; and
- Pivot-point model – use cost changes from a base year cost to estimate change in demand from a base year matrix.

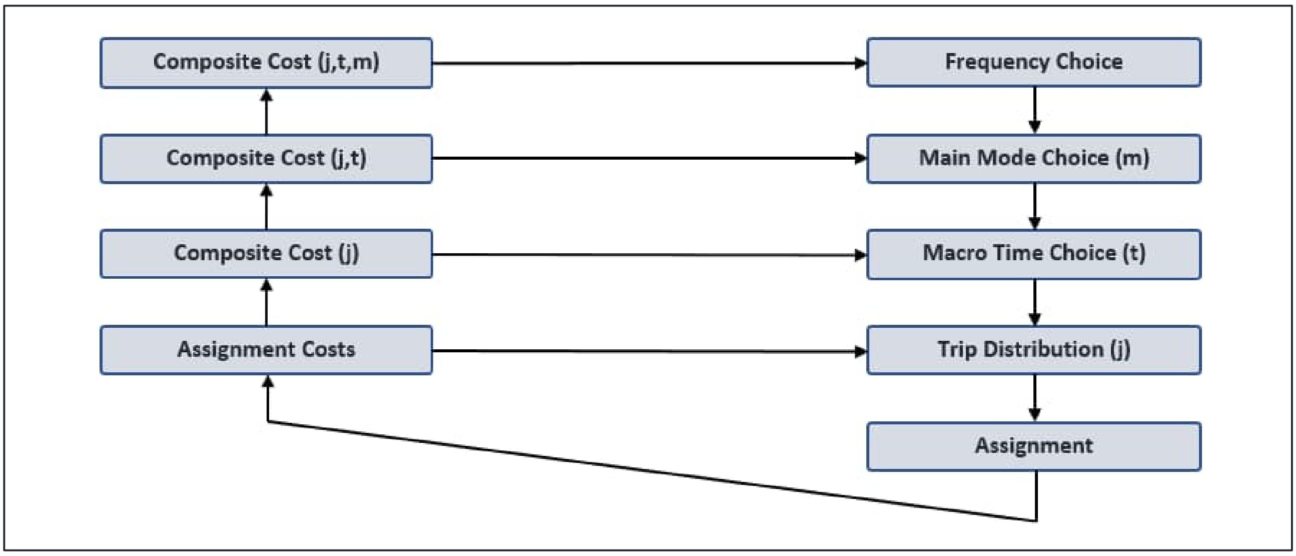
2.3.2. The Selby District Variable Demand Model (VDM) employs the Pivot-Point model as recommended by TAG M2, para 4.3.12, where incremental cost changes from the base year model would result in change in demand from a reference trip matrix (i.e. forecast demand matrix produced from the Selby District trip-end model).

2.3.3. TAG M2 describes the main choice response mechanisms and their hierarchical order that may be considered in Variable Demand Modelling (VDM) as below:

- Frequency choice (optional, if considered an important response and/or necessary to reflect expected behaviour);
- Main mode choice;
- Time of day choice (macro and/or micro time choice);
- Destination choice; and
- Route choice (i.e. assignment)

2.3.4. A choice mechanism placed higher in the hierarchy should reflect the composite costs of choices lower in the hierarchy. The mechanism adopts an iterative procedure to achieve stability by calculating composite costs from the choices made lower to the higher in the hierarchy and subsequently estimate change in demand down from the higher to the lower in the hierarchy until an acceptable degree of convergence is achieved. A choice hierarchy with associated costs and demand responses adopted for the Selby District VDM is illustrated in Figure 2-3 below.

Figure 2-3 Choice Hierarchy with Costs/Demand Responses



FREQUENCY CHOICE

2.3.5. Trip frequency represents change in number of trips being made in response to change in travel costs. This is distinct from trip generation which estimates total number of trips based on demographic and socio-economic characteristics of an area.

2.3.6. TAG M2, section 4.6 states that where active modes of walk and cycle are not explicitly included in the demand model, trip frequency may be thought of as, mainly, the transfer between the active modes and the mechanised modes. Otherwise, overall trip rates will be generally stable and there will often be no need to model the response of trip frequency.

2.3.7. Another explanation for inclusion of trip frequency can be improved accessibility, impacting upon propensity to travel although this is less commonly experienced in developed countries. Where it does occur, it is more commonly associated with discretionary trip purposes, having more flexible travel needs.

2.3.8. There will not normally be a requirement to model trip frequency for doubly-constrained trips such as commuting and education since the constraints on total travel are usually assumed to be binding, due to employment being assumed to be fixed. This implication, however, does not hold if active mode has been omitted from the demand model and they are likely to form a significant percentage of commuting trips and/or any planned interventions would likely result in a significant impact on active mode users.

2.3.9. For purpose of the Selby District VDM, the frequency choice function was built-in, however turned off, as during the calibration of the Base year demand model (i.e. Realism tests), the outturn elasticities calculated were within the recommended ranges from TAG without the need to activate the frequency choice.

MODE CHOICE

2.3.10. TAG M2, section 4.7 states that it is desirable to include some representation of mode choice in VDM, however the level of detail depends upon the importance attached to it based on the travel market and the study in question. It could be acceptable to include alternative modes merely as a set of fixed costs, but conversely it may be necessary to model mode choice alternatives in detail, for example, the effect of changing highway conditions on bus travel times.

2.3.11. According to TAG M2, if public transport is chosen by less than 5% of travellers then the use of fixed public transport costs will suffice, unless public transport alternatives need to be assessed as part of the scheme appraisal.

2.3.12. As the Selby District Transport Model will be primarily used to assess impacts of transport interventions and developments on travel within the study area, primarily highway related, furthermore, there is evidence that little competition between highways and PT within the Selby District local authority (according to NTEM 7.2 database, only 5% of trips making within Selby District local authority are attributed to public transport in 2019), the need for an active PT model that allow representation of PT usage was therefore not required as per TAG guidance. Instead, a set of fixed PT costs have been derived from the Base year highway models to allow approximation of modal choices between car and bus/rail as required from TAG M2.

2.3.13. There are two types of mode choice that can be represented within a VDM, as below:

- Main mode choice – representing fundamental choices, for example between car (private) and public transport and/or active modes (walk/cycle); and
- Sub-mode choice – representing choice within the specific nest, for example, between Bus and Rail within Public transport, or between car and Park & Ride within highways.

2.3.14. Sub-mode choice is not implemented within the Selby District VDM, since the absence of a PT model means that the modal split between bus and rail within public transport is not modelled and is therefore not undertaken within the VDM process. There is no modal split between car and Park & Ride currently implemented in the Selby District VDM model as per the scope of this study.

2.3.15. It is noted that the Selby District VDM does not include active modes (walk and cycle) therefore there is no mode choice mechanism between active mode and other modes.

TIME OF DAY CHOICE

2.3.16. There are two distinctly different aspects of time-of-day choice: macro time period choice and micro time period choice. Macro time period choice refers to the choice between broad modelled time periods, for example between AM period and Inter-Peak period, whereas micro time choice represents choices entirely within a particular modelled period, for example early or late arrival during the AM peak hour (i.e. peak spreading) to avoid congestion.

2.3.17. The Selby District VDM employs the macro time period choice using a logit choice model in a similar manner to choice-response mechanism as for other stages of the demand modelling, as cost differentials between time periods are evident in the base-year models and these are anticipated to develop further in the forecast years. No micro time choice has been implemented within the Selby District VDM model since limited evidence on this choice response within the study area.

DESTINATION CHOICE

2.3.18. Destination choice represents transfer of trips between different destinations because of change in travel costs and can be applied in terms of zonal productions and attractions or origins and destinations trip totals.

2.3.19. According to TAG M2, it is common to use doubly-constrained models for estimating commuting and education trips where their origins and destinations are well defined by planning data and singly-constrained (origin constraint) models for business and other purposes where total number of trips generated in each zone is known, but not necessarily the trip attractions.

ROUTE CHOICE (ASSIGNMENT)

2.3.20. Route choice or assignment models are normally required for a variable demand model to provide travel cost information for the demand model. In order to provide accurate travel costs, the assignments must be adequately converged to allow a good level of convergence between the assignment models and the demand model.

2.3.21. Travel costs from the Selby District highway assignment models are converted to appropriate format prior to being used for the choice mechanisms within the Selby District VDM model.

2.4 MODELLED PERIOD

2.4.1. The highway models reflect the typical traffic conditions on an average weekday (Monday to Friday) in 2019, during the morning, inter-peak and evening peak hours, as specified in the Model Specification Report:

- Morning peak hour (08:00-09:00);
- An average inter-peak hour (10:00-16:00); and
- Evening peak hour (17:00-18:00).

2.4.2. The demand model, however, represents a 24-hour weekday demand model that covers four time periods: AM peak period (07:00-10:00), Inter-peak period (10:00-16:00), PM peak period (16:00-19:00) and Off-peak period (19:00-07:00 of the following day). To ensure a linkage between the demand model and the supply assignment models, demands estimated from each time period have been converted to peak-hour matrices prior to the traffic assignment steps, using the conversion factors that have been obtained from observed ATC for the study area, as provided in the next chapter - see Table 3-9. Meanwhile, the periods themselves are detailed in Table 2-1 below.

Table 2-1 Demand Model and Assignment Model Period

ID	Demand Model Period	Assignment Model Hour
1	AM period (07:00-10:00)	AM Peak Hour (08:00-09:00)
2	Inter-Peak (10:00-16:00)	Inter-Peak Hour (hourly average 10:00-16:00)
3	PM Period (16:00-19:00)	PM Peak hour (17:00-18:00)
4	Off-Peak (19:00-07:00)	Not used in assignment model

2.4.3. It is noted that the off-peak demand was derived from the 12-hour weekday demand for the purpose of the demand model only and is not used in the assignment model.

2.5 DEMAND SEGMENTATION

2.5.1. The Selby District highways assignment models follow the TAG standard user classes that represent 5 distinct travel trip purposes as below:

- Car - Employer’s Business;
- Car - Commuting;
- Car - Other;
- LGVs; and
- HGVs.

2.5.2. For the demand model, it is necessary to include a more detailed segmentation to represent different impacts on demand, resultant from changes in travel costs as follows:

BY JOURNEY PURPOSE

- Home Based Commuting (HBW);
- Home Based Employer Business (HBEB);
- Home Based Education (HBED);
- Home Base Other (HBO);
- None-Home Based Employer Business (NHBEB);

- None-Home Based Education (NHBED); and
- None-Home Based Other (NHBO).

2.5.3. It is noted that demand segment by Income level is currently not included within the Selby District VDM as this is not required under the scope of the Selby District Transport Model study. It is also noted that education trips only account for a small proportion of the total trip makings within the study area, education trips were therefore merged within the 'Other' demand segments for the purpose of the Selby District demand model.

2.5.4. Overall, a total of 9 demand segments have been constructed for the Selby District VDM model. This includes freight demands - for the purpose of the Highways assignment models. The segmentation is summarised in Table 2-2 below.

Table 2-2 Demand Model Segmentation

ID	Purpose	Format	Highways User Class	Public Transport User Class
1	HBW	PA	Car - Commuting	Bus/Rail - Commuting
2	HBEB	PA	Car - Employer Business	Bus/Rail - Employer Business
3	HBED	PA	Car - Other	Bus/Rail - Other
4	HBO	PA	Car - Other	Bus/Rail - Other
5	NHBEB	OD	Car - Employer Business	Bus/Rail - Employer Business
6	NHBED	OD	Car - Other	Bus/Rail - Other
7	NHBO	OD	Car - Other	Bus/Rail - Other
8	LGV	OD	LGV	
9	HGV	OD	HGV	

2.5.5. It is noted that None-Car available (NCA) was not modelled explicitly within the Selby District VDM due to a) small proportion of NCA trips within the small total PT trip making, and b) the assumptions of the passive PT models with the fixed costs derived from the highway model as mentioned in the previous section. Only Car available (CA) therefore have been modelled within then Selby District Demand model.

2.5.6. Demand segments from the Demand Model will be converted from PA format to OD format by time periods and subsequently aggregated to respective Highways assignment user classes prior to Highways assignments being carried out.

2.5.7. As mentioned in the previous section, freight demand (LGV and HGV) is not subject to the VDM however is susceptible to route choice modelling through highway assignment.

2.6 GENERALISED COSTS

2.6.1. Generalised costs determine travel choice between alternative modes, time, destination and routes which is based on a combination of travel time, operating costs and charges in a unit of generalised time for the purpose of the demand modelling.

PRIVATE CAR

2.6.2. TAG M2, para. 3.1.6 defines that the generalised cost for private car trips normally includes elements relating to:

- In-vehicle time;
- Vehicle operating costs (fuel and non-fuel costs);
- Parking costs;
- Access/egress to/from the car; and
- Tolls or user charges.

2.6.3. The Selby District VDM follows the TAG formula for the definition of generalised costs for cars GC_{car} measured in units of time-minutes:

$$GC_{car} = T_{walk} * V_{walk} + T_{car} + \frac{D_{car} * VoC}{occ * VoT} + \frac{C_{park} + C_{toll/charge}}{occ * VoT}$$

where:

- T_{walk} is the total walk time from and to the car, in minutes;
- V_{walk} is the weight to be applied to walking time;
- T_{Car} is the journey time spent in the car, in minutes;
- VoC is the vehicle operating cost in pence per km for a journey of D_{Car} km;
- occ is the number of people in the car (who are assumed to share the cost);
- VoT is the appropriate value of time (VOT), in pence per minute; and
- $C_{park} + C_{toll/charge}$ is the parking cost and tolls or user charges, in pence.

2.6.4. The cost elements of travel time, distance and tolls (with the exception of walk time, which is set to zero in the demand model) are obtained directly from the highway assignment models to ensure a consistent calculation of costs between the assignment models and the demand model.

2.6.5. It is noted that travel time and distance include elements of the zone connectors to reflect total travel costs by car from origin ends to destination ends.

PUBLIC TRANSPORT

2.6.6. TAG M2, para. 3.1.8 defines the generalised cost formula for the Public transport with the following elements:

- Fares;
- In-vehicle time;
- Walking time from and to the service;
- Waiting time;
- Boarding and Interchange penalty; and
- Non-walk access, e.g. park and ride.

2.6.7. As no explicit PT model for this study, A set of fixed PT costs were derived from highway assignment models with the following assumptions to represent approximately the bus/rail travel costs within the Selby District traffic model:

- Access/egress time – derived from highway network zone connector travel time;
- In-vehicle time – derived from highway travel time along the network, factored by 1.3 to account for stops along PT routes (1.3 is an average figure that was derived from the analysis of actual highway travel times against bus time tables from number of similar studies within the region);

- Waiting time/boarding and interchange penalty – assumed 20 minutes that accounts for total wait time and interchange across the journey (derived from similar studies within the region);
- Fares – adopted the fare structure by distance that was derived from number of buses within Selby, rebased to 2010 prices as an approximation for the modelling purpose.

