South Essex Rapid Transit
Major Scheme Business Case

Appendix 4F
Model Development Report
Thames Gateway
Demand Model

April 2010

A partnership project between Essex County Council, Southend-on-Sea Borough Council and Thurrock Council

AECOM

Thames Gateway Demand Model
Model Development and Validation Report

Mouchel
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Thames Gateway Demand Model
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1 Introduction

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1.1 Context

Significant forecast changes in population and employment in the Thames Gateway area will influence, and be influenced by, the patterns of travel throughout the area and beyond. These changing patterns of demand will put pressure on the current transport system, and consequently, some remedial action will need to be investigated by the relevant authorities.

Transport models are used to represent current travel patterns, to forecast future changes in travel and conditions on the transport system, and to assess the benefits and disbenefits of policies, schemes and measures designed to cater in some way for the changed scale and patterns of demand.

The Thames Gateway Model is an umbrella term for a suite of models that has been developed by Mouchel for this purpose.

This report is focused on the model development and validation of the Thames Gateway Demand Model (TGDM), which is a variable demand model developed by AECOM with the specific objectives of providing:

- ‘*Core Scenario*’ forecasts of changes in traffic over time, as a result of changes in land-use, economic growth, travel costs and committed transport supply changes; and
- ‘*Policy/Scheme Test*’ forecasts of the demand responses of traffic to changes to the transport system, such as improvements to roads, the construction of new roads, and implementation of highway demand management schemes.

The TGDM has been developed from an existing demand model developed by AECOM, the East of England Regional Demand Model (EERDM).

1.2 Report Structure

Following this introduction, Chapter 2 further considers the background and purpose of TGDM, and Chapter 3 discusses the structure of the model. Chapter 4 describes the travel demand data used to construct TGDM, and Chapter 5 considers the modelling parameters used.

Chapter 6 discusses the highway supply model that is incorporated within TGDM, whilst Chapter 7 presents the validation of the base year model. Chapter 8 provides an assessment of the forecasting performance of TGDM, and Chapter 9 summarises our conclusions.

2 Context

2 Context

2.1 Thames Gateway Modelling Suite

In designing EERDM, from which TGDM has been developed, we sought to develop a demand model that will be suitable for the assessing the effects of population, employment and transport infrastructure changes in a fast-growing region, taking into account:

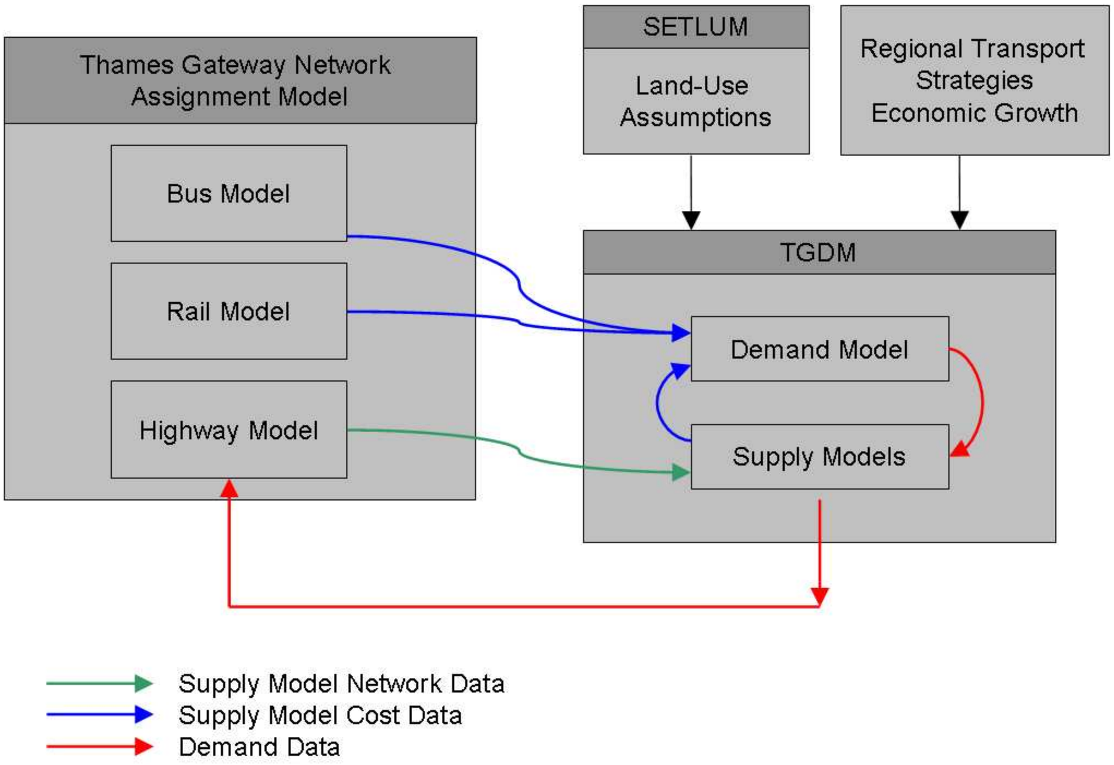
- the potential range of developments across the region and their possible implications for transport infrastructure;
- the credibility and robustness of the model to withstand detailed examination at Public Inquiry.

Recognising the current capabilities of modelling software and methods, Mouchel and AECOM has developed a suite of linked models, with each focused on specific issues, rather than seeking to create a single generic model. This suite of models is referred to hereon as the Thames Gateway Model (TGM), with the following key components:

- South Essex Transport Land Use interaction Model (SETLUM)
- An OmniTrans multimodal network assignment model incorporating highway and public transport modes; and
- TGDM, the subject of this document, covering trip generation, trip frequency, time period choice, mode choice and trip distribution, based upon the latest WebTAG guidance available from the Department for Transport (DfT) on the modelling of variable demand.

The interaction between these components and with the principle input assumptions is shown in Figure 2.1, whilst Table 2.1 sets out the key purpose of each component.

Figure 2.1: Structure of the Thames Gateway Model



The primary role of each of the key models is summarised in Table 2.1.

Table 2.1: Key Model Components of the Thames Gateway Model

Component		Purpose
SETLUM	South Essex Transport Land Use interaction Model	Estimates future land use changes based upon different levels of transport intervention to support developments.
TGDM	Thames Gateway Demand Model	Based on the pattern of development around the Thames Gateway, forecasts the future patterns of travel demand in the area, reflecting the performance and capacity of the transport infrastructure. TGDM also estimates demand responses of travellers to changes in the transport system.
	Thames Gateway MultiModal Assignment Model	Implemented in Omnitrans, this model forecasts route choice for highway traffic and public transport deamnd through and within the Thames Gateway area.

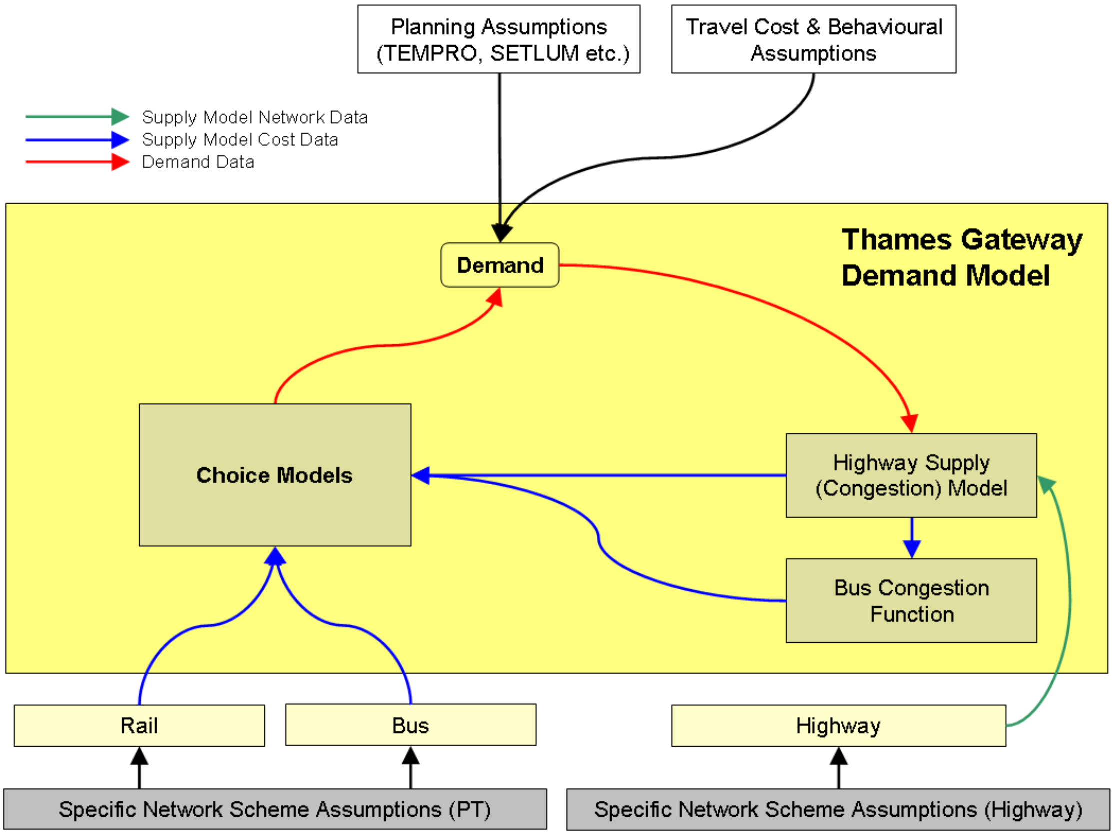
2.2 TGDM Objectives

The design of a model involves a simplified representation of reality. The aim of TGDM is to focus on the demand responses, as detailed supply modelling is addressed in the detailed network models listed in Table 2.1. The key objectives of TGDM are to:

- provide forecasts of changes in travel demand over time, as a result of changes in land-use, economic growth, travel costs and committed transport supply changes;
- provide forecasts of the demand responses of highway and public transport trips to changes to the transport system; and
- ensure that the forecast travel demand and generalised costs of travel are in equilibrium.

A model meeting these objectives provides the basis for undertaking assessments of the performance and benefits of transport strategies, using the network models.

Figure 2.2: Overall TGDM Structure



2.3 Guidance on the Modelling of Variable Demand

This report discusses the development of TGDM, which is compliant with DfT's modelling advice in WebTAG Units 3.5.6 and 3.10.1 to 3.10.4, as of March 2009, except where otherwise stated.

2.4 Policy Testing

TGDM is capable of testing the impacts of a broad range of changes in transport and land-use policy and the provision of infrastructure such as:

- changes in land-use assumptions, including the level and distribution of employment and population growth;
- changes in highway travel costs;
- changes in public transport fares;
- changes in rail service provision and capacity;
- changes in regional bus and coach service provision; and
- changes in highway network infrastructure and capacity.

In addition, a reference case, or 'core scenario', might need to reflect policies including:

- access restrictions to the trunk road network and restrictions on urban parking availability;
- slow mode (walk and cycle) policies; and
- impacts of 'soft measures' on commuting and education travel.