2.6.8. The above mentioned parameters were used to produce approximation of the fixed PT costs that were then used for the purpose of the variable demand modelling.

2.7 DEMAND MODEL STRUCTURE

2.7.1. An overview of the demand model stages, functional forms (i.e. PA/OD) and time periods is listed in a hierarchical order in Table 2-3 below.

Table 2-3 Demand Model Hierarchical Order

Stage	Choice Reponses	Period	Form	Person Type
1	Frequency Choice	24-hour	PA Trip-Ends	CA only
2	Main Mode Choice	24-hour	PA Trip-Ends	CA only
3	Macro Time Choice	Translate 24-hour to AM, Inter-Peak, PM and Off-Peak periods	PA Trip-Ends by time periods	CA only
4	Destination Choice	By individual AM, Inter-Peak, PM and Off-Peak periods	Translate PA trip-Ends to PA matrices by time periods	CA only
5	Assignment	AM, Inter-Peak and PM peak hour	Peak Hour OD matrices	CA only

2.7.2. It is noted that:

- Stages 1-4 are undertaken entirely within the demand model whilst stage 5 is provided through the Highways assignment models;
- No explicit PT assignment models as the PT costs remained fixed throughout the iterative process within the demand model.

2.7.3. The frequency choice was coded in the demand model, however it was ‘turned off’ initially. During the calibration of the base-year demand model, it may be made active following the outcomes of the outturn elasticity from the realism tests.

2.7.4. The demand model operates at 24-hour level until the Macro Time of day choice (Stage 3) is undertaken, where 24-hour demand is disaggregated to time-period level to allow for the Macro time choice mechanism to be implemented.

2.7.5. For the Destination choice (Stage 4), the demand model considers all 4 time periods (AM, Inter-Peak, PM and Off-Peak periods) for all person types in parallel. The resulting PA matrices by individual time periods from the Stage 4 are converted to peak hour OD matrices prior to the individual Highways assignments being undertaken.

2.8 MODEL FORMULATION

2.8.1. Following recommendation from TAG M2, the Selby District VDM adopts the incremental logit model form, pivoting off the base year models, in which the choice between travel alternatives (frequency, mode, time period and destination choices) depends upon an exponential function of the generalised cost, or disutility. The logit-base formulation implemented within the Selby District VDM is described below for each of the 4 demand modelling stages, with three distinct applications:

- Incremental P/A model – applied for HB trips;
- Incremental O/D model – applied for NHB trips; and
- Fixed demand – applied for car and PT trips external to the study area and for freight demand (LGV and HGV).

2.8.2. The demand model is implemented in terms of utilities and composite utilities that is consistent with the TAG hierarchical logit formulation in which travel costs or utilities are obtained from the lowest levels of the hierarchy and composite costs or utilities are calculated as the costs move up to the next level of the hierarchy. Demand is subsequently calculated from the top to the bottom level of the hierarchy to represent change in demand in response to cost change.

2.8.3. At the bottom of the hierarchy the lambda parameters are used for the destination choice and thetas as scaling parameters for appropriately weighting time, mode and frequency choices. The mechanism of modelling choice response from destination choice to frequency choice is provided in the steps below:

DESTINATION CHOICE

2.8.4. At the bottom level of the hierarchy, change in utility is given by the formula:

$$\Delta U_{ijmtpc} = -\lambda_{dest,mc}(GC^{1}_{ijmtpc} - GC^{0}_{ijmtpc})$$

Where:

- $\lambda_{dest,mc}$ is the destination choice parameters for mode m and person type c;
- $GC^{0}_{ijmtpc}, GC^{1}_{ijmtpc}$ is the pivot and forecast generalised costs between zone i and zone j for mode m, time period t, purpose p, and person type c.

2.8.5. TAG M2 recommends that destination choice should be modelled as a singly-constrained (origin constraints) for Business and Other purposes (HBEB, HBO, NHBEB and NHBO) whereas a doubly-constrained should be modelled for Commuting and Education purposes (HBW, HBED and NHBED).

2.8.6. The singly-constrained distribution is given by the formula below:

$$T_{ijmtpc} = O_{imtpc} \frac{T^{0}_{ijmtpc} \exp\left(\Delta U_{ijmtpc}\right)}{\sum_k T^{0}_{ikmtpc} \exp\left(\Delta U_{ikmtpc}\right)}$$

2.8.7. The doubly-constrained distribution is given by the formula below:

$$T_{ijmtpc} = O_{imtpc} \frac{B_{jp}\, T^{0}_{ijmtpc} \exp\left(\Delta U_{ijmtpc}\right)}{\sum_k B_{kp}\, T^{0}_{ikmtpc} \exp\left(\Delta U_{ikmtpc}\right)}$$

where:

- T^0_{ijmtpc} is the reference PA trip between zone i and zone j, over $mtpc$;
- O_{imtpc} is the reference production trip-ends for zone i, over $mtpc$;
- ΔU_{ijmtpc} is the change in generalised costs at the bottom level of the hierarchy, between zone i and zone j, over $mtpc$;
- T_{ijmtpc} is the output PA trip between zone i and zone j, over $mtpc$.

2.8.8. All distribution models, irrespective of whether they are singly or doubly constrained, must satisfy the row constraints:

$$T_{imtpc} = \sum_{j} T_{ijmtpc}$$

2.8.9. For doubly-constrained, an additional set of column constraints are to be satisfied:

$$\sum_{imtpc} T_{ijmtpc} = \sum_{imtpc} T^0_{ijmtpc}$$

2.8.10. A balancing factor B_{jp} is required to be calculated so that both origin and destination trip-ends are retained from the reference O/D trip-ends. This is done by the Furnessing process, running through a number of iterative loops until a convergence solution is achieved.

2.8.11. Once the Furnessing process has converged for the Destination choice, the probability of trips choosing alternative destinations is calculated by $p_{j/imtpc} = \frac{B_{jp}\, T^0_{ijmtpc} \exp\left(\Delta U_{ijmtpc}\right)}{\sum_k B_{kp}\, T^0_{ikmtpc} \exp\left(\Delta U_{ikmtpc}\right)}$

MACRO TIME CHOICE

2.8.12. TAG M2 suggests that Macro Time choice should be placed between the Main Mode choice and Destination choice, with the choice parameters similar in magnitude with the Main Mode choice parameters.

2.8.13. The formula for the Macro time choice between the four periods (AM, Inter-Peak, PM and Off-Peak periods) is as follows:

$$p_{t/impc} = \frac{p^0_{t/impc} \exp\left(\theta_c^{time} \Delta U^*_{imtpc}\right)}{\sum_k p^0_{k/impc} \exp\left(\theta_c^{time} \Delta U^*_{imkpc}\right)}$$

where:

- $p^0_{t/impc}$ is the reference case probability of trips from zone i that travel in each time period t, for mode m, purpose p and person type c, calculated from the formula: $\mathrm{p}^0_{t/\mathrm{impc}} = \frac{\sum_j \mathrm{T}^0_{\mathrm{ijmtpc}}}{\sum_{jk} \mathrm{T}^0_{\mathrm{ijmkpc}}}$
- $p_{t/impc}$ is the output probability resulted from change in the composite costs;
- θ_c^{time} is the theta parameter for the Time choice modelling; and
- ΔU^*_{imtpc} is the change in composite costs that are calculated from the bottom of the hierarchy, given by the formula: $\Delta \mathrm{U}^*_{\mathrm{imtpc}} = \ln \sum_{\mathrm{j}} \mathrm{B}_{\mathrm{jp}} \frac{\mathrm{T}^0_{\mathrm{ijmtpc}}}{\mathrm{O}^0_{\mathrm{imtpc}}} \exp\left(\Delta \mathrm{U}_{\mathrm{ijmtpc}}\right)$.

MAIN MODE CHOICE

2.8.14. TAG M2 suggests that the Main Mode choice between car and public transport for car-available travellers should be placed just below the frequency choice in the hierarchy. For non-car-available travellers, no Mode choice is modelled.

2.8.15. The formula for the Main Mode choice for car available travellers is as follows:

$$p_{m/ipc} = \frac{p^0_{m/ipc}\, exp\left(\theta_c^{mode}\Delta U^*_{impc}\right)}{\sum_k p^0_{k/ipc}\, exp\,(\theta_c^{mode}\Delta U^*_{ikpc})}$$

where:

- $p^0_{m/ipc}$ is the reference case probability of trips from zone i that choose mode m, for purpose p and person type c, calculated by the formula: $\mathrm{p}^0_{\mathrm{m/ipc}} = \frac{\sum_{jt}\mathrm{T}^0_{\mathrm{ijmtpc}}}{\sum_{jtk}\mathrm{T}^0_{\mathrm{ijktpc}}}$
- $p_{m/ipc}$ is the output probability resulted from change in the composite costs;
- θ_c^{mode} is the theta parameter for the Main mode choice modelling; and
- ΔU^*_{impc} is the change in composite costs that are calculated from the Macro Time choice hierarchy, given by the formula: $\Delta \mathrm{U}^*_{\mathrm{impc}} = \ln \sum_t p^0_{t/impc} \exp\left(\theta_c^{time}\Delta U^*_{imtpc}\right)$

FREQUENCY CHOICE

2.8.16. The frequency model is applied after the Main Mode choice modelling, using the formula:

$$T_{ijmtpc} = \exp\left(\theta_c^{freq}\Delta U^*_{ipc}\right) * T^0_{ipc} * p_{m/ipc} * p_{t/impc} * p_{j/imtpc}$$

where:

- T^0_{ipc} is the reference total production trip-ends for zone i, for purpose p and person type c;
- T_{ijmtpc} is the final trip between zone i and zone j, for mode m, time period t, purpose p and person type c; and
- ΔU^*_{ipc} is the composite costs that are calculated from the Main mode choice hierarchy, given by the formula $\Delta \mathrm{U}^*_{\mathrm{ipc}} = \ln \sum_m p^0_{m/ipc} \exp\left(\theta_c^{mode}\Delta U^*_{impc}\right)$ for car available and $\Delta \mathrm{U}^*_{\mathrm{ipc}} = \Delta \mathrm{U}^*_{\mathrm{impc}}$ for non-car available.

2.8.17. Frequency choice is at the bottom of the cost hierarchy / top of the choice hierarchy and needs separate costs by car availability segment.

2.8.18. As mentioned earlier in the report, the frequency choice modelling mechanism was built into the demand model however was turned off initially. During the calibration of the base year demand model it may be turned on following outcomes from the elasticity calculation from the realism tests.

2.9 DERIVATION OF BASE YEAR PT DEMAND

2.9.1. As mentioned in the previous section, there was no explicit PT model that has been developed for the Selby District traffic model. instead, an approximation of the PT costs in terms of fixed PT costs were produced by making use of the base year highway models. in order to allow for the model choice response to be undertaken within the variable demand model, it was required that the Base year PT demand matrices to be created as reasonably satisfactory as possible.

2.9.2. To achieve that, the validated Base year highway demand matrices at individual purposes by time periods were used as the starting point, coupled with the adjusted trip-ends (derived from calculating the proportion of PT trip-ends against car trip-ends at MSOA level using NTEM 7.2) and a Furnessing process to derive the equivalent base year PT demand matrices by individual purposes and by time periods.

2.9.3. This method, whilst a simple and crude method, allows a set of “synthetic” PT demand matrices to be created with similar PT to car proportions from the NTEM database at localised level. This would allow a reasonable mode choice response to be implemented within the Selby District variable demand model.

2.10 DERIVATION OF PA-BASED DEMAND

2.10.1. As recommended by TAG M2, variable demand models require demand and cost matrices to be in the P/A form for HB purposes and O/D form for NHB purposes. It is essential that the demand and the assignment models are correctly connected with consistent cost definition and appropriate conversion between the demand model P/A matrices and the assignment O/D matrices.

2.10.2. Unlike the OD-based demand modelling (the outbound and return would not be linked as they are considered two independent trips), the derivation of a PA-based demand modelling for a 24-hour period with explicit consideration of time choice modelling is complex, particularly when Time choice is placed after the Main Mode choice but before the Destination choice. The key technical challenge is how the demand and costs arising from the return leg of a Home-Based trip may be estimated in the demand model when timing of the return leg is dependent on the outward journey. In other words, if the outward leg of a Home-based trip in the morning peak changed departure time to the Inter-peak in response to morning peak congestion charges then when would the return leg take place?

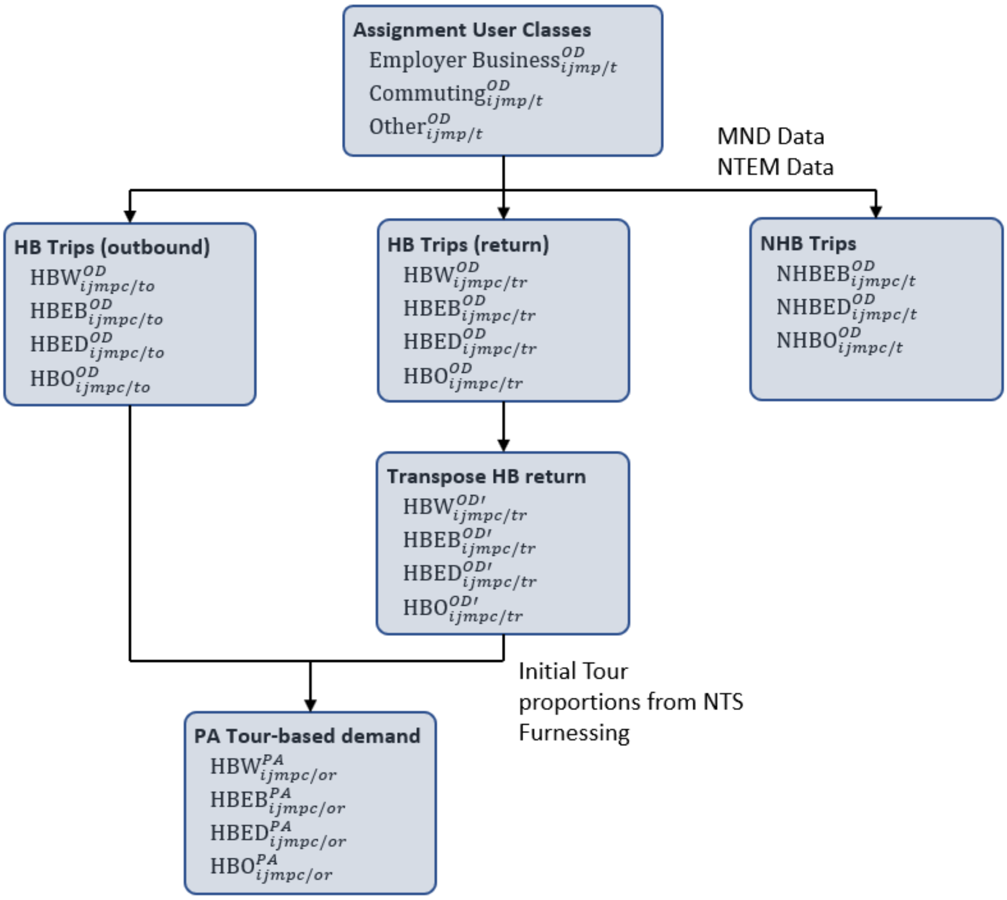
2.10.3. Within the demand model, the key issue was to determine the appropriate travel demand and associated costs of return legs of a home-based trip in a coherent and consistent manner given that the return leg journeys were constrained by the nature of the outward journeys. Whilst the TAG recommends that this functional form should be adopted, it does not provide any guidance on how it may be implemented.