The exogenously forecast net effects of these policies can be input to TGDM whilst undertaking forecasts, so that the forecasting reflects the future context in which they may apply.

Shorter journeys by walk and cycle modes within the model have not been included, with the exception of home-based work trips, where intrazonal slow mode trips are modelled (discussed later in Section 3.7).

2.5 Supply Relationships

The supply models represent changes in the availability of infrastructure and services, which result in changes in journey time and cost, and policies which might influence congestion by affecting overall levels of demand. The effects of capacity are also included, in terms of highway traffic congestion, though public transport crowding is *not* represented.

We assume that bus and coach capacity would be adjusted to meet demand, and so crowding is not represented for bus and coach, although tests may reflect assumptions such as service frequency changes.

The rail and bus network models generate changes in non-fare generalised cost in response to a change in service provision or policy. Changes in public transport fares, either over time, or as part of a strategy, are calculated within TGDM, based on input future travel cost assumptions. These generalised cost changes are combined and input into TGDM, and are assumed to be static throughout a TGDM test, with one exception, whereby a mechanism is provided to enable changes in highway congestion to affect bus/coach journey times, as described in Section 3.13.

Processes have also been developed to convert and simplify the Omnitrans-based highway network within the EMME-based TGDM. The volume-delay effects of the Omnitrans assignments are captured within the TGDM highway supply model. A discussion of the highway supply model and its implementation is the subject of Chapter 6.

The integration of the TGDM demand and supply models results in substantially reduced run times and simplifies the transfer of data within the TGDM modelling structure, whilst simulating the performance of the detailed assignment models. Critically, convergence of the demand and supply models is ensured, measured using the %Gap statistic (see Section 3.14.3).

The interaction of these supply relationships can be seen in Figure 2.2.

2.6 Exogenous Trip-End Growth

Although the choice of the policy and planning input assumptions used for TGDM forecasts is not the focus of this document, the nature of the trip-end forecasts used within TGDM is relevant and is therefore discussed.

The National Trip End Model, developed by the DfT, provides the latest DfT forecasts of road traffic growth associated with car ownership, demographic and land use changes. The TEMPRO program has been designed for fast and efficient access to these National Trip End Model projections.

As part of the work for developing the Thames Gateway Model suite, The South Essex Transport Land Use interaction Model (SETLUM) was created. SETLUM works through two integrated models, a land use model and a strategic transport model, running in tandem, building up a picture of the demographic and transportation changes through the period 2001-2021.

The land use model represents the United Kingdom using a series of zones. A fully modelled area covers Mid and South Essex, three London Boroughs and areas of North Kent. Further external zones outside the fully modelled area represent the rest of the UK. The model has been used to evaluate differing growth scenarios pivoting around population, job and household growth together with different transport strategies.

Trip End forecasts were developed using both SETLUM and TEMPRO. SETLUM was used to provide land use forecasts in future years. Trip End forecasts associated with these alternative land uses were created using TEMPRO alternative planning assumptions.

These trip-end growth forecasts are then applied to the base year trip matrices via a matrix-balancing procedure to create forecast year reference demand. This reference demand reflects changes in land-use assumptions, and household structure and car ownership factors, but does not include effects of changes in travel cost and conditions.

In addition to personal travel forecasts for domestic travel, global freight forecasts have been derived from National Transport Model forecasts (NTM) using existing published data.

3 Model Structure

3 Model Structure

3.1 Choice Model Structure

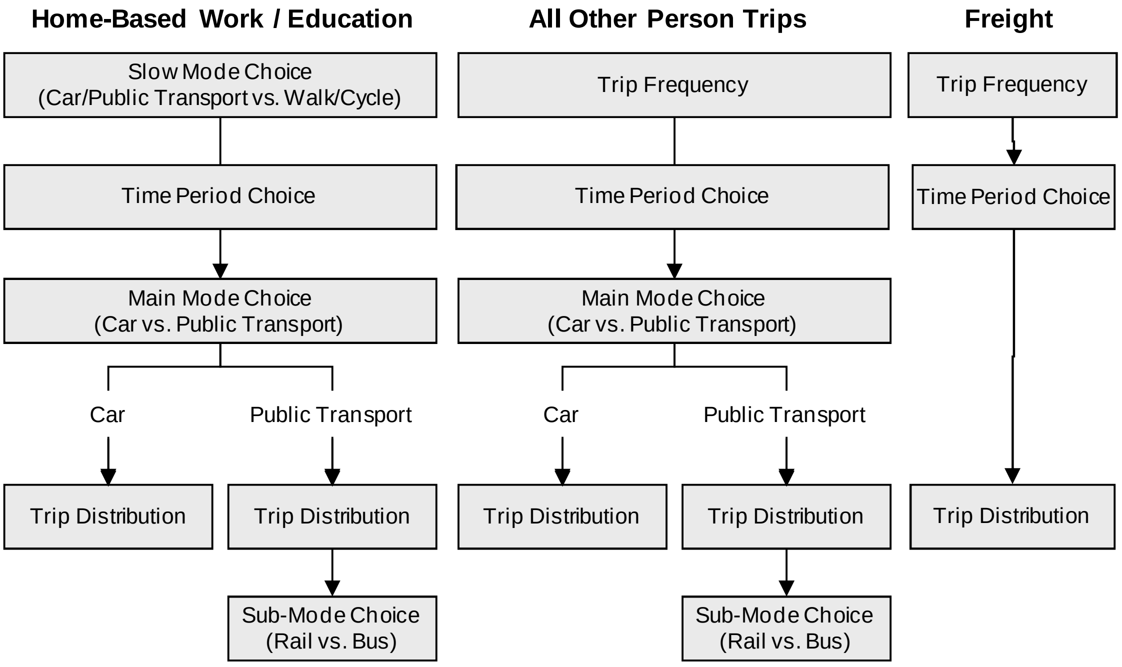
The demand model hierarchical choice structure reflects the relative sensitivity of the individual responses. The choice structures are implemented in the following order:

- trip frequency;
- macro time period choice;
- main mode choice;
- trip distribution; and
- public transport mode choice[1].

In addition, there is a mode choice process to choose between slow modes (walk and cycle) and other modes for home-based work and education trips, which effectively replaces trip frequency for those segments, as these trips are assumed to be doubly-constrained to the population (production) and employment/education (attraction) trip-end forecasts.

Figure 3.1 shows the TGDM choice structure, within which the choice processes are ordered in accordance with the guidance in WebTAG Unit 3.10.3 Section 1.9.

Figure 3.1: TGDM Choice Model Structure



3.2 Pivoting

TGDM is a pivot-point incremental model which estimates changes in trip patterns relative to a reference matrix in which observed movements have been used as much as possible. The predicted relative changes are applied to the reference matrix, so that the complexities of the reference matrix are preserved.

TGDM pivots from base year generalised costs for all future year forecasts, and so a *Core Scenario* and a *Policy/Scheme Test* use a similar forecasting methodology.

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[1] There is an alternative implementation of trip frequency, time period choice, main mode choice, trip distribution and public transport mode choice. See Appendix A for details.

3.3 Structure of Demand

TGDM is a trip-based rather than tour-based model. A tour-based approach would provide more accurate forecasts in cases where policies involve significant cost differences by time period, such as parking restraint, but would significantly increase the effort required both to develop and operate the model. More fundamentally, survey data from which Mouchel has developed demand matrices would not support a tour-based analysis for our primary area of interest without the use of additional data, such as travel diary data. The LATS household survey sample outside London is negligible for the Thames Gateway region, so would be inadequate for this analysis.

The trip-based approach adopted will provide a satisfactory response to, for example, policies that cause modest changes in demand between time periods. However, TGDM cannot model temporal effects within individual time periods.

Highway, bus and rail demand matrices at an origin-destination level have been provided by Mouchel; these have been converted to the appropriate production-attraction format for use in the TGDM, using the highway factors developed for the project as a proxy for public transport factors. The derivation of these factors from LATS data is discussed in Section 4.2.2.

3.4 Segmentation

The TG highway matrix building process (discussed in discussed in Section 4.2.2) created OD to PA factors that have enabled the conversion of period OD matrices to 16-hour PA matrices for the following person trip purposes:

- home-based work (HBW);
- home-based education (HBE);
- home-based employers’ business (HBEB);
- home-based other (HBO);
- non-home-based employers’ business (NHBEB); and
- non-home-based other (NHBO).

Each of these trip purposes is split by car availability (car available and no car available) to form twelve person demand segments. Light goods vehicles (LGVs) and heavy goods vehicles (HGVs) are modelled as two further market segments, bringing the total number of TGDM demand segments to fourteen. This segmentation incorporates the guidance in WebTAG Unit 3.10.2 Section 1.7.

3.5 Generalised Cost Calculations

TGDM is an incremental model that responds to changes in generalised cost. For the highway generalised cost calculations, the functions specified below are used, derived from WebTAG Unit 3.5.6. The data are expressed in minutes, pence and kilometres, unless otherwise stated:

$$\mathrm{FuelCost} = \mathrm{F} * \mathrm{D} * \mathrm{i} * \left(\mathrm{f}_a + \mathrm{f}_b * \mathrm{V} + \mathrm{f}_c * \mathrm{V}^2 + \mathrm{f}_d * \mathrm{V}^3\right)$$

$$\mathrm{NonFuelCost} = \mathrm{D} * \left(\mathrm{n}_a + \left(\frac{\mathrm{n}_b}{\mathrm{V}}\right)\right)$$ for employers’ business and freight trips

$$\mathrm{GenCost}_{\mathrm{Highway}} = \mathrm{PureTime} + \left(\frac{\mathrm{FuelCost} + \mathrm{NonFuelCost} + \mathrm{Charges}}{\mathrm{ValueOfTime} * \mathrm{VehicleOccupancy}}\right)$$

where:

- F = fuel price, pence per litre;
- D = assigned distance, kilometres;
- V = average assigned speed for the matrix cell, kilometres per hour;
- i = fuel efficiency improvement factor, which reduces fuel consumption over time;
- $f_{a/b/c/d}$ = fuel cost parameters; and
- $n_{a/b}$ = non-fuel cost parameters (assumed to be zero for non-work trips).

Public transport calculations use generalised costs (expressed in minutes) that are provided by the rail and bus models, and used within TGDM. Actual costs are never used - only cost changes from base year, as TGDM pivots from base year generalised costs (see Section 3.2).

For bus trips:

$$\mathrm{CostChange}_{PT} = \mathrm{ServiceChange} + \frac{\mathrm{Fare}_{current} - \mathrm{Fare}_{base}}{\mathrm{Value\ of\ Time}} + f_c(\mathrm{CarTime}_{current} - \mathrm{CarTime}_{base})$$

where the service change is the cost change imported and derived from the base year and future year bus models, and f_c is the bus congestion factor, applied to the changes in highway congestion, taken from the highway assignment (see Section 3.13 for a discussion of this factor).

For rail trips:

$$\mathrm{CostChange}_{PT} = \mathrm{ServiceChange} + \frac{\mathrm{Fare}_{current} - \mathrm{Fare}_{base}}{\mathrm{Value\ of\ Time}}$$

Within the highway and public transport generalised cost calculations there are differences in the parameter values used, according to purpose and car availability. There are variations in perceived fuel and non-fuel costs and vehicle occupancies (varying by work and non-work), values of time (varying by purpose and car availability), and rail fares (varying by purpose and time period). The parameter values adopted are discussed in Chapter 5.

The demand is generally represented in production-attraction (PA) form. Where this is the case, costs for travel between productions and attractions are weighted by the proportions of trips observed travelling from and to home in the 2001 LATS data, thus resulting in generalised cost changes in PA format, for each time period.

The highway generalised cost matrices are derived from the TGDM supply model, which assigns three user classes; HGV, LGV and car. Time and distance skims are obtained separately for each user class.

The rail generalised cost matrices are derived from the TG rail model and the bus generalised cost matrices are derived from the Thames Gateway public transport model which uses a single assignment user class.

3.6 Demand Sensitivity of Longer Distance Demand Movements

The functions in Sections 3.7 to 3.12 illustrate how incremental composite (logsum) costs are used throughout TGDM, ensuring that choices in the higher levels of the model hierarchy reflect the incremental composite cost of choices lower in the choice hierarchy.

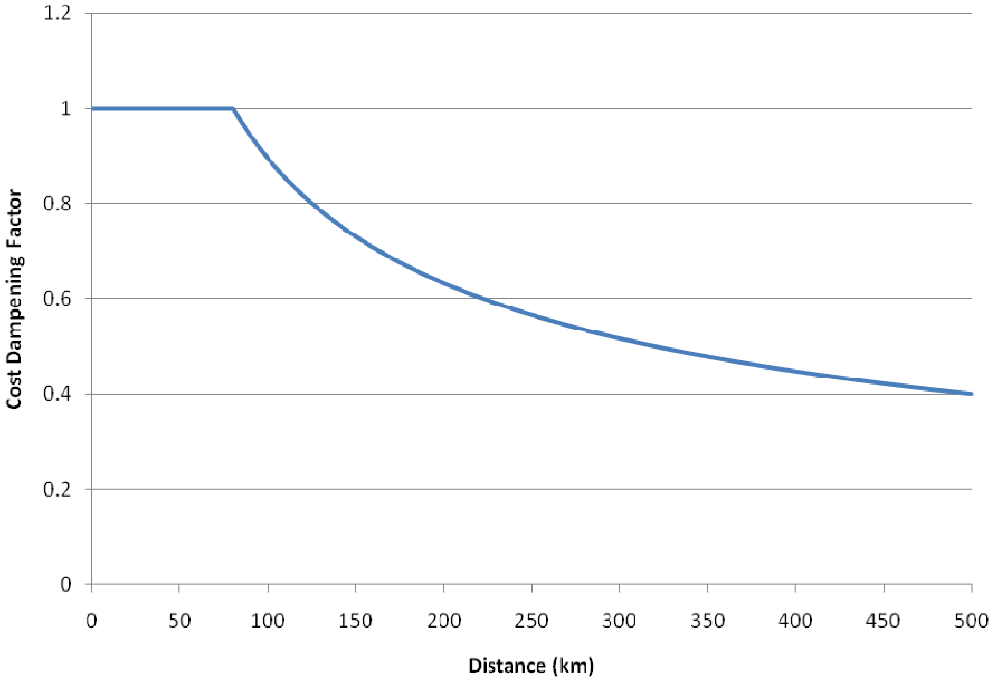
TGDM represents a very wide range of trip lengths, from less than 1 kilometre to over 1,000 kilometres. The sensitivity of response to a ten-minute change would be expected to be larger for a 30-minute journey than a six-hour journey, but in TGDM, a logit model based on absolute cost changes, this ten-minute change would result in a similar demand response, irrespective of trip length.

We have therefore adopted the following formulation to reflect the variation in response sensitivity to trip length:

$$\text{CostDampeningFactor} = \min\left(\frac{\sqrt{80}}{\sqrt{\text{distance}}}, 1\right)$$

The cost dampening function is derived from a function that was calibrated and used in the Heathrow Surface Access Model (HSAM). The function is plotted in Figure 3.2, and is applied to the cumulative generalised cost changes that are used within the demand model.

Figure 3.2: Cost Dampening Function



3.7 Trip Frequency

Lambda and theta values within the TGDM choice models are applied to incremental composite travel costs, according to travel purpose, as recommended in WebTAG Unit 3.10.3, Appendix 4. The values used are WebTAG illustrative values which we use in the absence of locally observed behavioural data; these have subsequently been calibrated as discussed in Section 5.2. These functions are applied to all demand using the following functions, starting with trip frequency:

$$\hat{D}_{**i*} = \sum_{tmj} D_{tmij} \; e^{\theta_f \Delta C_{**i*}}$$

with:

$$\Delta C_{**i*} = \log_e\left(\frac{\sum_{tmj} D_{tmij} e^{\theta_t \Delta C_{t*i*}}}{\sum_{tmj} D_{tmij}}\right)$$

where:

- $\Delta C_{tmij} =$ cost change;
- $D_{tmij} =$ input demand;
- $\hat{D}_{ijtm} =$ output demand;

- θ_f = frequency theta (sensitivity parameter relative to time period sensitivity);
- θ_t = time period choice theta (sensitivity parameter relative to main mode choice sensitivity);
- i = origin;
- j = destination;
- t = time period (morning peak, interpeak, evening peak or off-peak, as defined in Section 3.8);
- m = mode (car or public transport); and
- * = sum (for demand) or exponential aggregation (for cost) over corresponding subscript.

For HBW and HBE trips, there is assumed to be no trip-frequency response, in accordance with the guidance in WebTAG Unit 3.10.3 Section 1.7 that advises that trip frequency is not normally required for doubly-constrained segments (see Section 3.10). Instead, commuters are considered to be able to switch between motorised (car or public transport) modes and slow (walk or cycle) modes.

To take account of this effect, an additional mode choice stage (motorised vs. slow modes) for HBW and HBE is included, at the top level of the choice hierarchy (and consequently effectively replaces trip frequency for HBW and HBE). Given the regional context and that slow modes have not been modelled, the approach can be reasonably simplified by assuming that all slow mode travel is intrazonal.

This slow mode interzonal trip frequency response is forecast as a function of cost:

$$\hat{D}_{**i*} = \left(\sum_{tmj} D_{tmij} + D_i^{slow}\right) \frac{\sum_{tmj} D_{tmij} e^{\theta_f \Delta C_{**i*}}}{\sum_{tmj} D_{tmij} e^{\theta_f \Delta C_{**i*}} + D_i^{slow}}$$

$$\hat{D}_i^{slow} = \left(\sum_{tmj} D_{tmij} + D_i^{slow}\right) \frac{D_i^{slow}}{\sum_{tmj} D_{tmij} e^{\theta_f \Delta C_{**i*}} + D_i^{slow}}$$

3.8 Time Period Choice

TGDM simulates demand responses within, and between, the following time periods:

- morning peak (07:00 to 10:00);
- interpeak (10:00 to 16:00);
- evening peak (16:00 to 19:00); and
- off peak (06:00 to 07:00, 19:00 to 22:00).

TGDM includes a mechanism for the re-allocation of trips between these time periods on the basis of the respective cost changes for travel in different periods. There is no mechanism for reallocation of trips in time within a single modelled time period. i.e. TGDM does not have a micro time period choice mechanism.

$$\hat{D}_{t*i*} = \hat{D}_{**i*} \frac{\sum_{mj} D_{tmij} e^{\theta_t \Delta C_{t*i*}}}{\sum_{tmj} D_{tmij} e^{\theta_t \Delta C_{t*i*}}}$$

with:

$$\Delta C_{t*i*} = \log_e \left(\frac{\sum_{mj} D_{tmij} e^{\theta_m \Delta C_{tmi*}}}{\sum_{mj} D_{tmij}} \right)$$

The approach adopted aggregates trips by direction of travel and thus assumes that PA trips travelling from home have a similar sensitivity to trips returning to home in the same time period.

3.9 Main Mode Choice

Main mode choice (car vs. public transport) is forecast as a function of cost change for all non-freight and car available demand, applied separately for each time period:

$$\hat{D}_{tmi*} = \hat{D}_{t*i*} \frac{\sum_j D_{tmij} e^{\theta_m \Delta C_{tmi*}}}{\sum_{mj} D_{tmij} e^{\theta_m \Delta C_{tmi*}}}$$

with:

$$\Delta C_{tmi*} = \log_e \left(\frac{\sum_j D_{tmij} e^{-\lambda_d C_{tmij}}}{\sum_j D_{tmij}} \right)$$

3.10 Trip Distribution

Trip distribution is forecast as a function of cost change for all demand segments:

$$\hat{D}_{tmij} = \hat{D}_{tmi*} \frac{D_{tmij} e^{-\lambda_d \Delta C_{tmij}}}{\sum_j D_{tmij} e^{-\lambda_d \Delta C_{tmij}}}$$

where ΔC_{tmij} are cumulative generalised PA cost differences, with incremental cost differences being accumulated throughout each demand-supply iteration of TGDM. For car trips these are simple cost changes, output by the supply model and converted from OD to PA. For public transport trips there is one further aggregation to be performed, namely that between bus and rail costs:

$$\Delta C_{tPij} = -\frac{1}{\lambda_s} \log_e \left(\frac{\sum_m D_{tmij} e^{-\lambda_s \Delta C_{tmij}}}{\sum_m D_{tmij}} \right)$$

where the sums over m are now taken to be over sub-mode, that is, rail and bus, and λ_s is the sub-mode choice lambda, discussed in Section 3.11.

Following guidance in WebTAG Unit 3.10.3 Section 1.7, HBW and HBE trips are doubly-constrained within TGDM, ensuring that each zone produces and attracts a fixed total number of HBW and HBE trip-ends. All other trips are singly-constrained, with no constraint on the attractor zone. The double-constraint function is applied across modes, time periods and segments and is iterated until the two following criteria are achieved.

$$\sum_{tmj} D_{tmij} + D_i^{slow} = \sum_{tmj} \hat{D}_{tmij} + \hat{D}_i^{slow}$$

$$\sum_{tmi} D_{tmij} + D_i^{slow} = \sum_{tmi} \hat{D}_{tmij} + \hat{D}_i^{slow}$$

The HBW and HBE double-constraint is applied by accumulating trips by mode, including slow mode for intrazonal trips, to establish total trips by destination D’i*j*.

Segment and mode specific proportions are calculated before the double-constraint process so that the doubly-constrained output total demand matrix (total demand across all segments and modes) can be disaggregated into demand by mode, segment and slow mode, reflecting the distribution of these demand matrices before the double-constraint. These proportions are calculated using:

$$\%\hat{D}_{tmij} = \frac{\hat{D}_{tmij}}{\sum_{tm} \hat{D}_{tmij}}$$

The destination specific target totals are then calculated for use in the constraining process and the demand matrix is balanced to ensure that the double-constraint criteria (above) are enforced.

3.11 Public Transport Mode Choice

The choice between rail and bus/ coach is forecast as a function of cost change:

$$\hat{D}_{tmij} = \hat{D}_{tmij} \frac{D_{tmij} e^{-\lambda_p \Delta C_{tmij}}}{\sum_m D_{tmij} e^{-\lambda_p \Delta C_{tmij}}}$$

where ΔC_{tmij} are cumulative generalised OD cost differences. The “m” subscript is here used to indicate sub-mode, and main mode is exclusively public transport.