2.10.4. The fundamental assumption underpinning the formulation was the use of a simple “tour-based modelling” approach, with explicit linkage between the outbound and return time periods of trips, in other words, an initial ‘fixed return proportions’ whereby for outward trips leaving home within each time period, the proportions of trips returning in the same or subsequent time periods remain fixed by purposes prior to the demand model choice responses.

2.10.5. During the Macro time choice modelling, the differentials in costs between different time periods would result in change in the reference tour proportion however still ensure the sum of the outward journeys is equal to the sum of the return journeys.

2.10.6. The disaggregation of the OD demand from the assignment user classes and conversion to the PA tour-based demand is illustrated in Figure 2-4, with detail of steps, and denotations are described further in the subsequent sections.

Figure 2-4 Conversion from OD Period to 24-Hour PA Demand



ASSIGNMENT USER CLASS TO DEMAND SEGMENT

2.10.7. As mentioned in previous section, 3 user classes for Private car and Public transport (Employer business, Commuting, and Other) were required to be disaggregated to 5 segments (excepting LGV and HGV) for the purpose of the demand model.

2.10.8. For cars, the prior demand matrices by demand segments and directions (produced from observed Mobile Phone data (MND) and synthetic matrices), which were developed for the purpose of the base-year Highway demand development, were used to provide ‘splitting factors’ by demand segments; directions (outbound and return); and time periods. A quick summary of the process is described in the following paragraphs whilst a detailed description and process are provided in the LMVR report.

2.10.9. For PT, a set of synthetic matrices were also developed using the trip-ends data produced from NTEM trip-ends, coupled with a form of Gravity model and an observed trip-length distribution derived from NTS database to produce a form of “prior” PT matrices with detailed 5 demand segments similarly to the car demand segments. The “prior” PT demand matrices by segmentation were subsequently used to produce the similar “proportional split” to car demands that were applied to the “derived” Base year PT demand to disaggregate the Base year PT demand from user class level to appropriate demand segments for the purpose of the Selby District Demand model.

2.10.10. A summary of the proportional splits at the overall level are summarised in Table 2-4 and Table 2-5 below for Highways and Public transport respectively.

Table 2-4 Proportional Split from Highways User Class to Demand Segment

User Class	Purpose	AM Peak		Inter-Peak		PM Peak		Off-Peak	
		Outward	Return	Outward	Return	Outward	Return	Outward	Return
Employer's Business	HBEB	56%	7%	16%	21%	22%	48%	14%	39%
	NHBEB	37%		63%		30%		48%	
	Total	**100%**		**100%**		**100%**		**100%**	
Commute	HBW	97%	3%	35%	65%	7%	93%	57%	43%
	Total	**100%**		**100%**		**100%**		**100%**	
Other	HBED	34%	12%	5%	11%	3%	6%	5%	6%
	HBO	36%	9%	36%	34%	34%	46%	30%	47%
	NHBED	2%		1%		1%		1%	
	NHBO	6%		12%		11%		11%	
	Total	**100%**		**100%**		**100%**		**100%**	

Table 2-5 Proportional Split from PT User Class to Demand Segment

User Class	Purpose	AM Peak		Inter-Peak		PM Peak		Off-Peak	
		Outward	Return	Outward	Return	Outward	Return	Outward	Return
Employer's Business	HBEB	74%	7%	27%	34%	23%	57%	20%	49%
	NHBEB	18%		39%		20%		31%	
	Total	**100%**		**100%**		**100%**		**100%**	
Commute	HBW	97%	3%	35%	65%	6%	94%	33%	67%
	Total	**100%**		**100%**		**100%**		**100%**	
Other	HBED	50%	17%	5%	11%	5%	13%	7%	21%
	HBO	23%	6%	37%	37%	27%	42%	30%	34%
	NHBED	1%		1%		0%		0%	
	NHBO	4%		10%		13%		8%	
	Total	**100%**		**100%**		**100%**		**100%**	

2.10.11. It is noted that the proportional splits were calculated at the zonal level, following three steps:

- If the data were available at zonal level, calculate splitting factors at individual zonal level;
- Aggregate to District level and calculate the splitting factors using aggregated data at District level; and
- If aggregated data at District level were zero, then calculate splitting factors at matrix total level.

2.10.12. The three steps described above was to ensure that non-zero splitting factors were produced for each individual OD pairs so that the disaggregation from assignment user classes to the demand model segments would not miss out any trips. This method whilst not an issue with the base year demand, would help to allow disaggregation of forecast demand matrices user classes where new zones are included in the forecast models.

2.10.13. The splitting factors were subsequently applied to the validated base year Highways and PT demand user classes to produce the base year demand segments by time periods and directions. It is noted that at this stage the demand matrices were still at OD form. However, the information on the direction of travel (i.e. outbound and return leg) by time periods would allow for the production of the PA tour-based demand that is to be described in more detail in the sections below.

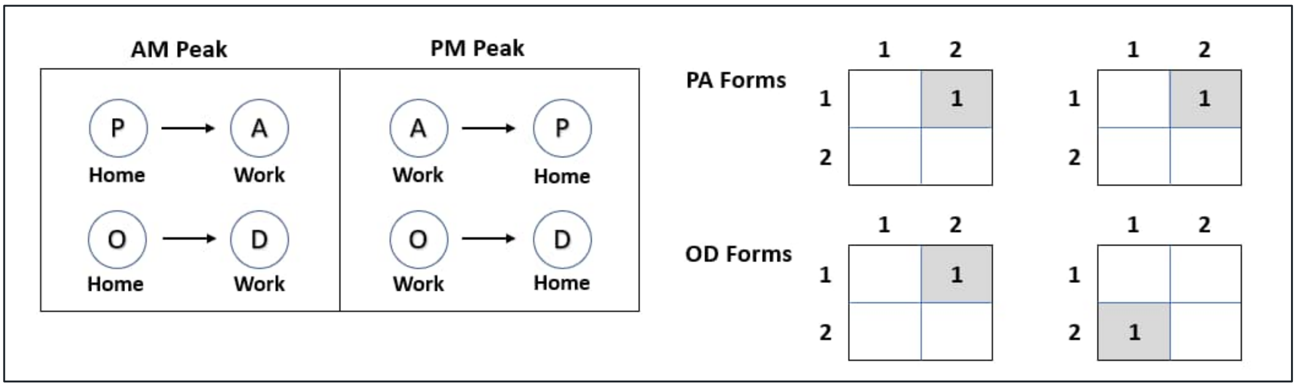
PRODUCTION/ATTRACTION FORMULATION

2.10.14. The Production/Attraction (P/A) definition is used to represent various trips that form a tour (whether outbound from home, return home, or non-home-based) in such a way that relates them most closely to the available demographic data. As the strongest and most relevant demographic data generally relates to residential population, it is useful to distinguish trip-ends that relate to 'home' from those that relate to 'non-home' activities.

2.10.15. The most common pattern for a tour as two trips: an **outbound** trip from home to an activity, and a **return** trip from the activity to home. Both of these are home-based (HB) trips with one end at home, and these are distinguished from non-home based (NHB) trips which have neither end at home. Tours with three or more trips have an outbound HB trip to the first activity, followed by series of NHB trips to other activities, and ending with a return HB trip from the final activity to home.

2.10.16. HB trip-ends are split by **Production** (home) and **Attraction** (activities) which is distinguished from the NHB trip-ends where they are split by **Origin** (start of an activity) and **Destination** (end of that activity). An example relating the P/A definition to the O/D definition is illustrated in Figure 2-5 below.

Figure 2-5 Example of P/A and O/D Trips



2.10.17. In contrast to the NHB purposes, the Production of a HB trip is always 'home' end and Attraction of the trip is always the 'non-home' end. That means, for a HB trip there will be 1 trip in the PA form (e.g., from home to work) as opposed to 2 trips in the OD form (i.e. one from home to work and the other one from work to home).

CONVERSION OF OD DEMAND TO REFERENCE PA

2.10.18. Prior to undertaking any VDM, it was required that a 'reference' demand be created or derived from either observed or synthetic data. The validated base-year demand disaggregated by demand segments produced in the previous section would provide information of a total outbound (P_{out}) and return (P_{ret}) trips by each time period based on the MND and Synthetic data (for example, total trips going out and return in the AM period).

2.10.19. To derive a 24-hour tour-based PA demand model, it was required that individual outbound-return proportions were to be estimated (for example, how many trips going out in the AM would return in the AM peak, Inter-Peak, PM peak and Off-peak), which was not possible unless significant data could be obtained and analysed for individual zones (for example, Household interview surveys, travel diaries, etc. which are undertaken relatively infrequently in the UK). A quick illustration of the data available and data needed for the 24-hour tour-based modelling are provided in Table 2-6 below.

Table 2-6 Data Available for 24-Hour Tour Proportions

Demand		**Return Leg**				
		AM	**Inter-Peak**	**PM**	**Off-Peak**	**Total**
Outward Leg	**AM**	×	×	×	×	$P_{out(AM)}$
	Inter-Peak	×	×	×	×	$P_{out(IP)}$
	PM	×	×	×	×	$P_{out(PM)}$
	Off-Peak	×	×	×	×	$P_{out(OP)}$
	Total	$P_{ret(AM)}$	$P_{ret(IP)}$	$P_{ret(PM)}$	$P_{ret(OP)}$	

2.10.20. The solution to estimate the required outbound-return proportions was relatively straightforward, i.e. using initial tour proportions as the starting point and the outbound-return matrix cells were then adjusted using the Furnessing process doubly-constrained to meet the required trip-ends (i.e. total outward and return by each time period that was produced for the base year demand from the observed MPOD data), as given by the formula:

$$T_{ijmpc/or} = A_{ijmpc/o} * B_{ijmpc/r} * T^{0}_{ijmpc/or}$$

Where:

- $T^{0}_{ijmpc/or}$ is the initial tour proportions of trips (produced from NTS) between zone **i** and zone **j**, for mode **m**, purpose **p** and person type **c** that go out in time period **o** and return in time period **r** ($\sum_{or} T^{0}_{ijmp/or}$ = 1);
- $A_{ijmpc/o}$ and $B_{ijmpc/r}$ are the balancing factors calculated using a Furnessing procedure with the constraints $\sum_{r} T_{ijmpc/or} = Pout_{ijmpc/o}$ and $\sum_{o} T_{ijmpc/or} = Pret_{ijmpc/r}$;
- $Pout_{ijmpc/o}$ is the locally observed number of trips for **ijmpc** that go out in time period **o**; and
- $Pret_{ijmpc/r}$ is the locally observed number of trips for **ijmpc** that return in time period **r**.

2.10.21. It is noted that the $Pret_{ijmpc/r}$ was derived by transposing the return trip from the base year demand, using the formula $Pret_{ijmpc/r}$ = $\left(Pret_{jimpc/r}\right)'$

2.10.22. The initial 24-hour tour proportions that were produced from the NTS database for the GB for each of the HB demand segments are provided in below.

Table 2-7 NTS Tour Proportions – Private Car

HBW		Return Leg				
		AM	Inter-Peak	PM	Off-Peak	Total
Outward Leg	AM	2.7%	11.5%	31.8%	5.7%	**51.6%**
	Inter-Peak	1.1%	5.4%	5.7%	4.9%	**17.1%**
	PM	1.3%	1.7%	3.2%	3.2%	**9.5%**
	Off-Peak	1.9%	6.9%	8.3%	4.8%	**21.9%**
	Total	**7.0%**	**25.5%**	**48.9%**	**18.7%**	**100.0%**
HBEB		Return Leg				
		AM	Inter-Peak	PM	Off-Peak	Total
Outward Leg	AM	2.4%	18.7%	20.1%	5.4%	**46.5%**
	Inter-Peak	1.5%	12.7%	8.2%	4.4%	**26.7%**
	PM	0.7%	3.2%	3.3%	4.8%	**12.0%**
	Off-Peak	1.1%	4.9%	4.9%	3.8%	**14.8%**
	Total	**5.6%**	**39.5%**	**36.5%**	**18.4%**	**100.0%**
HBED		Return Leg				
		AM	Inter-Peak	PM	Off-Peak	Total
Outward Leg	AM	14.9%	37.1%	11.9%	0.9%	**64.8%**
	Inter-Peak	9.5%	16.0%	3.2%	0.4%	**29.1%**
	PM	1.3%	1.3%	2.3%	0.5%	**5.3%**
	Off-Peak	0.2%	0.2%	0.2%	0.3%	**0.8%**
	Total	**25.8%**	**54.6%**	**17.6%**	**2.0%**	**100.0%**
HBO		Return Leg				
		AM	Inter-Peak	PM	Off-Peak	Total
Outward Leg	AM	2.1%	9.6%	5.2%	3.8%	**20.7%**
	Inter-Peak	2.3%	20.6%	12.8%	9.2%	**45.0%**
	PM	0.9%	7.4%	6.6%	6.6%	**21.5%**
	Off-Peak	0.6%	4.2%	3.0%	5.0%	**12.8%**
	Total	**6.0%**	**41.7%**	**27.7%**	**24.6%**	**100.0%**

Table 2-8 NTS Tour Proportions - Public Transport

HBW		Return Leg				
		AM	Inter-Peak	PM	Off-Peak	Total
Outward Leg	AM	0.2%	8.3%	44.4%	8.1%	**60.9%**
	Inter-Peak	0.3%	2.4%	5.1%	6.0%	**13.8%**
	PM	0.5%	0.5%	0.5%	2.0%	**3.5%**
	Off-Peak	1.0%	5.4%	12.1%	3.3%	**21.8%**
	Total	**2.0%**	**16.5%**	**62.0%**	**19.5%**	**100.0%**

HBEB		**Return Leg**				
		AM	**Inter-Peak**	**PM**	**Off-Peak**	**Total**
Outward Leg	**AM**	0.8%	17.5%	28.8%	5.7%	**52.8%**
	Inter-Peak	0.9%	7.8%	8.0%	4.9%	**21.6%**
	PM	0.3%	0.9%	1.0%	2.4%	**4.7%**
	Off-Peak	1.1%	6.5%	10.3%	3.0%	**20.8%**
	Total	**3.1%**	**32.7%**	**48.1%**	**16.0%**	**100.0%**

HBED		**Return Leg**				
		AM	**Inter-Peak**	**PM**	**Off-Peak**	**Total**
Outward Leg	**AM**	2.4%	60.4%	20.6%	0.9%	**84.4%**
	Inter-Peak	1.8%	7.1%	4.4%	0.7%	**14.0%**
	PM	0.0%	0.2%	0.1%	0.2%	**0.5%**
	Off-Peak	0.0%	0.6%	0.5%	0.1%	**1.2%**
	Total	**4.3%**	**68.2%**	**25.6%**	**1.9%**	**100.0%**

HBO		**Return Leg**				
		AM	**Inter-Peak**	**PM**	**Off-Peak**	**Total**
Outward Leg	**AM**	1.0%	16.8%	4.9%	1.7%	**24.4%**
	Inter-Peak	0.8%	35.5%	17.6%	6.7%	**60.6%**
	PM	0.2%	3.0%	2.6%	4.2%	**10.0%**
	Off-Peak	0.1%	1.4%	0.9%	2.5%	**5.0%**
	Total	**2.1%**	**56.8%**	**26.0%**	**15.1%**	**100.0%**

2.10.23. It is noted that due to limited sample from the NTS, the data were calculated by combining NTS data for bus and rail, for both CA and NCA, to provide a single set of tour proportions for Public transport.