Note that this process is applied solely to combine bus and rail costs properly; in actual practice the choice between bus and rail is forecast using an external public transport mode choice model operated by Mouchel.

3.12 Freight Choice Processes

LGV and HGV trips are only coded to respond to three choice processes within TGDM, namely trip frequency, time period choice and trip distribution. It should be noted that the trip frequency theta values for freight are actually set to zero, meaning that freight is, in practice, only subject to time period choice and trip distribution.

3.13 Bus Congestion Factor

A mechanism has been developed to reflect changing highway congestion on bus and coach model cost changes. Bus and coach journey times are assumed to change in proportion to highway journey times, and so highway supply model cost skims are used to estimate the impact on bus and coach journey times within each TGDM demand-supply iteration (see Section 3.14.1).

A scaling parameter is used to control the sensitivity of this bus congestion function to reflect the presence of (for example) designated bus lanes, which would largely isolate bus services from the effect of changing highway congestion.

3.14 TGDM Iterative Process

3.14.1 Demand-Supply Iterations

The highway supply model and the demand model are run in sequence iteratively until TGDM is deemed to have converged. The costs from the supply models and functions are fed into the demand calculations, with the resulting demand used to recalculate the costs. This process continues until convergence.

3.14.2 *Smoothing of Demand*

The demand model forecasts demand as a function of cost, and the supply model estimates cost as a function of demand. Demand averaging is implemented after the third demand-supply iteration of TGDM. This delay allows the demand and supply relationships to find an approximate convergence level around which they oscillate before the averaging is implemented to encourage model convergence. The process used calculates the demand matrices to be input to the supply model as follows:

$$\hat{D}_X = \frac{2 * D_X}{(X-1)} + \frac{(X-3)\hat{D}_{(X-1)}}{(X-1)}$$

where:

- X = the current iteration of TGDM;
- D_X = the demand matrix produced by the current iteration of the demand model in iteration X ; and
- $\hat{D}_X$ = the averaged demand matrix to be used as input to the supply model in iteration $X+1$.

Hence, the demand to be assigned in the next iteration is derived as a proportion of the previous estimate of demand and that estimated in the current iteration of the demand model.

3.14.3 *%Gap Demand-Supply Convergence*

Our measure of convergence of the demand and supply models uses the demand-supply gap function as recommended by WebTAG Unit 3.10.4. This %Gap statistic is calculated using the following function:

$$G = \frac{\sum_{ijtc} C(D_{ijtc}).\left|D_{ijtc} - D(C(D_{ijtc}))\right| * 100}{\sum_{ijtc} C(D_{ijtc}).D_{ijtc}}$$

- D_{ijtc} = OD demand;
- $C(D_{ijtc})$ = generalised OD cost generated by the assignment of D_{ijtcm} on the network;
- $D(C(D_{ijtc}))$ = OD demand generated by the demand model in response to cost changes created from $C(D_{ijtc})$; and
- i = origin, j = destination, t = time period, c = purpose

This %Gap statistic is calculated by TGDM as given above, and is also calculated separately for each car segment and time period for analysis purposes. TGDM is considered to have converged when the aggregate value is less than 0.01, ten times tighter than recommended by WebTAG Unit 3.10.4, Section 1.5. The tight convergence is felt to be necessary given the large scale of the model and the small scale of many of the schemes to be tested by it.

Note that public transport trips are not included in the %Gap statistic; the expression does not sum across mode. This is a deviation from the WebTAG guidance, but is a necessity because *absolute* public transport costs are not stored within the demand model, only cost *changes*.

4 Demand Data

4 Demand Data

4.1 Zone Structure

TGDM adopts the zone structure used in the Thames Gateway Network Assignment Model, consisting of 380 zones, with more detail in the Thames Gateway region and a greater degree of aggregation further away.

TGDM directly interacts with the highway and public transport models developed by Mouchel. Each of these models shares a common zoning system, also adopted by TGDM.

Figure 4.1 shows the TGDM zone system nationally and within the Thames Gateway region.

Figure 4.1: TGDM Zoning

4.2 Base Year Demand

4.2.1 *Overview*

The TGDM demand matrices are 16-hour PA matrices that represent 2006 demand on a weekday in a neutral month. The model contains matrices for car, freight (LGV and HGV), rail and bus, with the passenger modes (i.e. those other than freight) being segmented by purpose (HBW, HBE, HBEB, HBO, NHBEB and NHBO). Public transport passenger demand is further segmented by car availability (car available and no car available).

These 16-hour PA matrices have been derived from the base year OD matrices used within the detailed network models, discussed below.

4.2.2 *Highway Matrices*

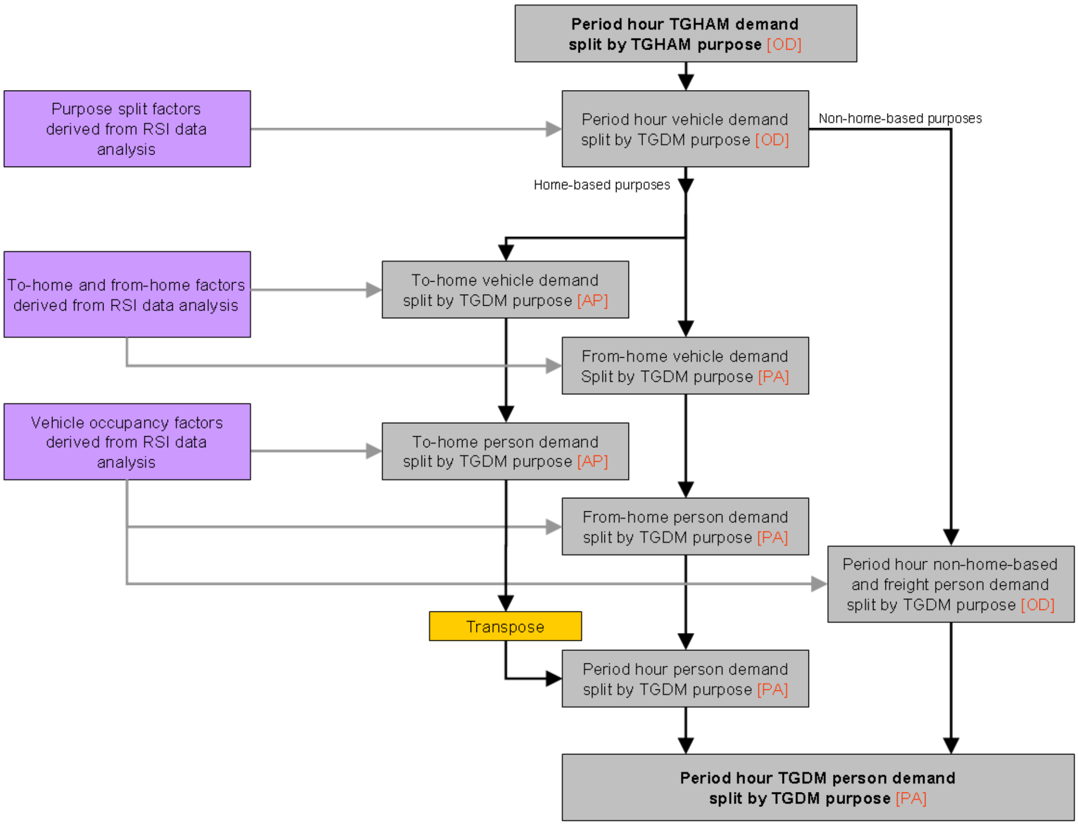
The Base Year (2006) OD car demand matrices have been developed specifically for use in the Omnitrans highway assignment model, and are based upon observed 2001 LATS data, 2006 RSI surveys, 2006 traffic count data and synthetic data used to represent unobserved trip movements.

This matrix development process created prior highway matrices, which were then adjusted by Mouchel through matrix estimation to create base year (2006) validation matrices. These are available for an average hour in the morning peak (07:00 to 10:00), an average inter peak period hour and an average hour in the evening peak (16:00 to 19:00). The highway demand is transferred to the TGDM demand segmentation as summarised below. All disaggregation within this process uses purpose split factors derived from RSI data analysis.

As part of the derivation of demand matrices, the RSI data analysis created a series of factor matrices to enable the calculation of to-home and from-home, all-day to period, period to hourly, and vehicle occupancy factors. These were calculated for each TGDM purpose, and so were suitable for use in the conversion of the hourly OD highway model validation matrices to 16-hour PA TGDM matrices.

The process used to convert hourly OD matrices to 16-hour PA matrices for a single time period is shown in Figure 4.2. This process is repeated for each time period, and the resulting matrices combined to yield 12-hour PA TGDM demand matrices.

Figure 4.2: Converting Demand from Highway model OD to TGDM PA



With an estimate of 12-hour PA demand, we then use factors derived from the EERDM LATS data analysis to estimate demand for an off peak period, as there is no off peak TGHAM assignment model and hence demand estimate. This, combined with the 12-hour PA demand, forms an estimate of 16-hour PA demand.

4.2.3 *Slow Mode Demand*

The inclusion of a measure of slow mode HBW demand was discussed in Section 3.10. Slow mode (walk and cycle) demand is assumed to be short in length, and thus only present in intrazonal matrix movements.

Analysis of NTEM data indicates that slow modes can be expected to form approximately 15% of total travel. We have adopted this estimate for use in the slow mode choice function.

4.2.4 *Public Transport Matrices*

Mouchel has provided rail demand matrices which are derived from those in the OmniTrans rail model, in turn derived from DfT Rail's PLANET model. These demand matrices are segmented into commuting, business and leisure, and were developed during 2005 to incorporate 2001 LATS data.

The business matrices have been disaggregated into HBEB and NHBEB, and the leisure matrices into HBO and NHBO, using factors derived from NTEM data (i.e. from relevant planning data and trip rates derived from the National Travel Survey). The commuting matrices are retained as HBW.

Bus demand matrices have also been provided by Mouchel, by demand segment, as used in the OmniTrans bus model (in an aggregated form).

We have used the database that stores the National Trip End Model forecasts extract data that enables us to disaggregate rail and bus demand data further, splitting the six TGDM purposes by car availability into twelve demand segments.

4.3 Planning Data

Table 4.2 summarises the correlation between the zonal 16-hour TGDM and NTEM base year car trip-ends. These comprise car drivers and car passengers, and are split into the home-based and non-home-based purposes. The TGDM trip-ends have been derived from the NTEM trip-end forecasting software.

The data show a reasonable correlation between the TGDM and NTEM trip-ends, suggesting that the effect of merging the observed and synthetic data, followed by the highway model matrix estimation, has done little to distort the trip-ends.

Table 4.2: Comparison of 12-Hour Productions/ Attractions (2006)

Purpose	TGDM 12-Hour	NTEM 12-Hour	Variance
HBW	21,590,218	25,016,773	-14%
HBE	11,533,831	9,211,146	25%
HBEB	2,887,674	3,144,970	-8%
HBO	45,729,972	40,019,975	14%
NHBEB	2,487,499	2,554,648	-3%
NHBO	9,825,567	9,243,453	6%
Totals	**94,054,761**	**89,190,965**	**5%**

4.4 Future Year Demand

4.4.1 *Car, Bus and Rail Demand Growth*

Car and public transport demand growth is derived by applying purpose-specific trip-end growth factors (derived from NTEM software and incorporating land use assumptions derived from SETLUM, constrained to aggregate TEMPRO planning data) using a matrix-balancing procedure. This is applied at the 16-hour level.

4.4.2 *Freight Demand Growth*

We have no available data for freight trip-end growth, and therefore adopt NTM freight growth forecasts for both Heavy Good Vehicles (HGV) and Light Goods Vehicles (LGV) from December 2008. For forecast years other than those for which NTM data exist, we have interpolated or extrapolated, as appropriate.

5 Parameters

5 Parameters

5.1 Generalised Cost Parameters

The functions used to calculate generalised cost were provided in Section 3.5. This section presents the parameter values used in these functions.

5.1.1 Values of Time

The base year (2006) values of times used in TGDM are derived from WebTAG Unit 3.5.6. Table 5.1 shows the base year values used in TGDM, expressed per person rather than per vehicle. Note that in common with all other monetary values in the TGDM, they are in 2002 prices, as used in WebTAG data.

Table 5.1: TGDM 2006 Person Values of Time (pence per minute), 2002 prices

	Values of Time, ppm	
Purpose	**Car Available**	**No Car Available**
HBW	9.12	6.57
HBE	8.07	7.02
HBEB	38.53	38.53
HBO	8.07	7.02
NHBEB	38.53	38.53
NHBO	8.07	7.02
LGV	15.54	
HGV	35.81	

HBE values of time have been assumed to be equal to the non-work “other” values provided by WebTAG, as no explicit values for education trips are provided.

Whilst the car available values were calculated directly using WebTAG guidance, these values have been modified for non-work persons with no car available (the rationale being that households with no car can be expected to have typically lower incomes than car-owning households). Data from the 2002/03 Family Expenditure Survey and National Travel Survey have been analysed along with the guidance in WebTAG Unit 3.12.2, Section 11.4, to estimate factors that distinguish between income levels in households with and without a car available.

Work trips are assumed to have the same values of time regardless of car-ownership. Factors of 0.7 and 0.85 for commuting and other trips respectively have been derived as multipliers for no-car-available values of time.

The HGV values of time used deviate from WebTAG guidance to reflect operators’ rather than drivers’ value of time. This adjustment is based on DfT guidance that precedes WebTAG[1].

Non-work values of time, for the purposes of choice modelling only, (i.e. not during assignment), are subject to a further variation by distance. This is in accordance with evidence from ITS which suggests that such an effect is reasonable. Value of time is assumed to *increase* with distance, meaning that non-work trips become less sensitive to monetary cost changes with increasing distance. The formulation is applied only to trips longer than 12 km and is as follows:

$$\mathrm{VoT} = \mathrm{VoT_b} * \left(\frac{\max(\mathrm{Length\,of\ trip}, 4\mathrm{km})}{12} \right)^{\eta}$$

---

[1] Advice on Modelling of Congestion Charging or Tolling Options for Multimodal Studies, DfT (ITEA), January 2002

Where

- VoT_b is the base value of time, as taken from the table above and used for all trips of length less than 12km.
- η is the elasticity, for which 0.421 is used for HBW, and 0.315 for all other trips. These are taken from WebTAG Unit 3.12.2, Annex A.
- Employers' business and freight values of time are not subject to this variation, and are thus constant with respect to distance.

5.1.2 *Vehicle Operating Costs*

Vehicle operating costs have been implemented using WebTAG Unit 3.5.6 guidance, summarised in Table 5.2.

Table 5.2: TGDM Base Year (2006) Vehicle Operating Cost Parameters

	VOC Parameters		
Value	**Car**	**HGV**	**LGV**
Work Fuel Cost, pence per litre	71.08	73.10	73.10
Non-Work Fuel Cost, pence per litre	83.51	n/a	n/a
Fuel VOC A-Factor	0.176	0.881	0.196
Fuel VOC B-Factor	-0.00400	-0.02595	-0.00301
Fuel VOC C-Factor	0.0000452	0.0003729	0.0000166
Fuel VOC D-Factor	-0/00000014	-0.00000164	-0.00000006
Non-Fuel Cost A Factor	4.069	7.769	5.910
Non-Fuel Cost B Factor	111.39	304.66	33.97
Fuel Efficiency Improvement Factor	0.966	0.990	0.960

The vehicle operating costs in Table 5.2 are perceived costs in 2002 prices. These values have been derived from the 2002 values specified in WebTAG using the forecast changes in fuel cost, fuel efficiency and fleet mix (diesel vs. petrol). It should be noted that non-work trips are not allocated non-fuel vehicle operating costs.

5.1.3 *Vehicle Occupancy*

The base year TGDM vehicle occupancy data vary by vehicle type, purpose, time period, and trip direction (from home/ to home, for home-based trips only). They have been provided by Mouchel.

Table 5.3: TGDM Base Year (2006) Vehicle Occupancies

	Vehicle Occupancies		
Value	**AM Peak**	**Interpeak & Off-peak**	**PM-Peak**
HBW, From Home	1.15	1.20	1.23
HBW, To Home	1.17	1.17	1.13
HBE, From Home	2.01	1.47	1.52
HBE, To Home	1.50	1.75	1.86
HBEB, From Home	1.17	1.23	1.30
HBEB, To Home	1.11	1.29	1.22
HBO, From Home	1.48	1.59	1.73
HBO, To Home	1.42	1.52	1.63
NHBEB	1.39	1.35	1.39
NHBO	1.45	1.54	1.55
LGV	1.25	1.24	1.31
HGV	1.10	1.11	1.14

Car passenger occupancies are assumed to reduce over time in accordance with WebTAG guidance. Freight vehicle occupancies are assumed to remain constant over time.

5.1.4 *Public Transport Fares*

The OmniTrans rail and bus models calculate generalised cost including fares. Fare data are therefore taken directly from the public transport model as a matrix.

5.2 Choice Model Sensitivity Parameters

5.2.1 *Overview*

The demand model uses theta and lambda values, the use of which is detailed in Sections 3.7 to 3.11, to calculate demand changes. The values used are given in the following paragraphs, along with discussions as to their origin.

Following WebTAG guidance, lambda values are specified for trip distribution; all other choice processes above distribution (frequency, mode, time period) use thetas, which are relative sensitivities with respect to the choice process below in the hierarchy. Theta parameters indicate the relative sensitivity of a choice process when compared with the next process down in the choice hierarchy. As the sensitivity of choice parameters should not increase when moving up the choice hierarchy, theta values will never be greater than unity.

5.2.2 *Trip Frequency*

Table 5.4 shows the trip frequency theta values (θ_f) used within TGDM. These have been calibrated using WebTAG guidance on elasticities of vehicle kilometres with respect to journey time. Section 7.3 discuses this process in more detail.

Table 5.4: TGDM Trip Frequency and Slow-Mode Choice Theta Values

Purpose	Theta
HBW	0.2 (slow)
HBE	0.2 (slow)
HBEB	0
HBO	0.2 (freq)
NHBEB	0
NHBO	0.15 (freq)

HBW and HBE have no frequency response, but do have a slow mode choice response, discussed in Section 3.7. Employers' business trips have neither. Car other trips have a trip frequency response but no slow mode response.

5.2.3 *Main Mode Choice*

The main mode choice thetas used are taken directly from WebTAG Unit 3.10.3 and shown in Table 5.5.

Table 5.5: TGDM Main Mode Choice Theta Values

Purpose	Theta
HBW	0.68
HBE	0.68
HBEB	0.45
HBO	0.53
NHBEB	0.73
NHBO	0.81

5.2.4 *Time Period Choice*

Time period choice and main mode choice have identical sensitivity in TGDM, and so every time period choice parameter (including those for freight) is equal to 1. WebTAG Unit 3.10.3, Section 1.9 advises that the two choice mechanisms should have similar or identical sensitivity, indicating that there is no conclusive evidence as to whether individuals give preference to their choice of mode or their choice of time period of travel.

5.2.5 *Trip Distribution*

The lambda values for trip distribution used in TGDM are reproduced in Table 5.6 and Table 5.7. The values used for trips outside London are identical with those in WebTAG Unit 3.10.3, as are the non-home-based parameters. All other parameter values are derived from the London Transportation Studies (LTS) model.

Table 5.6: Highway Trip Distribution Lambda Values

Purpose	To Central London	To rest of London	From London	Orbital, London	Outside London
HBW	0.066	0.081	0.073	0.086	0.065
HBE	0.066	0.081	0.073	0.086	0.065
HBEB	0.067	0.074	0.070	0.085	0.067
HBO	0.084	0.111	0.107	0.128	0.090
HNBEB	0.081	0.081	0.081	0.081	0.081
NHBO	0.077	0.077	0.077	0.077	0.077
LGV	0.030	0.030	0.030	0.030	0.030
HGV	0.035	0.035	0.035	0.035	0.035

Table 5.7: Public Transport Trip Distribution Lambda Values

Purpose	To Central London	To Rest of London	From London	Orbital, London	Outside London
HBW	0.033	0.039	0.042	0.034	0.033
HBE	0.033	0.039	0.042	0.034	0.033
HBEB	0.025	0.038	0.041	0.037	0.036
HBO	0.043	0.050	0.053	0.044	0.036
HNBEB	0.042	0.042	0.042	0.042	0.042
NHBO	0.033	0.033	0.033	0.033	0.033

We are not aware of guidance for suitable LGV and HGV trip distribution model parameters, and so we have assumed the freight lambda values in Table 5.6, considering them to be reasonable values, and cross-checked these with the freight sensitivity calibration parameters that were derived during the synthetic matrix building process that was part of the EERDM LATS data analysis.

5.2.6 Public Transport Mode Choice

The public transport mode choice lambda is equal to 0.1 for all purposes. It is therefore considerably more sensitive than main mode choice, in accordance with WebTAG guidance.

5.3 Convergence

WebTAG Unit 3.10.4, Section 1.5 advises that a %Gap (see Section 3.14.3) of 0.1 is acceptable. To ensure stable model outputs, including scheme economics, we have implemented a %Gap of 0.01 as the requirement for convergence. Testing has established that this gap is relatively easy to achieve within a practicable number of iterations, and it is well below the WebTAG recommended gap of 0.1.

The TGDM supply (assignment) model itself also requires a measure of convergence, measured using a normalised gap, which is calculated internally within EMME. This is the difference between the current mean (demand-weighted) trip time and the mean minimum trip time (using the shortest-time paths available). In a perfectly converged assignment, this value would be 0. A normalised gap value of 60 milliseconds is used, a value that is one thousandth of that specified by DMRB (1 minute). This unusually tight level of convergence is both useful (as the model is required to test very small schemes in a network covering the whole country) and practically achievable, as the EMME assignment process and network representation are quite simple. A highway assignment converges in around ten minutes.

6 Highway Supply Model

6 Highway Supply Model

6.1 Context

A simplified version of the OmniTrans highway network is used within the TGDM to significantly reduce model run times whilst maintaining demand-supply convergence that exceeds current WebTAG guidance. Two alternatives were considered, summarised as follows.