2.10.24. The Furnessing process was subsequently undertaken for each of the HB purposes to produce each of the outbound and return legs of the 24-hour tour-based demand for the Selby District VDM. For a given time period t, reference PA demand were calculated using the formula:

$$T^{PA}_{ijmpc/t} = \frac{1}{2}\left(T^{OD}_{ijmpc/to} + T^{OD}_{jimpc/tr}\right) = \frac{1}{2}\left(T^{OD}_{ijmpc/t} * Pout_{ijmpc/t} + T^{OD}_{jimpc/t} * Pret_{ijmpc/t}\right)$$

where:

- $T^{OD}_{ijmpc/to}$ is the OD outbound trip from zone i to j, in the time period t, over mode m, purpose p and person type c;
- $T^{OD}_{jimpc/tr}$ is the return trip from zone j to i, in the time period t, over mode m, purpose p and person type c;

2.10.25. The total 24-hour PA reference demand is a sum of the PA demand from each of the 4 time periods t, as below:

$$T^{PA}_{ijmpc} = \sum_{t} T^{PA}_{ijmpc/t}$$

2.10.26. The method of utilising the initial tour proportions to derive the outbound-return trips by each time periods is currently implemented in the DIADEM software. During the calculation of choice responses, particularly at the time choice model, change in outbound-return trips by time period were subsequently adjusted following the change in the total outbound-return costs that were described in the section below.

2.11 CONVERSION OF OD COSTS TO PA FORMAT

2.11.1. For each demand/supply loop, the skims from the OD-based assignments by time period were converted to PA-based costs to be used for the choice response calculation within the demand model. For the NHB purpose, since the demand were modelled as Incremental OD, the costs from the assignments were fed directly to the demand model. For the HB trips, however, the costs were converted to individual outbound-return legs of the 24-hour tours so that the choice responses could be implemented, particularly for the macro time choice modelling. The PA costs for a HB trip that travelled outbound in the time period o and returned in the time period r for a particular mode m, purpose p and person type c is given by the formula below:

$$C^{PA}_{ijmpc/or} = \frac{1}{2}\left(C^{OD}_{ijmpc/o} + C^{OD}_{jimpc/r}\right)$$

Where:

- $C^{OD}_{ijmpc/o}$ is the OD costs produced from the assignment models from zone i to zone j travelling in time period o, for mode m, purpose p and person type c;
- $C^{OD}_{jimpc/\mathrm{r}}$ is the OD costs produced from the assignment models returning from zone j to zone i during time period r, for mode m, purpose p and person type c.

2.11.2. By adding the relevant return costs, interventions such as, for example, road pricing in the AM period will be appropriately allocated to return-home trips in the same and subsequent time periods (i.e. IP, PM and OP) and therefore the impacts of road pricing in the AM period will be distributed across all the time periods rather than incorrectly allocated to the AM demand calculation.

2.12 CONVERSION OF PA DEMAND TO OD FORMAT

2.12.1. The output highway PA demand produced from the demand model was required to be converted to OD format for the purpose of highway assignment. For this, it was necessary to produce the total outbound and return trips for each of the four time periods since the total OD demand is a sum of the outbound leg and the return leg for a time period (t), as given in the formula below:

$$T^{OD}_{ijmpc/t} = T^{OD}_{ijmpc/to} + T^{OD\prime}_{ijmpc/tr}$$

Where:

- $T^{OD}_{ijmpc/to}$ and $T^{OD\prime}_{ijmpc/tr}$ are the total outbound and return element of the trips from zone I to zone j, for mode m, purpose p and person type c in the time period t.
- The outbound leg of the OD trip can be directly extracted from the PA demand by summing total of trips travelling out in that time period: $T^{OD}_{ijmpc/to} = \sum_k T^{PA}_{ijmpck/to}$

- The return leg of the OD trip was calculated by: a) summing all the trips returning in the time period t from the PA demand, and then b) transpose origin to destination of the trip, using the formula $T^{OD}_{ijmpc/tr} = \sum_k T^{PA}_{jimpck/tr}$

2.12.2. The OD demand matrices produced at the period level from the step above were subsequently converted to peak hour matrices prior to the highway assignment models to be undertaken.

2.13 MODELLING OFF-PEAK PERIOD

2.13.1. The off-peak (OP) period was modelled within the demand model to allow 24-hour tour-based model to be implemented. A representation of the off-peak costs and demand were therefore needed for the PA-based modelling.

2.13.2. TAG M2 does not provide any guidance on how off-peak periods should be represented. A number of assumptions were therefore made to derive the off-peak costs and demand from the modelled periods so that the demand modelling can be implemented at 24-hour level. The assumptions were:

2.13.3. Off-peak costs were equal to the inter-peak costs;

2.13.4. NHB off-peak demand was derived from 12-hour NHB demand with a global factor obtained from the observed ATC data; and

2.13.5. HB off-peak demand was derived from the 24-hour PA demand by subtracting the AM, IP and PM PA demand.

2.13.6. These assumptions were to ensure that the shift in demand to the off-peak period from any of the AM, IP and PM periods are limited and as resulted from the choice response mechanism.

2.14 DEMAND AND SUPPLY MODEL OUTPUTS

2.14.1. The output from the demand model after the destination choice includes a set of updated matrices in OD form that was then to be used for the highway assignments:

- Highways OD peak hour matrices: AM peak hour matrices (08:00-09:00), Inter-peak average hour matrices (10:00-16:00), and PM peak hour matrices (17:00-18:00), segmented by Car user classes, LGV and HGV.
- Public Transport OD peak hour matrices: AM peak hour matrices (08:00-09:00), Inter-peak average hour matrices (10:00-16:00), and PM peak hour matrices (17:00-18:00), aggregated over person types and segmented by User classes.

2.14.2. Output from the Highways assignment models were a set of cost skim matrices, produced by the assignment models to feed into the demand mode, as below:

- Skimmed highway time matrices, and;
- Skimmed highway distance matrices.

2.14.3. The highway skims, by time period and user class, were converted from OD format to the equivalent PA format within the Selby District VDM prior to the choice response calculation being undertaken.

2.14.4. The same PT fixed costs are also fed back into the choice response calculation.

3 MODEL PARAMETERS

3.1 INTRODUCTION

3.1.1. This chapter presents key parameters that were used for the Selby District VDM, including:

- Sensitivity parameters to be used in the realism tests;
- Generalised Cost parameters and the introduction of cost damping;
- Car occupancies, peak hour factors; and
- Base year PA demand by demand segments.

3.2 SENSITIVITY PARAMETERS FOR REALISM TESTS

3.2.1. TAG M2 suggests that if the locally calibrated parameters or parameters derived from existing models or local knowledge is not possible, illustrative values that were obtained from a number of UK transport models can be used to assist in delivering the realism tests.

3.2.2. It is noted that for the PT demand modelling, as recommended by TAG, the same sensitivity parameters can be used for both Car Available and Non-Car Available person trips.

DESTINATION CHOICE

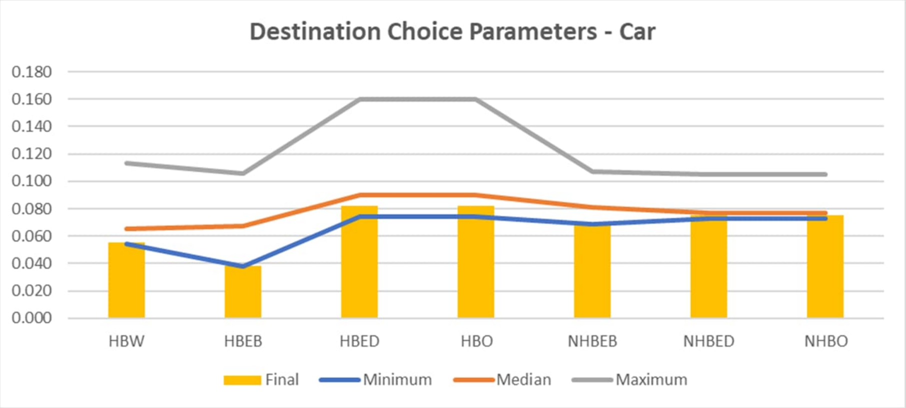
3.2.3. Resultant highway destination choice sensitivity parameters for the Selby District VDM are provided in Table 3-1 and Figure 3-1 below (absent negative signs) alongside the illustrative parameters as provided in the TAG M2 guidance. By showing the range of the TAG illustrative values, it is clear the highway destination choice parameters calibrated for the Selby District VDM are all within the recommended ranges by purpose, more specifically:

- HBW, HBEB and NHBEB: close to the TAG minimum values; and
- HBED, HBO, NHBED and NHBO: between TAG minimum and median values.

Table 3-1 Destination Choice Parameters - Highways

ID	Demand Segment	TAG M2 (Lambda)			Selby District VDM
		Minimum	Median	Maximum	
1	HBW	0.054	0.065	0.113	**0.055**
2	HBEB	0.038	0.067	0.106	**0.038**
3	HBED	0.074	0.090	0.160	**0.082**
4	HBO	0.074	0.090	0.160	**0.082**
5	NHBEB	0.069	0.081	0.107	**0.069**
6	NHBED	0.073	0.077	0.105	**0.075**
7	NHBO	0.073	0.077	0.105	**0.075**

Figure 3-1 Destination Choice Parameters - Highways



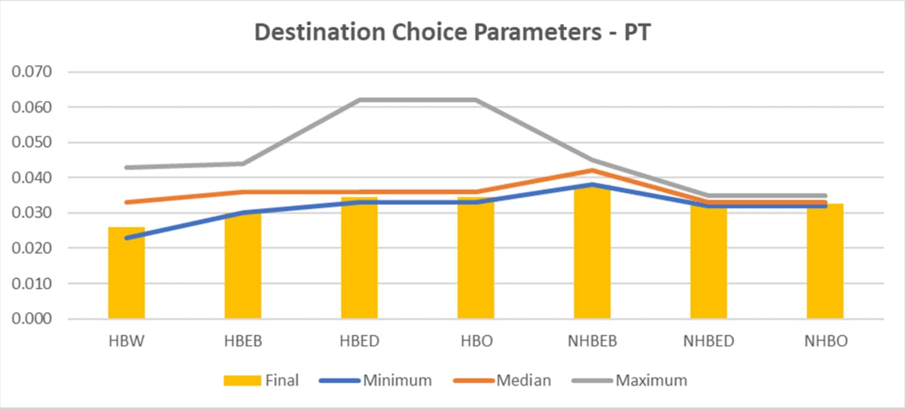
3.2.4. The Public transport destination choice parameters adopted for the Selby District VDM are provided, in Table 3-2 and Figure 3-2 below, alongside the illustrative parameters from TAG M2. By showing the range of the TAG illustrative values, it is clear that the public transport destination choice parameters calibrated for the Selby District VDM are all within the recommended ranges by purpose, similar to the highways:

- HBW, HBEB and NHBEB: close to the TAG minimum values; and
- HBED, HBO, NHBED and NHBO: between TAG minimum and median values.

Table 3-2 Destination Choice Parameters – Public Transport

ID	Demand Segment	TAG M2 (Lambda)			Selby District VDM
		Minimum	Median	Maximum	
1	HBW	0.023	0.033	0.043	
2	HBEB	0.030	0.036	0.044	
3	HBED	0.033	0.036	0.062	
4	HBO	0.033	0.036	0.062	
5	NHBEB	0.038	0.042	0.045	
6	NHBED	0.032	0.033	0.035	
7	NHBO	0.032	0.033	0.035	

Figure 3-2 Destination Choice Parameters - Public Transport



3.2.5. The above destination choice sensitivity parameters for highway and PT were calibrated during the realism tests (as explained later in the next chapter) to ensure outturn elasticities with respect to car fuel cost and PT fare were within the recommended TAG values.

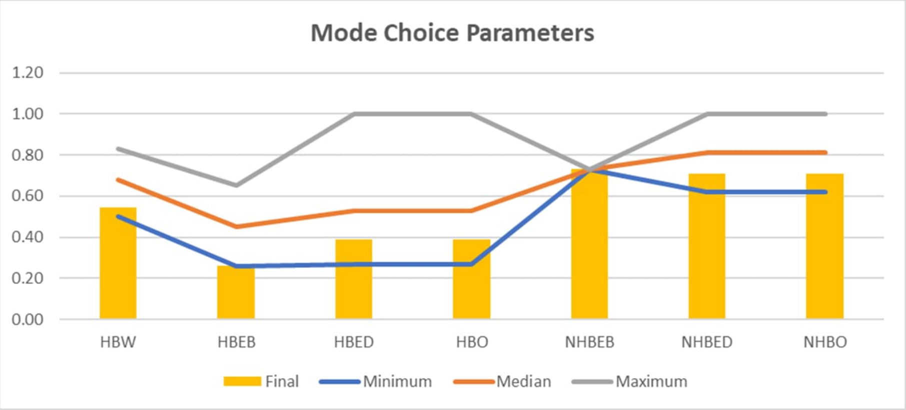
MAIN MODE CHOICE

3.2.6. The parameters adopted for the main mode choice and macro time choice for the Selby District VDM are provided in Table 3-3 and Figure 3-3 below alongside the TAG illustrative parameters. The theta values for all demand segments were within the TAG ranges.

Table 3-3 Main Mode Choice Parameters

ID	Demand Segment	TAG M2 (Theta)			Selby District VDM (Theta)
		Minimum	Median	Maximum	
1	HBW	0.50	0.68	0.83	**0.55**
2	HBEB	0.26	0.45	0.65	**0.26**
3	HBED	0.27	0.53	1.00	**0.39**
4	HBO	0.27	0.53	1.00	**0.39**
5	NHBEB[1]	0.73	0.73	0.73	**0.73**
6	NHBED	0.62	0.81	1.00	**0.71**
7	NHBO	0.62	0.81	1.00	**0.71**

Figure 3-3 Main Mode Choice Parameters



3.2.7. It is noted that TAG suggests that the main mode choice and the macro time period have the same sensitivity in the demand model. Since the Time choice modelling was placed under the mode choice modelling in the hierarchy in the Selby District VDM, the values adopted are as below:

- the time choice model adopted the same theta parameters as provided in Table 3-3; and
- the theta values for mode choice were set to 1 to represent same sensitivity between the macro time choice and the main mode choice.