- The full Omnitrans highway models could have been embedded within TGDM. This would have provided complete consistency in that the TGHAM models could be directly used to produce the highway costs required by the TGDM. However, this approach carried with it a number of disadvantages.
    - It would have increased model run times, as Omnitrans assignments are slower than EMME.
    - It would have required a method of running Omnitrans and EMME alternately in batch mode, which is difficult because Omnitrans cannot (or could not at the time) be run in batch mode.
    - It would have made the possible application of Area-Wide Road User Charging within the TGDM impossible (a process that is established within EMME).
    - Finally, the use of Omnitrans would have necessitated AECOM acquiring the Omnitrans software. This approach was therefore rejected.
- The TGHAM highway networks could be converted from Omnitrans to EMME format, enabling the TGHAM highway model to be embedded within the EMME TGDM model, and the highway model (in Omnitrans) used only for a final assignment of the output demand. This is the approach adopted, one consistent with that adopted in EERDM, and is discussed in further detail below.

6.2 Implementation

6.2.1 Network Conversion

We have developed software that can convert an assigned Omnitrans network into an EMME network for use within the EMME TGDM databank. The converted EMME network is identical to the Omnitrans network, except that non-highway links (bus only, for example) are removed; chains of links of the same type with no junctions (of which there are many within the highway model, due to the way in which the network was constructed) are aggregated; and dead-end links which do not connect to zones are also removed. This removal of links is intended to simplify the Omnitrans network without loss of modelling detail.

For a given highway network and demand scenario, the assigned Omnitrans networks are converted for use in the TGDM supply model. The assigned strategy-specific networks from the Omnitrans models are used for the following main reasons:

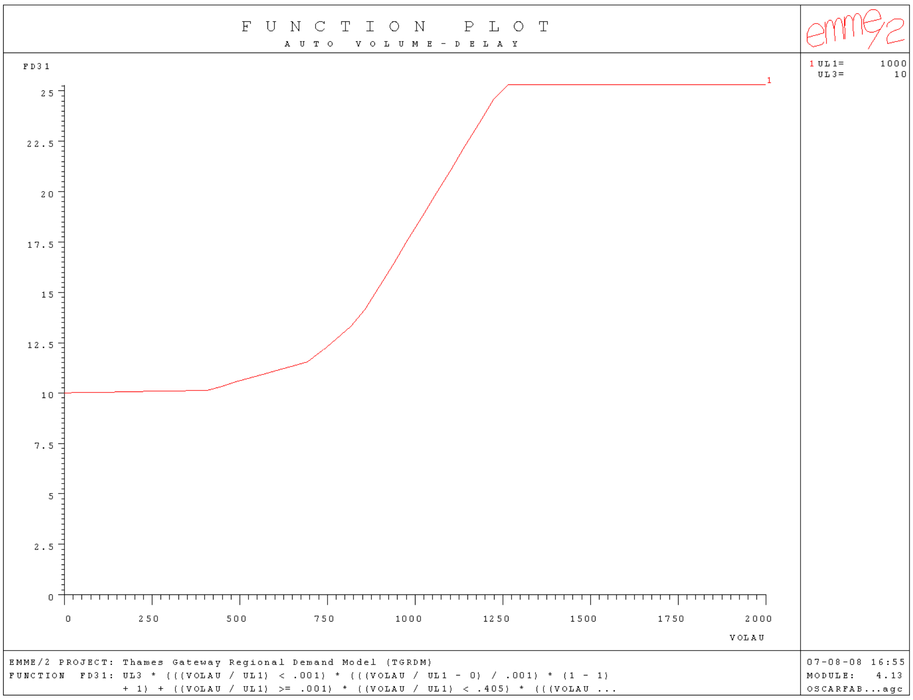
- there is no need for manual coding of the EMME TGDM networks;
- assigned link times and volumes are copied from the assigned highway networks to the TGDM, allowing for the easy comparison of the OmniTrans highway and TGDM supply models; and
- EMME is unable to replicate the subtleties of Omnitrans junction delays accurately. Consequently, junction delays are fixed at the Omnitrans values. In order to get a reasonable estimate of these for a given strategy, it is necessary to use assigned strategy-specific networks.

The volume-delay functions used in EMME are identical to those in Omnitrans, and take the following form:

Each link has attributed to it three delay-related characteristics, its capacity (C), its length (d) and its free flow speed (v_f). The time taken to traverse the link is then calculated based upon one of twenty functions, of which each link is assigned one, varying by general class of link (motorway, rural main road, etc.). These functions have the three attributes as parameters.

The speed-flow functions take the form of linear extrapolation between a series of three to five points on a load-impedance graph, with load being equal to the assigned traffic volume divided by C and impedance being equal to the resultant assigned time divided by d/v_f (i.e., free-flow time). At zero volume, the time is always given by d/v_f (an impedance of 1). At traffic volumes higher than that of the final point, the impedance (and thus time) is fixed at the flow rate of the last point, and so every link has an effective maximum time. Links generally have a maximum impedance of between 1.6 and 2.6. This maximum impedance is not necessarily reached at a load of 1; most of the speed-flow relationships reach maximum impedance at loads between 1.3 and 2.1, i.e. well above capacity.

An example of a speed-flow relationship is below, plotting volume along the x axis and time along the y axis.



```
EMME/2 PROJECT: Thames Gateway Regional Demand Model (TGRDM)
FUNCTION  FD31: UL3 * (((VOLAU / UL1) < .001) * (((VOLAU / UL1 - 0) / .001) * (1 - 1)
                + 1) + ((VOLAU / UL1) >= .001) * ((VOLAU / UL1) < .405) * (((VOLAU ...
```

```
07-08-08  16:55
MODULE:   4.13
OSCARFAB...agc
```

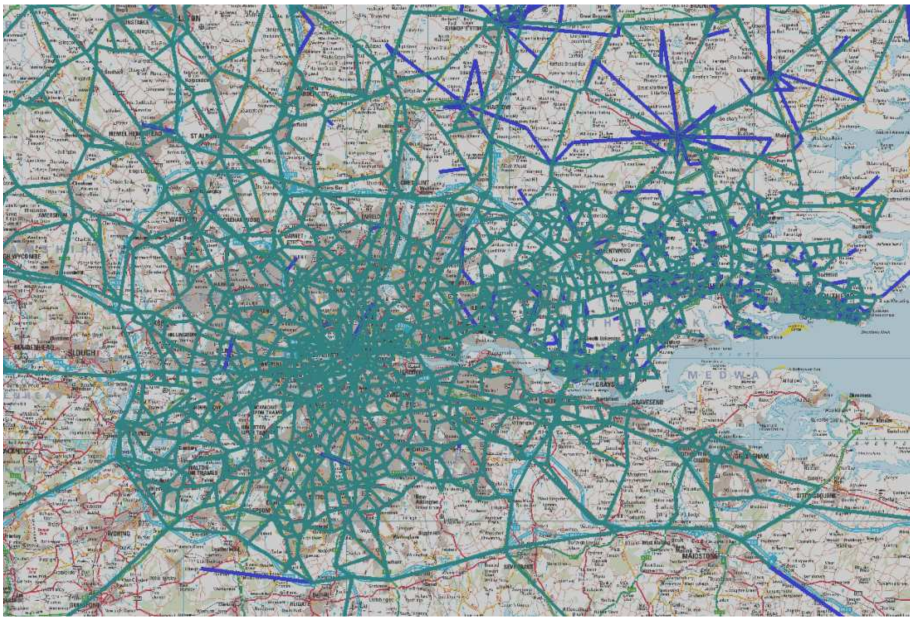
The volume-delay functions are in every respect identical with the equations used by Omnitrans. Junction delays, as mentioned above, are fixed within the EMME model.

6.2.2 *Network Coverage*

The base year validation network consists of 380 centroid connectors and approximately 8,000 nodes and 20,000 links. Centroid connectors are assumed to have a fixed speed, equal to that assigned in the highway model, of 100kph, and all other links assume the functions described earlier.

Figure 6.3 shows the level of network detail in the base year network within the TGDM highway supply model. The network outside the Thames Gateway and London areas is largely skeletal.

Figure 6.3: The TGDM Highway Supply Model Network



6.2.3 *Demand Segmentation and Assignment*

The OmniTrans highway model represents three time periods forming a 12-hour day: AM peak average hour, average interpeak hour and PM peak average hour. Unlike the OmniTrans highway model, the TGDM modelled hours represent a 16-hour day, including an off-peak average hour, which assigns an estimate of off-peak demand on an interpeak network.

The OmniTrans highway model assigns three user classes on to the highway network; HGV, LGV and Car. HGV and LGV trips are pre-loaded, so that freight routing is almost entirely unaffected by levels of congestion.

The TGDM supply model assigns the same three user classes. A multi-class generalised cost assignment is used, incorporating the distance-based operating cost (ppk) parameters used in the OmniTrans highway model. Freight trips are pre-loaded in the same way as in the OmniTrans highway model. Congested times, are, however, used in the demand model for freight demand response. This involves assigning freight trips twice for each assignment, once to determine routing and a second time, after the car assignment, but using the same routing methodology, to obtain time matrices. Freight assignment takes a few seconds, however, so this has little impact on model run times.

7 Base Year Validation

7 Base Year Validation

7.1 Context

TGDM is an incremental model that uses cost changes to estimate changes in demand from a base matrix. The base demand matrices have been derived from those in the OmniTrans highway network model, as detailed in Section 4.2.

The validation of TGDM is a consideration of the reality (or sensitivity) tests and recommended acceptable values or ranges of values for model sensitivity, generally derived from WebTAG. A number of reality tests have been undertaken to demonstrate that the model responses are plausible, both in the direction of change and in terms of the scale of the change. Data from these tests are presented below.

Where elasticities are discussed below, these are (except where otherwise specified) based on changes in vehicle or passenger kilometres with respect to changes in some element of cost, and are calculated via the arc-elasticity formula:

$$\mathrm{elasticity} = \frac{\log_e\left(\frac{\mathrm{km}_t}{\mathrm{km}_b}\right)}{\log_e\left(\frac{v_t}{v_b}\right)}$$

where:

- km_t is the vehicle or passenger kilometres in the test case;
- km_b is the vehicle or passenger kilometres in the base case;
- v_b is the base value of the variable for which the elasticity is being calculated (fuel cost, rail fares, journey time, etc.); and
- v_t is the test value of that variable.

An alternative formulation, used where specifically noted, for consistency with the data available, is that of the trip elasticity, which is given by:

$$\mathrm{elasticity} = \frac{\log_e\left(\frac{t_t}{t_b}\right)}{\log_e\left(\frac{v_t}{v_b}\right)}$$

where:

- t_t is the total trips in the test case; and
- t_b the total trips in the base case.

7.2 Definition of TGDM Calibration Area

There is no formal WebTAG guidance that specifies how to calibrate a variable demand model that covers a large geographical area, such as TGDM.

Particular issues that have been considered in the calibration of TGDM include:

- which matrix cells to use when calibrating the demand model response; and
- whether to include intrazonal movements.