---

[1] Only 1 sample available from TAG M2's illustrative values

FREQUENCY CHOICE

3.2.8. TAG M2 suggests that if active modes are omitted, a small sensitivity value can be assumed to act as a proxy to allow modal shift between active and car/PT modes. However, the evidence of appropriate sensitivity parameters is limited, and therefore no explicit values have been recommended.

3.2.9. For the Selby District VDM, the frequency choice was built in however turned off following satisfactory outcomes from the initial realism tests.

3.3 GENERALISED COST PARAMETERS

HIGHWAYS

3.3.1. The generalised cost parameters used for the demand modelling were extracted from the Highways base year assignments for the calculation of Pivot costs in a form of Pence Per Minute (PPM) and Pence Per Kilometre (PPK).

For the realism tests with the car fuel cost changes, the PPK values for cars were recalculated by applying 20% increase to the fuel cost elements. The PPM and PPK values for the highway base year model and the car fuel cost models are provided in Table 3-4 and Table 3-5 below (based on the TAG Databook November 2021).

Table 3-4 Generalised Cost Parameters – Base Year Model

ID	User Class	AM Peak		Inter-Peak		PM Peak	
		PPM	PPK	PPM	PPK	PPM	PPK
1	Employer Business	30.92	12.78	31.68	12.78	31.36	12.78
2	Commuting	20.73	6.27	21.07	6.27	20.81	6.27
3	Other	14.31	6.27	15.24	6.27	14.98	6.27
4	LGV	22.41	13.65	22.41	13.65	22.41	13.65
5	HGV	51.32	43.99	51.32	44.36	51.32	46.09

Table 3-5 Generalised Cost Parameters – With 20% Fuel Cost Change

ID	User Class	AM Peak		Inter-Peak		PM Peak	
		PPM	PPK	PPM	PPK	PPM	PPK
1	Employer Business	30.92	13.82	31.68	13.82	31.36	13.82
2	Commuting	20.73	7.52	21.07	7.52	20.81	7.52
3	Other	14.31	7.52	15.24	7.52	14.98	7.52
4	LGV	22.41	13.65	22.41	13.65	22.41	13.65
5	HGV	51.32	43.99	51.32	44.36	51.32	46.09

3.3.2. It is noted that in contrast to the Commute and Other, which does not perceive non-fuel elements, Business purpose perceives non-fuel elements in modelling as per TAG A1-3 guidance, paras. 5.1.17 and 5.1.18. That means Generalised cost parameters for Business include non-fuel cost elements in the calculation of the PPK value. As a result, the 20% increase in fuel costs in the Car Fuel elasticity test does not equate to a 20% increase in PPK values for the Business purpose.

PUBLIC TRANSPORT

3.3.3. As mentioned in the previous chapter, the in order to allow for the mode choice mechanism to be undertaken within the demand model, the fixed PT costs that were derived from the highway costs, with separate cost elements were provided to allow for the realism tests with PT fare elasticity and also for the forecasting purpose.

3.3.4. For the purpose of Selby District VDM model, the Value of Time values that have been derived from the TAG Databook November 2021 have been used, as provided in Table 3-6 below.

Table 3-6 - Value of Times - Public Transport

ID	User Class	AM Peak	Inter-Peak	PM Peak
1	Employer Business	15.50	15.50	15.50
2	Commuting	18.31	18.31	18.31
3	Other	8.36	8.36	8.36

3.3.5. During the realism tests with PT fare elasticities, fares were adjusted by applying 20% increase prior to carrying out the Selby District VDM model to test the elasticities with respect to PT fare changes.

3.4 EXTERNAL DEMAND & COST DAMPING

3.4.1. Initial tests with the base year model show that the elasticity with respect to car fuel cost changes were very strong, particularly for Business and Other trip purposes. Analysis of the demand model results show that:

- Large number of long-distance trips of Business and Other from external areas travelling from/to the detailed modelling area (which is anticipated as the nature of the area that attracts tourists from across the country); however
- The network coverage outside the study area were coded at aggregate level with fixed speed and aggregate zone system.

3.4.2. In terms of demand modelling, the fixed speed network for the external areas without any response mechanism to flow change would result in overestimating the change in demand to external zones as opposed to internal zones since external zone costs would experience less change compared to larger change in the detailed modelling area.

3.4.3. According to TAG M2, there is strong empirical evidence that the sensitivity of demand responses to change in generalised costs reduces within increasing trip length. Furthermore, external-external trips tend to be inelastic to the choice responses as their journeys are primarily pre-determined based on the destinations as opposed to localised congestion within the study area.

3.4.4. To be able to represent the demand response for long distance and external-external movements outside the area of focus, two mechanisms were applied for the Selby District VDM, as below:

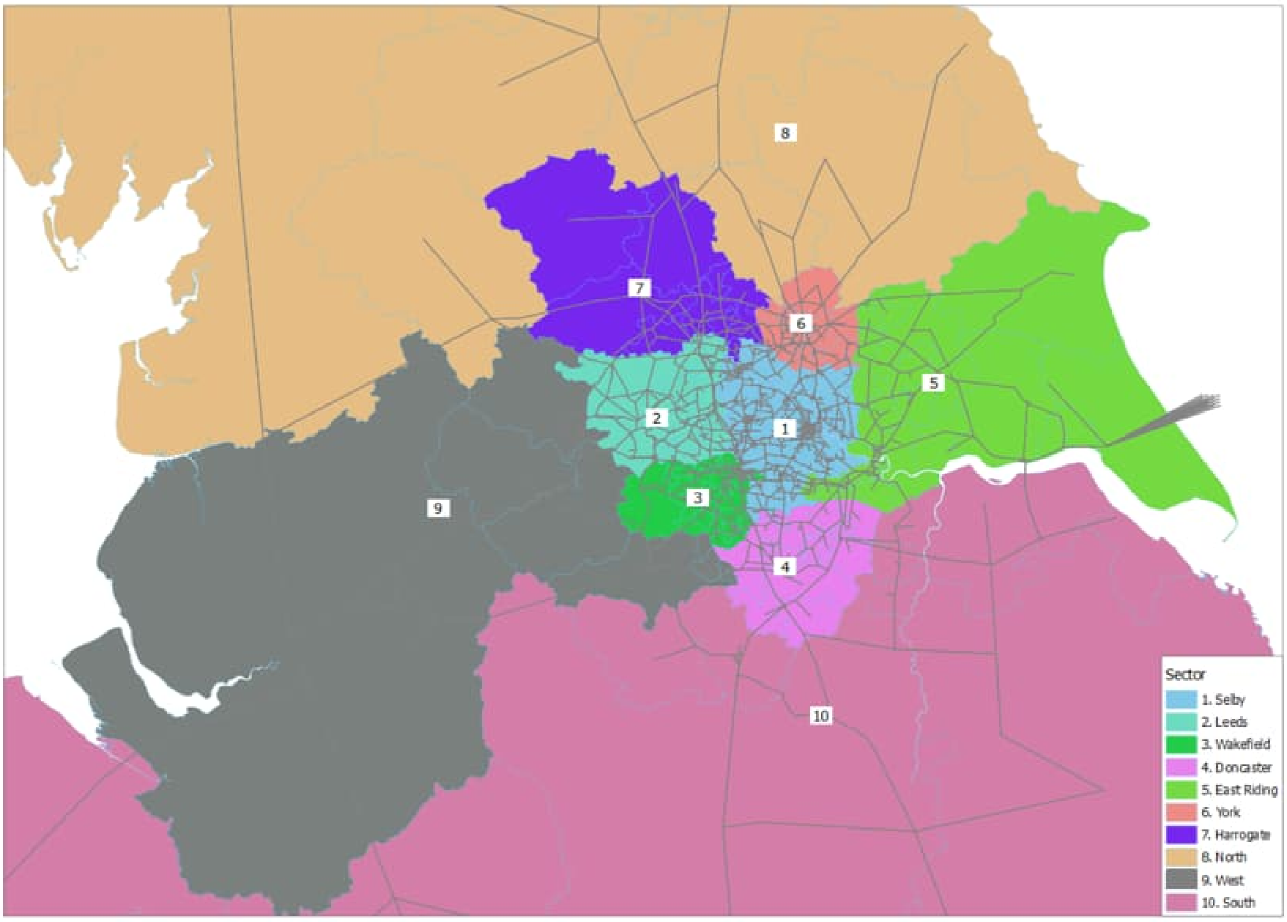
- Apply a form of cost moderation to ‘dampen’ the effects of the long-distance trips; and
- Fix external-external movement.

3.4.5. The application of the cost damping to the long-distance trips and freezing of the external-external movements are described in more detail below.

EXTERNAL-EXTERNAL MOVEMENTS

3.4.6. As mentioned in the previous chapter, the Selby District Transport Model's detailed modelling area consists of at least some parts of 4 LADs: Selby District, Wakefield, Leeds, East Riding and York. For the purpose of the Selby District VDM, LADs 1-7 representing Selby, Leeds, Wakefield, Doncaster, East Riding, York and Harrogate were included as 'Internal' areas and the rest of the model zone system were considered 'External' areas, as highlighted in Figure 3-4 below.

Figure 3-4 Internal / External Area for Selby District VDM



3.4.7. For the purpose of the Selby District VDM, trips that are whithin the Internal-Internal, Internal-External, and External-Internal movements have been included for the calculation of the choice-demand response whereas External-External demand were treated as fixed demand and not subject to the Selby District VDM.

COST DAMPING

3.4.8. TAG M2 provides a number of approaches to employ the cost damping mechanism, as below:

- Varying VOT with Distance;
- Damping Generalised cost by a function of distance;

- Power function of Utility;
- Log cost plus Linear cost; and
- Combination of above.

3.4.9. Following research on effectiveness the Selby District VDM method of ‘damping generalised cost by a function of distance’ was adopted using the formula below:

$$G' = \begin{cases} (d/k)^{-\alpha} * \left(t + \frac{c}{VoT}\right) & if\ d \geq d' \\ \left(t + \frac{c}{VoT}\right) & if\ d < d' \end{cases}$$

Where:

- G' is the damped generalised cost;
- $(t + c/VoT)$ is the generalised costs;
- d is the trip length;
- d’ is the minimum cut-off distance in which the cost damping applies; and
- k and α are parameters that need to be provided or calibrated.

3.4.10. It is noted that the purpose of the cut-off is to prevent short-distance trips, particularly intra-zonal rips, becoming unduly sensitive to cost change.

3.4.11. The values of k and d’ were derived from the average trip length across the journey purposes from the validated base year highway models. Subsequently, a number of runs were undertaken to determine the most appropriate ∝ parameters prior to the realism tests. Table 3-7 below provides the final cost damping parameters to be used for the Selby District VDM. The values of K and D’ have been derived based on the average trip length calculated for the study area whilst the alpha values have been derived following series of calibration steps during the Realism tests.

Table 3-7 Cost Damping Parameters

Mode	User Class	K	Alpha (α)	D’
Highways	Employer Business	35	0.70	35
	Commuting	25	0.00	25
	Other	25	0.70	25
Public Transport	Employer Business	35	0.70	35
	Commute	25	0.00	25
	Other	25	0.70	25

3.5 INTRA-ZONAL COSTS

3.5.1. TAG M2 suggests that average intra-zonal trip costs should be calculated as accurately as possible to remove bias against shorter trips in the distribution model, particularly to zones with very low intra-zonal costs, and where mode choice is less sensitive than destination choice, then distribution of car trips using a function could lead to an excess of very short distance car trips.

3.5.2. At the distribution stage it is important to be able to redistribute intra-zonal to become inter-zonal trips and inter-zonal to become intra-zonal trips, if relative costs change. If the zone sizes are small this is less of a problem, but for large zones it is important that average intra-zonal costs are as realistic as possible.

3.5.3. Since both the Highways and PT assignment models do not produce intra-zonal costs, various approaches may be used to derive intra-zonal costs. For the Selby District VDM, the fixed proportion of the costs of inter-zonal trips to the nearest neighbouring zones was adopted to derive the average costs of an intra-zonal trip, following the formula below:

$$IZCost_{impct} = 0.5 * Min(Cost_{ijmpct})$$

where:

- $IZCost_{impct}$ is the intra-zonal cost of zone i, for mode m, purpose p, person type c and time period t; and
- $Cost_{ijmpct}$ is the generalised costs between zone i and j, for mode m, purpose p, person type c and time period t.

3.5.4. This approach has been widely used as a standard approach for modelling and appraisal projects within the UK.

3.6 CAR OCCUPANCY

3.6.1. The car occupancy values adopted for the Selby District VDM is provided in Table 3-8 below by trip purposes and time periods (adopted TAG Databook November 2021).

Table 3-8 Car Occupancies in Persons per Vehicle

ID	User Class	AM Peak	Inter-Peak	PM Peak	Off-Peak
1	Employer Business	1.131	1.159	1.147	1.169
2	Commuting	1.132	1.151	1.136	1.153
3	Other	1.712	1.823	1.793	1.786

3.6.2. The car occupancy values used in the demand model were taken from the TAG DataBook (May 2019). These are the same values that were used to build the trip matrices for the Base-year highway model. It is noted that there is no distinction between home-based and non-home-based trips within a trip purpose.

3.7 CONVERSION TO PEAK HOURS

3.7.1. As mentioned in the previous chapter, the PA demand produced from the demand model were initially converted to OD format by periods and subsequently converted to peak hour OD matrices prior to highways and PT assignments. The peak hour to period factors adopted for the Selby District VDM is provided in Table 3-9 below.

Table 3-9 Peak Hour to Peak Period Factor

ID	Mode	AM Peak	Inter-Peak	PM Peak	Off-Peak
1	Highways	2.710	6.000	2.650	12.000
2	Public Transport	3.000	6.000	3.000	12.000

3.7.2. The peak hour for the highways model were derived from the observed ATC count data which were used for the development of the base year highway model. The factors for PT, however, due to no explicit PT model that has been developed or observed data available, it was assumed that the factors of 3, 6 and 3 were used to represent conversion from peak hour to period.

3.8 BASE YEAR DEMAND

3.8.1. The total base-year Car and PT demand in the PA format by time period and at all-day level is summarised in Table 3-10 and Table 3-11 below.

Table 3-10 Base Year PA Demand – Private Cars (person trips)

Segment	Direction	AM Peak	Inter-Peak	PM Peak	Off-Peak	All Day
HBW	Outbound	156,603	38,787	11,549	71,508	278,447
	Return	5,182	71,504	147,709	54,051	278,447
HBEB	Outbound	20,315	8,699	6,409	4,165	39,588
	Return	2,507	11,613	13,877	11,591	39,588
HBED	Outbound	96,837	36,724	9,231	14,739	157,531
	Return	35,238	83,164	20,846	18,284	157,531
HBO	Outbound	104,146	268,934	115,094	88,684	576,858
	Return	26,722	252,888	155,543	141,704	576,858
NHBEB	All	13,471	34,036	8,646	14,268	70,421
NHBED	All	5,979	10,025	3,225	3,450	22,679
NHBO	All	18,588	92,818	37,045	31,851	180,303
Total	**All**	**485,589**	**909,191**	**529,175**	**454,297**	**2,378,252**

Table 3-11 Base Year PA Demand – Public Transport (person trips)

Segment	Direction	AM Peak	Inter-Peak	PM Peak	Off-Peak	All Day
HBW	Outbound	14,281	1,807	622	2,336	19,046
	Return	383	3,429	10,416	4,817	19,046
HBEB	Outbound	1,160	583	349	252	2,343
	Return	115	722	884	622	2,343
HBED	Outbound	9,706	2,075	833	1,221	13,833
	Return	3,262	4,684	1,980	3,908	13,833
HBO	Outbound	4,361	16,471	4,206	5,464	30,501
	Return	1,060	16,605	6,559	6,277	30,501
NHBEB	All	287	849	315	388	1,839
NHBED	All	133	320	48	107	607
NHBO	All	726	4,225	2,116	1,404	8,471
Total	**All**	**35,473**	**51,769**	**28,327**	**26,795**	**142,365**

4 DEMAND MODEL CALIBRATION

4.1 INTRODUCTION

4.1.1. According to TAG M2, section 6.4, once a variable demand model has been constructed, it is essential to ensure that the model behaves 'realistically', by varying the various components of travel costs and times of the base year model and checking that the overall demand response accords with general experience. If it does not, then the values of the sensitivity parameters controlling the response of demand to costs should be adjusted until an acceptable demand response is achieved.

4.1.2. The acceptability of the model's responses is determined by its demand elasticities, which is measured by change in travel made as a result of change in costs. The process of adjusting model sensitivity parameters to achieve the acceptable demand response is called the 'Realism Tests'.

4.1.3. As required by TAG M2, there are 3 types of realism tests with the target elasticities as below:

- Car Fuel cost - recommended elasticities between -0.1 and -0.4 (weaker for mandatory trips and stronger for discretionary trips), with an overall target value of between -0.25 and -0.35 across all segments;
- Car journey time – recommended elasticities no stronger than -2.0; and
- PT fare – recommended elasticities between -0.2 and -0.6 for short terms and up to -0.9 for longer term.

4.1.4. TAG M2 also states that if the model does not behave in accordance with general experience, it should not be used to appraise a transport scheme, unless a convincing case can be made to explain the differences in terms of special local circumstances. However, the model parameters should be modified until its responses are plausible.

4.1.5. For the Selby District Transport Model, since no locally calibrated parameters were available, TAG M2 recommended that the illustrative sensitivity parameters were to be used as the starting point to determine the calibrated values in the realism tests.

4.2 SUPPLY-DEMAND CONVERGENCE

4.2.1. The Selby District VDM employs an iterative method to achieve convergence between the assignment model (i.e. SATURN highways model) and the bespoke CUBE demand model. Convergence was achieved by passing costs from the assignment model along with the fixed PT costs to the demand model and subsequently passing trips from the demand model back to the assignment model. The process terminates once the convergence criterion has been met.

4.2.2. The recommended criterion specified by TAG M2, for measuring convergence between the demand and supply models, is the demand/supply %Gap over all segments, defined by the formula below:

$$Convergence\ Gap = \frac{\sum_{ijmpct} C\left(X_{ijmpct}\right) * ABS\left(D\left(C\left(X_{ijmpct}\right)\right) - X_{ijmpct}\right)}{\sum_{ijmpct} C\left(X_{ijmpct}\right) * X_{ijmpct}} * 100$$

where:

- X_{ijmpct} is the current demand matrix from the model;
- $C\left(X_{ijmpct}\right)$ is the generalised cost matrix obtained by assigning the matrix X_{ijmpct};

- $D(C(X_{ijmpct}))$ is the demand matrix output by the demand model, using costs $C(X_{ijmpct})$ as input; and
- $ijmpct$ represents origin i, destination j, mode m, purpose p, person type c and time period t.

4.2.3. It is of crucial importance to achieve a high level of supply-demand convergence to provide assurance that the model results are as free from error and 'noise' as possible. For this reason, TAG M2 recommends that the %Gap of less than 0.1% should be achieved and remedial steps should be taken to improve the convergence if the convergence Gap is over 0.2%.

4.2.4. To aid searching for the convergence solution, a number of methods were explored to achieve a stable converged solution between the demand and supply responses:

- Conventional method – the demand output from the demand model for current iteration used directly as the input demand in the next iteration. This method can reach a lower gap value very quickly however can lead to a non-converged solution if the networks are congested;
- Method of successive average (MSA) – a 'slow but true' traditional method with a lengthy duration to a convergence solution; and
- Fixed step length – this is normally the best of the three with quicker convergence solution. However, with a congested network this method may take longer or not converge if the step length is not appropriately selected.

4.2.5. For the Selby District VDM, a 'variable step length' method was adopted, a combination of the conventional method and the fixed step length method, as illustrated by the equation below:

$$X^N = X^{N-1} + \alpha * \left(D\left(C(X^{N-1})\right) - X^{N-1}\right)$$

where:

- X^N is the demand matrix to be used to the next demand model loop;
- X^{N-1} is the current demand matrix from the demand model;
- $D\left(C(X^{N-1})\right)$ is the new demand matrix output by the demand model, using the costs $C(X^{N-1})$ produced from the assignment of the matrix X^{N-1} as the input; and
- α is the variable step length to be applied, being set to 1.0, 0.9, 0.8, etc. for VDM loop 1, 2, 3, etc. respectively and set to 0.5 from loop 6 onward (this was devised from number of trial test runs while searching for the optimal convergence solutions from number of previous experiences).

4.2.6. The variable step length was implemented to allow faster yet more stable when searching for the convergence solutions compared to the above-mentioned methods. Table 4-1 below provides a summary of the demand/supply convergence of the realism tests for the car fuel elasticity and PT fare elasticity. It is noted that the journey time elasticity realism test was undertaken using a single VDM loop therefore no convergence summary was provided.

Table 4-1 Realism Test Convergence

VDM Loop	Car Fuel Cost Elasticity				PT Fare Elasticity			
	Total Costs	%Gap (Car)	%Gap (PT)	%Gap (All)	Total Costs	%Gap (Car)	%Gap (PT)	%Gap (All)
1	31,072,845	5.520	3.120	5.201	30,011,660	0.242	5.299	0.977
2	30,208,830	0.330	0.217	0.314	29,857,805	0.044	0.063	0.046
3	30,249,160	0.058	0.077	0.061				

4.2.7. As can be seen, the VDM models converged quickly within 3 demand/supply loops and the convergence gap calculated from the realism tests were well within the TAG M2 recommended criterion of 0.1%.

4.3 REALISM TESTS & ELASTICITIES

4.3.1. As mentioned above, the purpose of the realism tests was to ensure that the model behaves ‘realistically’ prior to applying to the modelling and appraisal of any forecast demand model. The acceptability of the model’s responses is determined by the demand elasticities, which was given by the formula as recommended by TAG M2:

$$E = \frac{\log(T^1) - \log\,(T^0)}{\log(C^1) - \log\,(C^0)}$$

Where:

- $T^0\ and\ T^1$ are the demand before and after the change produced from the demand model; and
- $C^0\ and\ C^1$ are the costs before and after the change produced from the demand model.

4.3.2. It is noted that:

- For fuel cost elasticity, T represents **car-kms** travelled whilst C represents **fuel cost**; and
- For PT fare, T represents PT **trips** and C represents **fares**

4.3.3. The realism tests were undertaken using the following assumptions:

- Car fuel cost elasticity - 20% increase in car fuel prices;
- Car journey time elasticity – 20% increase in car journey time; and
- PT fare elasticity – 20% increase in PT fares.

4.3.4. These assumptions were adopted to ensure that any effects due to model noise would be minimised particularly for models with high congestions in the study area.

4.4 CAR FUEL COST ELASTICITIES

4.4.1. The car fuel cost elasticities are calculated as the percentage change in vehicle-kms with respect to the percentage change in fuel cost. The calculation adopted for the Selby District VDM was carried out for a 20% increase in **fuel** cost only. It is noted that the element of non-fuel operating costs was not included in the calculation of fuel cost elasticities.

4.4.2. As mentioned in the TAG M2, the car fuel cost elasticities should be calculated using two methods: a) the Matrix-based method, and b) the Network-based method. A summary of the resultant elasticities with respect to car fuel cost changes with each method is described in the following sections.

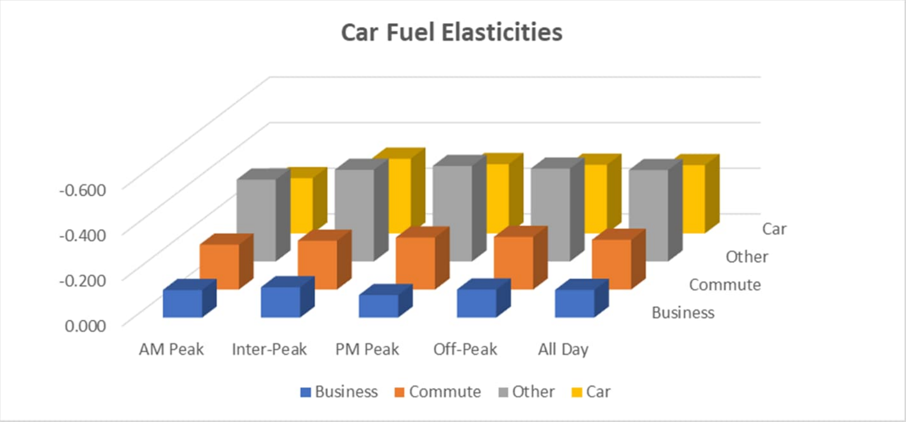
MATRIX-BASED METHOD

4.4.3. The matrix-based fuel cost elasticities are presented in Table 4-2 below with the elasticities reported by time period, trip purposes and for trips travelling within, from and to the study area.

Table 4-2 Car Fuel Cost Elasticities – Matrix-Based

User Class	Demand Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	All Day
Business	HBEB, NHBEB	-0.120	-0.133	-0.098	-0.123	-0.121
Commute	HBW	-0.198	-0.213	-0.228	-0.230	-0.218
Other	HBED, HBO, NHBED, NHBO	-0.358	-0.402	-0.418	-0.407	-0.400
Car	**All purposes**	**-0.242**	**-0.328**	**-0.304**	**-0.300**	**-0.299**

Figure 4-1 Car Fuel Elasticities - Matrix-Based



4.4.4. It is noted that, as per TAG guidance, since the external-external movements were treated as fixed, the calculation of car fuel cost elasticities using the matrix-based method does not include the external-external movements.

4.4.5. Matrix based vehicle-kms elasticities with respect to car fuel cost changes in general show plausible responses at annual level, in accordance with the TAG M2 guidance, of which:

- The annual average fuel cost elasticity is -0.30, which lies within the range -0.25 and -0.35;
- Fuel cost elasticities are generally weaker for short distance trips and stronger for longer distance trips, as can be seen in the fuel elasticity figures at sectoral level as provided Table 4-3;
- The annual elasticity values are close to -0.1 for business trips (-0.12), close to -0.4 for Other trips (-0.40) and near the average for Commuting trips (-0.22);
- The overall elasticities for cars show plausible results by time periods (i.e. stronger response in the inter-peak and off-peak periods relative to AM and PM peak period), in line with TAG guidance.

4.4.6. A summary of the car fuel cost elasticities by sector level is provided in Table 4-3 below.

Table 4-3 Car Fuel Cost Elasticities by Sector

Sector	1	2	3	4	5	6	7	8	9	10	Total
1. Selby	-0.04	-0.32	-0.26	-0.42	-0.40	-0.14	-0.38	-0.33	-0.33	-0.39	**-0.25**
2. Leeds	-0.31	-0.06	-0.26	-0.55	-0.68	-0.44	-0.24	-0.38	-0.09	-0.42	**-0.32**
3. Wakefield	-0.25	-0.28	-0.03	-0.33	-0.67	-0.53	-0.57	-0.49	-0.12	-0.32	**-0.26**
4. Doncaster	-0.43	-0.56	-0.33	-0.08	-0.54	-0.66	-0.68	-0.53	-0.37	-0.16	**-0.35**
5. East Riding	-0.37	-0.66	-0.63	-0.52	-0.30	-0.32	-0.63	-0.36	-0.43	-0.36	**-0.40**
6. York	-0.14	-0.46	-0.54	-0.72	-0.36	0.00	-0.30	-0.26	-0.44	-0.55	**-0.28**
7. Harrogate	-0.36	-0.22	-0.54	-0.65	-0.66	-0.27	-0.08	-0.15	-0.31	-0.44	**-0.28**
8. North	-0.22	-0.26	-0.35	-0.40	-0.29	-0.14	-0.07	NA	NA	NA	**-0.25**
9. West	-0.25	-0.05	-0.06	-0.29	-0.37	-0.34	-0.28	NA	NA	NA	**-0.25**
10. South	-0.26	-0.29	-0.19	-0.07	-0.27	-0.39	-0.32	NA	NA	NA	**-0.27**
Total	**-0.22**	**-0.27**	**-0.22**	**-0.31**	**-0.38**	**-0.23**	**-0.25**	**-0.35**	**-0.32**	**-0.38**	**-0.30**

4.4.7. It can be seen from the Table 4-3 above that movements associated with shorter travel generally show weaker outturn elasticities compared to movements that are associated with longer travel distance. The stronger elasticities for longer distance travels can be explained by change in traffic volumes (in response to fuel cost changes) would mean more alternative routes choice can be made to minimise travel costs, thus resulting in stronger responses compared to shorter distance travel trips, where alternative route choices are limited by the congestions across the road networks within the Selby District town centre.

NETWORK-BASED METHOD

4.4.8. Car vehicle-kms should be accumulated over a specified network from the before and after fuel cost change runs and the difference taken. The network used for this calculation should extend to cover the area over which the highway assignment model has been validated but should exclude external areas where the model is more approximate.

4.4.9. Table 4-4 provides a summary of the elasticities with respect to the car fuel cost changes, using the network-based method with the calculation undertaken across the simulation network.