The research upon which the DfT has based its -0.3 guidance (see Section 7.3) relates to national evidence, and on this basis it would seem desirable to use all cells in the matrices in TGDM, which is a representation of total travel within mainland Great Britain.

There is, however, a difficulty with this. The model, despite its size, is designed to model the effects of a small proportion of national trips and the majority of demand (in excess of 90%) is represented by travel between and within external zones. Given the dominance of this category, the sensitivity of model response in areas irrelevant to the ‘area of interest’ and where the modelling is coarse will dominate. Consequently, using a total model statistic would not necessarily indicate the model sensitivity in the area we are studying.

For example, in the zone representing Scotland and Northern England, 99.5% of trips are intrazonal and only 0.5% are interzonal. The trip lengths for intrazonal trips are defined as half the (non-zero) shortest interzonal distance, capped to a maximum, a reasonable but coarse assumption. The sensitivity of the model for external zones like this is therefore predominantly a function of the transfer of demand between interzonal and intrazonal movements. There is also no basis in the model to represent a possible change in the length of intrazonal trips that might be expected in response to a change in fuel cost. The implication is that, in the extremities (zones such as Scotland/ North England), the model will only represent a small proportion of trip redistribution and a measure of fuel elasticity will be biased.

This bias, however, is not a concern for the ‘area of interest’. In this area, due to much more disaggregate zoning, the proportion of trips which are intrazonal is quite small and any deficiency in representing changes in the pattern of intrazonal trips is not, therefore, of great importance.

A simplistic interpretation that the model is a full national travel model is thus flawed and a direct use of the full trip matrices for calibration would result in bias in the model sensitivity. In particular, the sensitivity of response within the ‘area of interest’ would be too large.

Nevertheless, the principle remains that the -0.3 elasticity is based on national statistics and it would be best to calibrate as large a proportion of trips as possible to be consistent with this definition. The measure needs to be based on complete trip length profiles: if we were to select a subset, such as internal to internal trips, we would introduce a bias as trips are re-allocated between long trips (excluded from this sample) and short trips (included in the sample). For this reason we consider that the most suitable calibration area should comprise all trips originating in the internal area, including intrazonals and including those destined for zones outside the internal area.

The change in distribution of trips produced in an ‘internal’ zone is not biased by a particularly large proportion of intrazonal trips, and provides a complete distribution of trip lengths. The implication is that the largest ‘reasonable’ collection of ‘internal’ zones will provide the best indicator of the model sensitivity.

External to internal trips are primarily excluded so as to remove the scope for bias that singly-constrained (production) trips may introduce. The distribution model could redistribute trips into and out of the calibration area, hence introducing bias via a ‘boundary effect’.

7.3 Car Trip Frequency Calibration

The process used to calibrate the trip frequency response follows the suggestion in versions of WebTAG issued in June and September 2005, Unit 3.10.3, Paragraph 1.11.10:

> *Some models include trip frequency but the evidence on the appropriate sensitivity parameter value is limited and as a result we do not currently have any suitable recommended values. {However, the Department is aware of the following way in which the values of θ_{freq} in the frequency choice process, as specified in Appendix 4, may be determined. Set up the model with main mode, time period and destination choice parameters as provided below and adjust as necessary to ensure that the output fuel cost elasticity is about -0.3. Then*

> *calculate the output car journey time elasticity. Then turn on the trip frequency response with a starting value for θ_{freq} and adjust that starting value until the car journey time elasticity increases by the elasticities given in the right hand column in Table 1 in 1.1.13 of appendix 1 below. Then, finally, check the output fuel cost elasticity and scale all parameters if necessary to ensure that an elasticity of -0.3 is output}.*

This WebTAG guidance was withdrawn in 2006, with Paragraph 1.11.10 now reading:

> *Some models include trip frequency but the evidence on the appropriate sensitivity parameter value is limited and as a result we do not currently have any suitable recommended values.*

There is therefore no current guidance on suitable parameters for trip frequency response, so the suggested methodology from the previous versions of WebTAG has been retained. Table 7.1 shows the journey time elasticities with and without the calibrated trip frequency response, isolating the trip frequency effect. The difference between the elasticities in a model run with no frequency response and those in a model run with the frequency response is given in column 3, and compared with the WebTAG recommended value for this number (column 4).

Table 7.1: Calibrated Car Trip Frequency Response (16-hour)

Purpose	Car Journey Time Elasticities, TGDM		TGDM Difference	WebTAG Difference
	Without Frequency	With Frequency		
HBW	-0.98	-0.99	0.01	-0.04
HBE	-0.45	-0.45	0.00	n/a
HBEB	-1.23	-1.24	0.01	-0.15
HBO	-1.35	-1.25	-0.10	-0.11
NHBEB	-0.93	-0.94	0.01	-0.15
NHBO	-1.18	-1.06	-0.12	-0.11

The HBO and NHBO modelled frequency responses reproduce the withdrawn WebTAG guidance. The HBW trip frequency response was not calibrated, as it is driven by the slow mode choice procedure discussed in Section 3.7.

HBE trips are not included in the WebTAG table; they too have no trip frequency response, as, like HBW, they are doubly-constrained and subject to slow-mode choice.

Nor have we calibrated HBEB and NHBEB trips either. This is because more recent WebTAG guidance (Unit 3.10.3, Paragraph 1.11.9) advises that employers' business trips should not generally experience a trip frequency response. Consequently, these purposes have no trip frequency response in TGDM.

Note that small positive changes in elasticity due to trip frequency are observed for purposes other than HBO and NHBO- this is a secondary effect due to the decrease in the HBO and NHBO response.

The journey time elasticities of the different segments are broadly similar, which is an expected outcome, as the demand response to changes in journey time will not be directly influenced by differing values of time, as is the case for fuel cost or fare elasticities. Education has the lowest values, because of the double-constraint on trip redistribution (see Section 3.7), which inhibits large-scale changes in trip lengths, and short average trip length, which causes the 10% reduction in journey time to be smaller in absolute terms.

WebTAG Unit 3.10.4, Paragraph 1.6.12 recommends that the output journey time elasticities should be checked to ensure that the model does not produce very high output elasticities (no greater than -2.0). This criterion is clearly met.

7.4 Car Fuel Cost Elasticity

To assess the sensitivity of the TGDM highway demand to fuel cost, the primary measure adopted is that of the change in car vehicle kilometres with respect to a change in car fuel cost.

Car fuel costs were therefore reduced by 10%, the resulting change in car vehicle kilometres measured, and elasticities calculated.

WebTAG Unit 3.10.4, Paragraph 1.6.11 provides the following guidance for reasonable car fuel cost elasticities:

> *"A number of studies in this country using time-series data on car travel, and fuel prices and costs have shown an elasticity of car use with respect to fuel cost of about -0.3 (see Bradburn and Hyman (2002), Graham and Glaister (2002), Hanly Dargay and Goodwin (2002)) and this value equates well with a review of European research on this topic (TRACE, 1999). A realistic model does not necessarily provide precisely this value of -0.3, which is based upon a national mix of trip purposes and time periods. Variation by journey purpose will show elasticities in the range of -0.1 to -0.4 with employer's business trips having values close to -0.1 and the more discretionary trip purposes nearer -0.4."*

Fuel cost elasticities from TGDM are, therefore, expected to be around -0.3, with variation by journey purpose that should show elasticities for business trips at the lower end of this range, and discretionary trips such as leisure and shopping (i.e. HBO) at the higher end.

Table 7.2 shows the final car fuel cost vehicle kilometre elasticities for all trips originating in the Thames Gateway region, as derived from the test reducing fuel cost by 10%.

Table 7.2: TGDM Car Fuel Cost Elasticities (10% fuel cost reduction)

Purpose	**Car Fuel Cost Elasticities (matrix calculation, all origins in TG Region)**				
	Morning Peak	**Interpeak**	**Evening Peak**	**Off Peak**	**16-Hour**
HBW	-0.20	-0.25	-0.22	-0.33	**-0.23**
HBE	-0.09	-0.14	-0.09	-0.18	**-0.11**
HBEB	-0.08	-0.18	-0.07	-0.24	**-0.12**
HBO	-0.38	-0.36	-0.28	-0.47	**-0.37**
NHBEB	0.02	-0.07	-0.03	-0.21	**-0.05**
NHBO	-0.39	-0.34	-0.34	-0.47	**-0.36**
Overall	**-0.23**	**-0.29**	**-0.22**	**-0.42**	**-0.28**

These data demonstrate that the car fuel cost sensitivity of TGDM is consistent with current research and guidance. Interpeak and off peak model sensitivity is higher than peak period sensitivity, reflecting lower levels of highway congestion which constrain the effects of the fuel cost change in the peak periods.

Business trips have a much lower sensitivity, as might be expected. Education trips also, perhaps surprisingly, demonstrate a low sensitivity. This is because they have a very short average trip length, and as the model is based upon absolute cost changes, they experience less benefit from a fuel cost reduction due to the shortness of their trips.

We have also calculated car fuel cost vehicle kilometre elasticities (for all trips originating in the Thames Gateway region) from a test that *increases* fuel cost by 10%. The resulting model sensitivities are presented in Table 7.3.

Table 7.3: TGDM Car Fuel Cost Elasticities (10% fuel cost increase)

Purpose	Car Fuel Cost Elasticities (matrix calculation, all origins in TG Region)				
	Morning Peak	Interpeak	Evening Peak	Off Peak	16-Hour
HBW	-0.22	-0.28	-0.24	-0.36	**-0.25**
HBE	-0.10	-0.15	-0.09	-0.19	**-0.12**
HBEB	-0.09	-0.18	-0.08	-0.25	**-0.13**
HBO	-0.42	-0.39	-0.30	-0.50	**-0.40**
NHBEB	0.01	-0.07	-0.04	-0.22	**-0.05**
NHBO	-0.43	-0.36	-0.37	-0.49	**-0.38**
Overall	**-0.25**	**-0.30**	**-0.24**	**-0.44**	**-0.30**

Using an increased, rather than reduced, fuel cost in the sensitivity test results in a consistent and slight increase in model sensitivity, still close to the target value of -0.3.

The TGDM fuel cost sensitivity was calibrated by adjusting the threshold distance for the cost-dampening function, discussed in Section 3.6. This has the effect of increasing or reducing all choice sensitivities.

7.5 Public Transport Fare Elasticities

WebTAG Unit 3.10.4, Paragraph 1.6.13 states that:

> *"Elasticities of public transport trips with respect to public transport fares have been found to lie typically in the range -0.2 to -0.4 for changes taking place within 12 months, and up to -0.9 for changes over a longer period. (TRL, 2004) with those in the peak, or for more obligatory purposes, at the lower end and those in the off-peak, or for more discretionary purposes, at the higher end. These values apply to the totality of public transport passengers; arguably, those with a car available would be expected to show a greater elasticity since they have greater choice, but there is little consistent evidence on what values are appropriate."*

In assessing the sensitivity of the TGDM public transport demand to changes in fares, we have carried out three tests: one in which all public transport fares were reduced by 10%, and two in which bus and rail fares were separately reduced by 10%.