Table 4-4 Car Fuel Cost Elasticities – Network-Based

User Class	Demand Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	All Day
Business	HBEB, NHBEB	-0.075	-0.081	-0.067	NA	**-0.076**
Commute	HBW	-0.194	-0.187	-0.217	NA	**-0.202**
Other	HBED, HBO, NHBED, NHBO	-0.265	-0.265	-0.284	NA	**-0.270**
Car	**All purposes**	**-0.190**	**-0.221**	**-0.228**	**NA**	**-0.216**

4.4.10. As the off-peak period was not modelled the elasticities were not able to be calculated using the network-based approach. To calculate the ‘All day’ elasticities, the following was calculated:

$$E_{All\ day} = \frac{\log(\sum_t T_t^1) - \log(\sum_t T_t^0)}{\log(\sum_t C_t^1) - \log(\sum_t C_t^0)}$$

where:

- $\sum_t T_t^0$ and $\sum_t T_t^1$ are the 'All Day' **car-kms** before and after the change produced from the demand model, calculated by summing car-kms from each individual time periods as given by the formula: $\sum_t T_t = (f_{AM} * Car.Kms_{AM} + f_{IP} * Car.Kms_{IP} + f_{PM} * Car.Kms_{PM}) + 2 * Car.Kms_{IP}$;
- $\sum_t C_t^0$ and $\sum_t C_t^1$ are the 'All Day' costs, calculated by summing costs from each individual time period similar to the car-kms.
- f_{AM}, f_{IP} and f_{PM} are the factors converting peak hour to periods as provided in Table 3-9, and the factor of 2 was used to convert inter-peak model to represent the off-peak period.

4.4.11. As can be seen, the network-based fuel cost elasticities generally show weaker than the matrix-based elasticities as it includes the external-external movements in the calculation (i.e. in line with the TAG M2 guidance). The patterns of response to car fuel cost changes are, however, similar to elasticity values that were calculated from the matrix-based method.

4.5 JOURNEY TIME ELASTICITIES

4.5.1. As per TAG M2, the car journey time elasticities calculation considers the change in car trips with respect to change in journey time, which should be calculated using a single run of the demand model. Target elasticities in this case were derived from Stated Preference data, where the costs for each option and attribute were exogenous (TAG M2, para. 6.4.27).

4.5.2. The resultant journey time elasticities should be checked to ensure that the model does not produce very high output elasticities (i.e. stronger than -2.0).

4.5.3. There are two methods of calculating elasticities with respect to car journey time increase: a) a crude method, and b) a more accurate method. Summary of the elasticities with respect to car journey time increase by each method is provided in the subsequent paragraphs.

CRUDE METHOD

4.5.4. For the crude method, the elasticity with respect to journey time increase can be derived from the car fuel cost elasticities, by multiplying each of them with relevant ratios between car journey costs and fuel costs, using a formula below:

$$E_{time} = E_{fuel}\frac{a * T}{b * K}$$

where:

- E_{fuel} is the car fuel cost elasticity calculated from the calibrated demand model outputs;
- a and b are the cost per hour and cost per kilometre respectively, $a = 60 * PPM$ and $b = PPK$;
- K and T are the total vehicle kilometres and total vehicle hours respectively, obtained from the calibrated demand model outputs.

4.5.5. The outturn elasticities with respect to car journey time increase using the crude method is summarised in Table 4-5 below.

Table 4-5 Journey Time Elasticities – Crude Method

User Class	Demand Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	All Day
Business	HBEB, NHBEB	-0.246	-0.265	-0.206	-0.245	**-0.245**
Commute	HBW	-0.556	-0.568	-0.629	-0.600	**-0.592**
Other	HBED, HBO, NHBED, NHBO	-0.677	-0.750	-0.815	-0.758	**-0.755**
Car	**All purposes**	**-0.544**	**-0.656**	**-0.683**	**-0.636**	**-0.638**

ACCURATE METHOD

4.5.6. The elasticities with respect to car journey time increase can be calculated using a more accurate method, which is described below (extracted from DIADEM manual).

- Extract skimmed time and distance from the validated base year assignment, calculate Pivot costs $Cost_{pivot} = Time + \frac{PPK}{PPM} * Distance + \frac{Toll}{PPM}$;
- Calculate forecast generalised costs with 20% increase in car travel time, using the formula: $Cost_{time} = 1.2 * Time + \frac{PPK}{PPM} * Distance + \frac{Toll}{PPM}$
- Undertake variable demand model for a single loop with the pivot costs and forecast costs to produce new demand matrix (as the elasticities were derived from the Stated Preference data);
- Assign the new matrix to the base year network to produce the assignment;
- Calculate car-kms using the matrix-based method to produce the elasticities with respect to car journey time increase.

4.5.7. The output elasticities with respect to car journey time increase using the accurate method is provided in Table 4-6 below.

Table 4-6 Journey Time Elasticities – Accurate Method

User Class	Demand Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	All Day
Business	HBEB, NHBEB	-0.577	-0.573	-0.524	-0.515	**-0.552**
Commute	HBW	-0.587	-0.542	-0.664	-0.578	**-0.600**
Other	HBED, HBO, NHBED, NHBO	-0.676	-0.740	-0.823	-0.741	**-0.749**
Car	**All purposes**	**-0.619**	**-0.682**	**-0.723**	**-0.649**	**-0.672**

4.5.8. It can be seen that the outturn elasticities with respect to car journey time increase produced from both the crude method and the more accurate method are similar and generally weaker than -2.0 as recommended by the TAG M2 guidance.

4.6 PT FARE ELASTICITIES

4.6.1. Public transport fare elasticities represent the percentage change in public transport trips by all public transport mode with respect to percentage change in public transport fares. For the SEDVDM, the elasticity calculation was carried out with a 20% increase in public transport fares, applied to all public transport modes equally.

4.6.2. Public transport fare elasticities should be calculated using a matrix-based method, by time-period and trip purposes and should only include movements with a full range of demand responses applied in the demand model (i.e. exclude external-external movements).

4.6.3. Elasticities of public transport trips with respect to public transport fares are provided in Table 4-7 below.

Table 4-7 PT Fare Elasticities

User Class	Demand Segment	AM Peak	Inter-Peak	PM Peak	Off-Peak	All Day
Business	HBEB, NHBEB	-0.147	-0.198	-0.143	-0.178	**-0.168**
Commute	HBW	-0.159	-0.150	-0.142	-0.162	**-0.153**
Other	HBED, HBO, NHBED, NHBO	-0.257	-0.244	-0.249	-0.263	**-0.251**
Car	**All purposes**	**-0.211**	**-0.232**	**-0.200**	**-0.232**	**-0.221**

4.6.4. The overall all-purpose elasticity with respect to public transport fares is -0.22, which is within the range of -0.2 to -0.9 as recommended by TAG M2. Analysis of the elasticities in more detail show that:

- The patterns of the annual average elasticities show weaker elasticities for business trips and commuting trips and stronger values for discretionary trips; and
- Patterns of all-purpose elasticities show stronger elasticities during the off-peak periods compared to peak periods.

5 SUMMARY

5.1 OVERVIEW

5.1.1. The Selby District demand model was developed to assess the transport impacts of a range of potential transport interventions in the Selby District area. These potential interventions include traffic management schemes to assist North Yorkshire County Council in decision-making for a number of studies within the area.

5.1.2. The demand model is a five-stage multi-modal incremental PA model that considers the impacts of frequency choice, main mode choice, macro time choice, destination choice and route choice modelling in response to change in generalised costs.

5.1.3. The model represents travel demands over a 24-hour period comprising tour-based modelling techniques, incorporating explicit time-period-choice modelling with reference data sourced from NTS.

5.2 SUMMARY

5.2.1. The demand model is fully compliant with the latest TAG M2 guidance, functioning with a zone system common to the assignment models, ensuring the consistency between cost and demand at each stage of the Selby District Transport Model is maintained.

5.2.2. The demand model iterates between the hourly-based AM, IP and PM supply models and the 24-hour PA demand model. The convergence algorithm delivered, using ‘variable step length’ functionality, was implemented to search for the demand/supply convergent solution within the shortest time possible. The demand model achieves the required level of convergence as recommended by the TAG M2.

5.2.3. Initial tests with the base year model show very strong responses in the model with respect to cost change. The implementation of ‘cost damping by distance’ and ‘fixed external-external movements’ was adopted to reduce the impact of response as per TAG guidance during the calibration of the base year demand model.

5.2.4. The destination choice lambda parameters for highway and PT and the macro time choice/mode choice theta parameters adopted for the Selby District VDM calibration were within the TAG M2 guidance. Overall, the realism tests undertaken have identified a set of demand response parameters that achieve appropriate outturn elasticities with respect to car fuel cost, journey time and PT fares as recommended by TAG.

5.2.5. The derived car fuel elasticity, car journey time elasticity and PT fare elasticity, established through the realism tests, have been reported by purpose, time period and spatial locations. All outturn elasticity values by purpose are within the TAG recommended ranges, with weaker elasticities for non-discretionary trips and stronger elasticities for discretionary trips, and weaker elasticities for peak period and stronger elasticities for non-peak periods.

On this basis, the TAG-compliant demand model is considered to be fit for purpose, robust and therefore suitable for application within for the forecast demand models.

Appendix A

ELASTICITIES

Table A-1 Car Fuel Cost Elasticities – Minimum TAG

Period	Purpose	TripOD0	TripOD1	VehKms0	VehKms1	VehHrs0	VehHrs1	Elasticity
AM Peak	Business	30,127	30,088	1,446,277	1,414,886	22,011	21,551	-0.120
	Commute	135,705	135,705	2,510,596	2,423,062	42,527	41,219	-0.195
	Other	221,422	221,327	2,526,027	2,380,386	41,495	39,377	-0.326
	Car	**387,254**	**387,120**	**6,482,900**	**6,218,333**	**106,033**	**102,148**	**-0.229**
Inter-Peak	Business	44,415	44,411	1,979,106	1,931,687	28,652	28,001	-0.133
	Commute	90,592	90,605	1,604,558	1,544,983	25,345	24,494	-0.208
	Other	574,880	574,375	7,842,300	7,335,986	119,560	112,544	-0.366
	Car	**709,886**	**709,391**	**11,425,964**	**10,812,656**	**173,556**	**165,038**	**-0.303**
PM Peak	Business	24,216	24,204	1,098,770	1,079,224	16,964	16,649	-0.098
	Commute	134,780	134,346	2,834,228	2,721,554	46,886	45,142	-0.223
	Other	268,434	267,837	3,926,949	3,665,736	63,650	59,770	-0.378
	Car	**427,430**	**426,386**	**7,859,947**	**7,466,514**	**127,499**	**121,561**	**-0.282**
Off-Peak	Business	25,213	25,170	1,170,532	1,144,575	16,869	16,525	-0.123
	Commute	107,346	106,783	2,370,621	2,276,537	36,600	35,322	-0.222
	Other	240,948	240,347	3,593,025	3,361,770	54,624	51,482	-0.365
	Car	**373,508**	**372,300**	**7,134,178**	**6,782,882**	**108,092**	**103,329**	**-0.277**
All Day	Business	123,971	123,873	5,694,686	5,570,372	84,495	82,726	-0.121
	Commute	468,423	467,439	9,320,003	8,966,135	151,357	146,177	-0.212
	Other	1,305,684	1,303,886	17,888,301	16,743,878	279,329	263,173	-0.363
	Car	**1,898,078**	**1,895,197**	**32,902,990**	**31,280,384**	**515,181**	**492,076**	**-0.277**

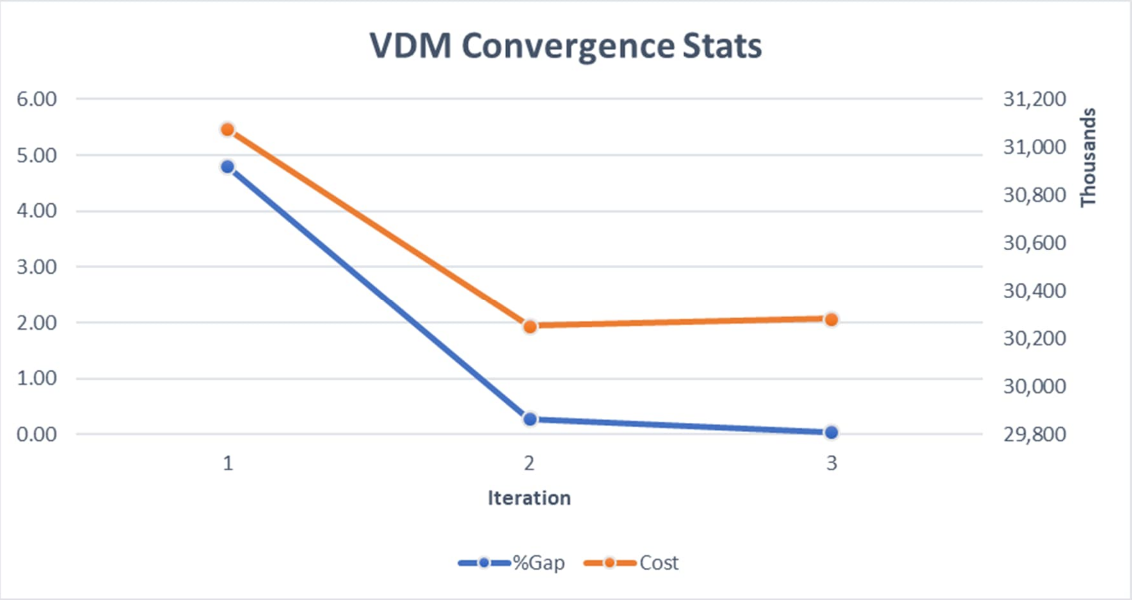


Table A-2 Car Fuel Cost Elasticities – Median TAG

Period	Purpose	TripOD0	TripOD1	VehKms0	VehKms1	VehHrs0	VehHrs1	Elasticity
AM Peak	Business	30,127	30,068	1,446,277	1,401,134	22,011	21,348	-0.174
	Commute	135,705	135,700	2,510,596	2,407,570	42,527	40,947	-0.230
	Other	221,422	221,246	2,526,027	2,351,777	41,495	38,910	-0.392
	Car	**387,254**	**387,014**	**6,482,900**	**6,160,481**	**106,033**	**101,205**	**-0.280**
Inter-Peak	Business	44,415	44,404	1,979,106	1,916,978	28,652	27,795	-0.175
	Commute	90,592	90,593	1,604,558	1,532,058	25,345	24,304	-0.254
	Other	574,880	573,765	7,842,300	7,239,772	119,560	111,140	-0.438
	Car	**709,886**	**708,762**	**11,425,964**	**10,688,808**	**173,556**	**163,239**	**-0.366**
PM Peak	Business	24,216	24,197	1,098,770	1,069,237	16,964	16,496	-0.149
	Commute	134,780	134,095	2,834,228	2,696,730	46,886	44,725	-0.273
	Other	268,434	267,203	3,926,949	3,611,549	63,650	58,916	-0.459
	Car	**427,430**	**425,495**	**7,859,947**	**7,377,516**	**127,499**	**120,137**	**-0.347**
Off-Peak	Business	25,213	25,130	1,170,532	1,133,571	16,869	16,374	-0.176
	Commute	107,346	106,419	2,370,621	2,252,355	36,600	34,966	-0.281
	Other	240,948	239,559	3,593,025	3,309,101	54,624	50,725	-0.452
	Car	**373,508**	**371,107**	**7,134,178**	**6,695,027**	**108,092**	**102,066**	**-0.348**
All Day	Business	123,971	123,799	5,694,686	5,520,920	84,495	82,012	-0.170
	Commute	468,423	466,806	9,320,003	8,888,712	151,357	144,942	-0.260
	Other	1,305,684	1,301,773	17,888,301	16,512,199	279,329	259,692	-0.439
	Car	**1,898,078**	**1,892,378**	**32,902,990**	**30,921,832**	**515,181**	**486,646**	**-0.341**

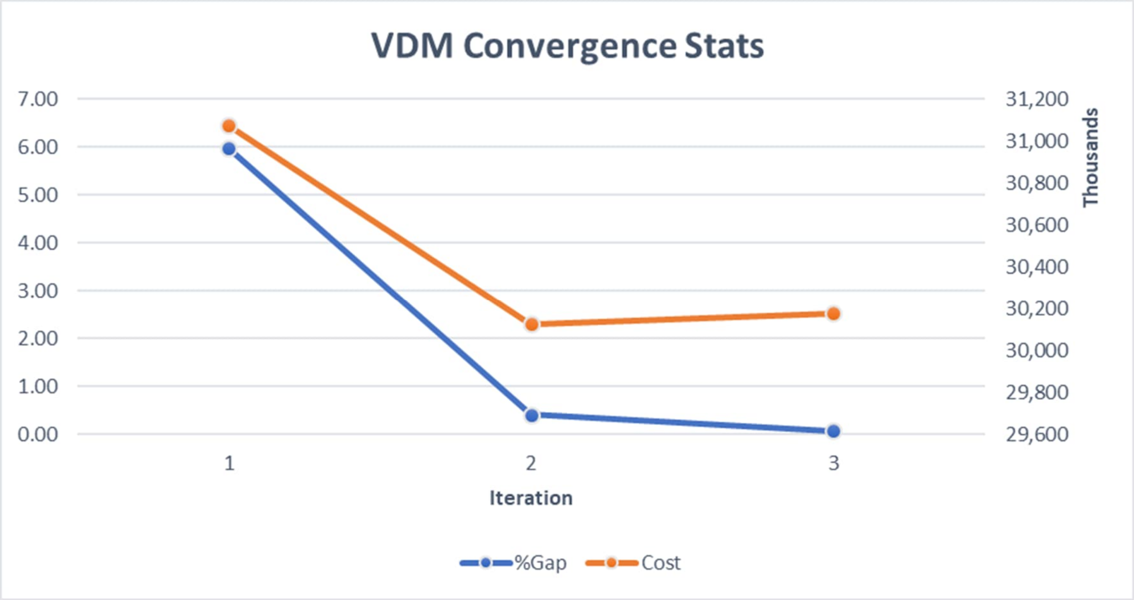


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Table A-3 Car Fuel Cost Elasticities – Maximum TAG

Period	Purpose	TripOD0	TripOD1	VehKms0	VehKms1	VehHrs0	VehHrs1	Elasticity
AM Peak	Business	30,127	30,038	1,446,277	1,381,122	22,011	21,042	-0.253
	Commute	135,705	135,674	2,510,596	2,345,476	42,527	39,925	-0.373
	Other	221,422	220,926	2,526,027	2,234,956	41,495	37,074	-0.671
	Car	**387,254**	**386,638**	**6,482,900**	**5,961,554**	**106,033**	**98,041**	**-0.460**
Inter-Peak	Business	44,415	44,386	1,979,106	1,893,126	28,652	27,452	-0.244
	Commute	90,592	90,544	1,604,558	1,484,819	25,345	23,593	-0.425
	Other	574,880	571,257	7,842,300	6,843,464	119,560	105,398	-0.747
	Car	**709,886**	**706,187**	**11,425,964**	**10,221,408**	**173,556**	**156,443**	**-0.611**
PM Peak	Business	24,216	24,203	1,098,770	1,055,821	16,964	16,283	-0.219
	Commute	134,780	133,512	2,834,228	2,609,649	46,886	43,289	-0.453
	Other	268,434	264,999	3,926,949	3,397,059	63,650	55,561	-0.795
	Car	**427,430**	**422,714**	**7,859,947**	**7,062,530**	**127,499**	**115,133**	**-0.587**
Off-Peak	Business	25,213	25,034	1,170,532	1,115,364	16,869	16,123	-0.265
	Commute	107,346	105,446	2,370,621	2,169,428	36,600	33,751	-0.486
	Other	240,948	236,484	3,593,025	3,096,537	54,624	47,667	-0.816
	Car	**373,508**	**366,964**	**7,134,178**	**6,381,329**	**108,092**	**97,541**	**-0.612**
All Day	Business	123,971	123,661	5,694,686	5,445,434	84,495	80,900	-0.245
	Commute	468,423	465,175	9,320,003	8,609,372	151,357	140,557	-0.435
	Other	1,305,684	1,293,667	17,888,301	15,572,017	279,329	245,700	-0.761
	Car	**1,898,078**	**1,882,502**	**32,902,990**	**29,626,822**	**515,181**	**467,157**	**-0.575**

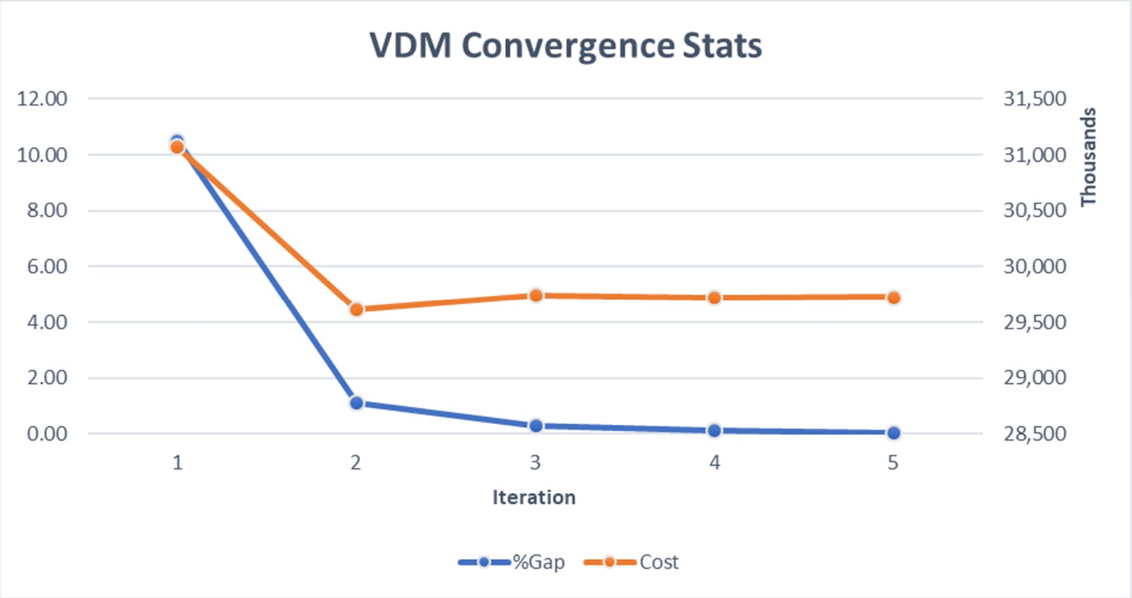

Table A-4 Car Fuel Cost Elasticities – Calibrated Values

Period	Purpose	TripOD0	TripOD1	VehKms0	VehKms1	VehHrs0	VehHrs1	Elasticity
AM Peak	Business	30,127	30,091	1,446,277	1,414,875	22,011	21,549	-0.120
	Commute	135,705	135,710	2,510,596	2,421,755	42,527	41,188	-0.198
	Other	221,422	221,302	2,526,027	2,366,225	41,495	39,150	-0.358
	Car	**387,254**	**387,103**	**6,482,900**	**6,202,854**	**106,033**	**101,886**	**-0.242**
Inter-Peak	Business	44,415	44,410	1,979,106	1,931,644	28,652	28,000	-0.133
	Commute	90,592	90,602	1,604,558	1,543,458	25,345	24,473	-0.213
	Other	574,880	574,109	7,842,300	7,288,346	119,560	111,854	-0.402
	Car	**709,886**	**709,121**	**11,425,964**	**10,763,448**	**173,556**	**164,327**	**-0.328**
PM Peak	Business	24,216	24,204	1,098,770	1,079,248	16,964	16,646	-0.098
	Commute	134,780	134,298	2,834,228	2,718,594	46,886	45,082	-0.228
	Other	268,434	267,539	3,926,949	3,638,621	63,650	59,343	-0.418
	Car	**427,430**	**426,041**	**7,859,947**	**7,436,463**	**127,499**	**121,071**	**-0.304**
Off-Peak	Business	25,213	25,168	1,170,532	1,144,501	16,869	16,524	-0.123
	Commute	107,346	106,710	2,370,621	2,273,307	36,600	35,274	-0.230
	Other	240,948	240,005	3,593,025	3,336,111	54,624	51,114	-0.407
	Car	**373,508**	**371,883**	**7,134,178**	**6,753,920**	**108,092**	**102,912**	**-0.300**
All Day	Business	123,971	123,873	5,694,686	5,570,268	84,495	82,718	-0.121
	Commute	468,423	467,321	9,320,003	8,957,114	151,357	146,017	-0.218
	Other	1,305,684	1,302,955	17,888,301	16,629,303	279,329	261,461	-0.400
	Car	**1,898,078**	**1,894,148**	**32,902,990**	**31,156,685**	**515,181**	**490,196**	**-0.299**

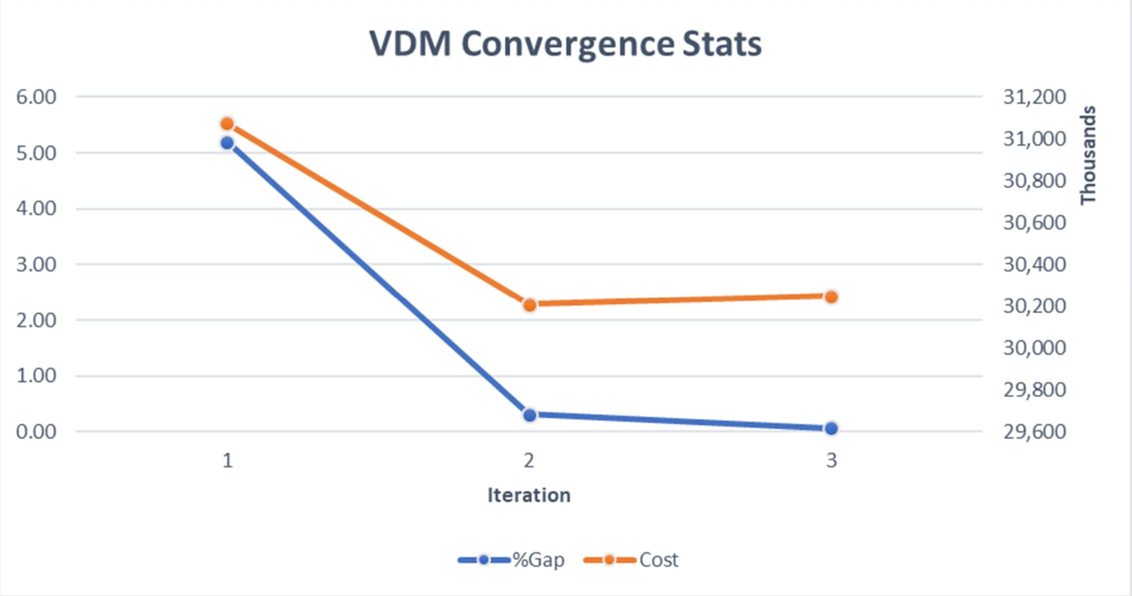

Table A-5 Car Journey Time Elasticities – Accurate Method

Period	Purpose	TripOD0	TripOD1	VehKms0	VehKms1	VehHrs0	VehHrs1	Elasticity
AM Peak	Business	30,127	29,851	1,446,277	1,301,931	22,011	19,749	-0.577
	Commute	135,705	135,167	2,510,596	2,255,606	42,527	38,042	-0.587
	Other	221,422	221,103	2,526,027	2,233,289	41,495	36,538	-0.676
	Car	**387,254**	**386,121**	**6,482,900**	**5,790,826**	**106,033**	**94,330**	**-0.619**
Inter-Peak	Business	44,415	44,509	1,979,106	1,782,858	28,652	25,770	-0.573
	Commute	90,592	90,770	1,604,558	1,453,676	25,345	22,943	-0.542
	Other	574,880	573,086	7,842,300	6,852,708	119,560	104,536	-0.740
	Car	**709,886**	**708,365**	**11,425,964**	**10,089,241**	**173,556**	**153,249**	**-0.682**
PM Peak	Business	24,216	23,982	1,098,770	998,665	16,964	15,326	-0.524
	Commute	134,780	133,159	2,834,228	2,511,218	46,886	41,296	-0.664
	Other	268,434	265,703	3,926,949	3,379,602	63,650	54,582	-0.823
	Car	**427,430**	**422,844**	**7,859,947**	**6,889,485**	**127,499**	**111,204**	**-0.723**
Off-Peak	Business	25,213	25,127	1,170,532	1,065,586	16,869	15,361	-0.515
	Commute	107,346	105,958	2,370,621	2,133,491	36,600	32,986	-0.578
	Other	240,948	239,091	3,593,025	3,138,916	54,624	47,909	-0.741
	Car	**373,508**	**370,176**	**7,134,178**	**6,337,993**	**108,092**	**96,257**	**-0.649**
All Day	Business	123,971	123,469	5,694,686	5,149,039	84,495	76,206	-0.552
	Commute	468,423	465,054	9,320,003	8,353,991	151,357	135,267	-0.600
	Other	1,305,684	1,298,983	17,888,301	15,604,515	279,329	243,566	-0.749
	Car	**1,898,078**	**1,887,505**	**32,902,990**	**29,107,545**	**515,181**	**455,039**	**-0.672**

Table A-6 PT Fare Elasticities

Period	Purpose	PersOD0	PersOD1					Elasticity
AM Peak	Business	1,559	1,518					-0.147
	Commute	14,137	13,732					-0.159
	Other	18,092	17,262					-0.257
	Total	**33,787**	**32,513**					**-0.211**
Inter-Peak	Business	2,152	2,076					-0.198
	Commute	5,022	4,887					-0.150
	Other	41,759	39,940					-0.244
	Total	**48,933**	**46,903**					**-0.232**
PM Peak	Business	1,545	1,506					-0.143
	Commute	10,476	10,209					-0.142
	Other	14,775	14,121					-0.249
	Total	**26,797**	**25,836**					**-0.200**
Off-Peak	Business	1,261	1,221					-0.178
	Commute	6,908	6,706					-0.162
	Other	17,463	16,645					-0.263
	Total	**25,632**	**24,572**					**-0.232**
All Day	Business	6,518	6,320					-0.168
	Commute	36,543	35,535					-0.153
	Other	92,089	87,968					-0.251
	Total	**135,149**	**129,823**					**-0.221**