Reducing the public transport fares by 10% for rail and bus results in the fare elasticities shown in Table 7.4. These data are derived from matrix calculations, for all origins in the Thames Gateway region, and relate to passenger *trips*, rather than *passenger kilometres*.

Table 7.4: TGDM Public Transport Fare Elasticities (10% fare decrease)

Purpose	Elasticity (16-Hour)
HBW	-0.10
HBE	-0.15
HBEB	-0.05
HBO	-0.19
NHBEB	-0.10
NHBO	-0.36
Overall	**-0.16**

We would expect values towards the "longer-period" recommendations, and so an overall public transport fare elasticity of -0.16 seems low.

There are two characteristics of the fares used in the TGDM that will be contributing to this low fare elasticity, both relating to bus. These are discussed in Section 7.7.

7.6 Rail Fare Elasticities

In assessing the sensitivity of TGDM rail demand, we have used demand elasticities with respect to changes in fare. To calculate these fare elasticities, rail fares were reduced by 10%, with bus fares unchanged.

WebTAG provides scant guidance on rail fare elasticities, but rail trip (not passenger kilometre) fare elasticities published by the Association of Train Operating Companies (ATOC), are summarised in Table 7.5.

Table 7.5: ATOC Rail Fare Trip Elasticities (2002)

Trip Pattern	Season Tickets	Other Tickets
Trips To London	-0.30	-0.66
Other Trips In London Area	-0.60	-0.72
Outside South East England	-0.60	-0.90

The TGDM rail fare elasticities for trips (again, not passenger kilometres, for consistency with ATOC data) derived from the test reducing fares by 10% are shown in Table 7.6, split by demand purpose. These data are derived from matrix calculations, for all origins in the Thames Gateway region.

Table 7.6: TGDM Rail Fare Trip Elasticities (10% fare decrease)

Purpose	Elasticity (16-Hour)
HBW	-0.40
HBE	-0.13
HBEB	-0.08
HBO	-0.52
NHBEB	-0.19
NHBO	-0.75
Overall	**-0.38**

The sensitivity of rail demand to fare change is broad in line with WebTAG guidance of around -0.6 and with the ATOC data, although at the lower end of the range. The variations in sensitivity are largely a reflection of the assumed values of time for each demand segment (see Table 5.1).

7.7 Bus Fare Elasticities

Research into bus fare elasticities suggests that there can be greater variation in sensitivity to fares, depending upon the location of the study, the type of user etc. The research also distinguishes between short-term and long-term impacts.

WebTAG Unit 3.11.1 provides indicative bus passenger kilometre fare elasticities. Guidance (WebTAG Unit 3.11.1, section 9.2) suggests a central passenger kilometre elasticity value of around -0.70, within a range of -1.12 to -0.44.

The TGDM bus passenger kilometre fare elasticities, derived from a 10% reduction in bus fares, with rail fares unchanged, are shown in Table 7.7. These data are for all trips with origins in the Thames Gateway region.

Table 7.7: TGDM Bus Fare Elasticities (10% fare decrease)

Purpose	Elasticity (16-Hour)
HBW	-0.10
HBE	0.00
HBEB	-0.03
HBO	-0.20
NHBEB	-0.05
NHBO	-0.33
Overall	**-0.17**

These elasticities are low when compared with WebTAG guidance. There are a couple of obvious reasons underpinning these low elasticity values in TGDM:

- Firstly, the absolute value of the bus fares is low. By substituting the TGDM fares with the higher fares used in EERDM, the public transport fare elasticity doubles to a value consistent with EERDM. This demonstrates that the TGDM and EERDM models produce comparable fare elasticities when using similar fares (providing comfort that the TGDM is coded correctly), and reinforces the fact that elasticities will tend to be low when fares are low, and consequently the fare changes being input into the choices models are also low.
- Secondly, the bus matrix in TGDM is focussed on local travel, implying greater emphasis on shorter, lower fare trips, resulting in less longer distance (and higher fare) demand in the matrix. As with the first point, this demand distribution will be contributing to low public transport fare elasticity values.

7.8 Demand-Supply Convergence (%Gap)

The %Gap statistic is used to determine when TGDM has a converged set of demand and costs. The approach adopted to calculate the %Gap was discussed in Section 3.14.3. Table 7.8 shows the TGDM %Gap statistics that were calculated during the base year car fuel cost elasticity test (see Section 7.4), which converged in 7 demand-supply iterations to a %gap criterion of 0.02% (Note that 0.01% is currently used as the required threshold for modelling; sensitivity tests need not be run to the same level of convergence).

Table 7.8: TGDM %Gap Statistics, Fuel Cost Elasticity Test

Iteration	%Gap
1	1.454
2	0.627
3	0.479
4	0.427
5	0.148
6	0.029
7	0.019
Final	**0.019**

7.9 Base Year Costs

The primary function of the TGDM supply model is to generate pure time matrices that are a reasonable estimate of those that would be created using the full OmniTrans highway model.

To assess the performance of the TGDM supply model, we have assigned the OmniTrans highway model demand on the converted TGDM highway networks.

The pure time skimmed matrices taken from the TGDM and TGHAM assignments have been compared, and the results are summarised in Table 7.9. These data relate to all interzonal movements originating in the Thames Gateway region (the *calibration area*). A linear function through the origin has been fitted to the data.

Table 7.9: Base Year Cost Correlations: TGDM vs. TGHAM

Period	Slope	r^2
Morning Peak	1.038	0.998
Interpeak	1.030	0.998
Evening Peak	1.027	0.999

Scatter diagrams have not been provided for these data, as little additional information is shown (except demonstration of a very good correlation).

7.10 Assigned Link Volumes

7.10.1 Overview

Although it is considered that the generation of costs is the primary purpose of the TGDM supply model, it is also felt to be desirable that the assigned link flows demonstrate a reasonable approximation of the OmniTrans highway model link flows, as the routeing of assigned TGDM demand will affect the skimmed costs. Furthermore, it is important to capture within the TGDM supply model the routeing effects resulting from any new highway schemes that are tested.

7.10.2 DMRB Assignment Validation Acceptability Guidelines

The approach that we have adopted to comparing the TGDM and OmniTrans highway model link volumes is to use the DMRB guidance for assignment validation, which is summarised in Table 7.10.

Table 7.10: DMRB Guidance Criteria for Acceptable Link Flows

Observed Hourly Flow	Tolerance For Modelled Flows
0 to 700	100 vehicles per hour
700 to 2700	15% of observed flows
Greater than 2700	400 vehicles per hour

These criteria would normally be applied to observed traffic volumes. However, in the context of this comparison between TGDM and OmniTrans highway model, the highway model volumes are treated as the observed data, since the objective of this validation exercise is to demonstrate consistency between the TGDM supply model and OmniTrans highway model.

Figure 7.4, Figure 7.5 and Figure 7.6 provide a comparison of the TGDM and OmniTrans highway model base year assigned link volumes across all the validation links for each time period. The DMRB acceptability criteria are also plotted on the figures. Data plotted outside the DMRB bands fail the criteria.

Figure 7.4: Comparison of TGDM and TGHAM Link Volumes, Morning Peak

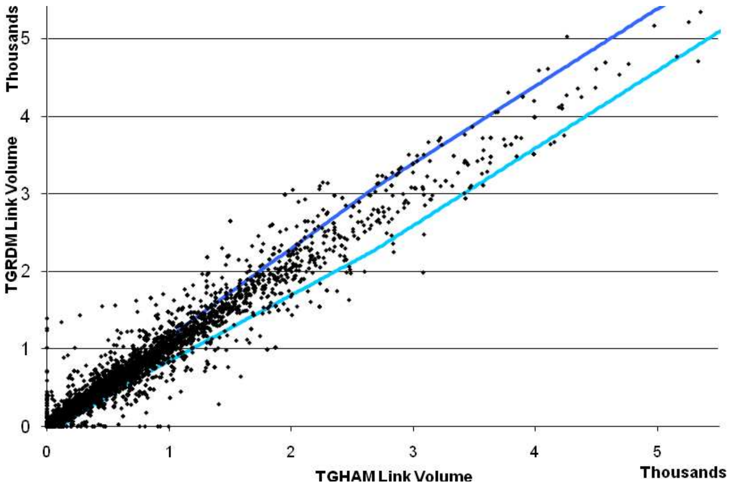


Figure 7.5: Comparison of TGDM and TGHAM Link Volumes, Interpeak

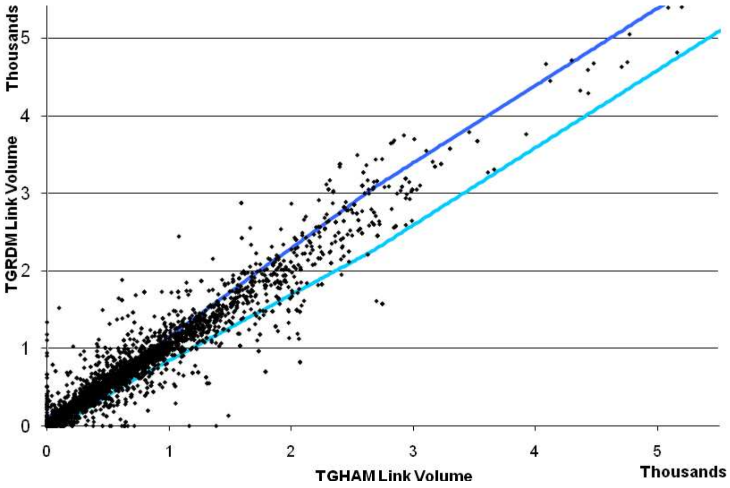
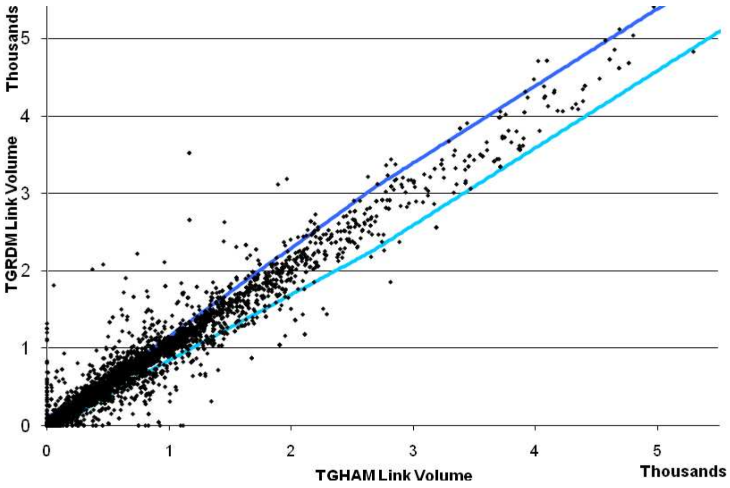


Figure 7.6: Comparison of TGDM and TGHAM Link Volumes, Evening Peak



A summary of the regressions statistics associated with these figures is shown in **Table 7.11**

Table 7.11: Base Year Assigned Volume Correlations: TGDM vs. OmniTrans highway model

Period	Slope	Intercept	r^2
Morning Peak	1.01	18.41	0.97
Interpeak	1.02	16.68	0.95
Evening Peak	1.01	13.95	0.96

These graphs and regression statistics demonstrate that the TGDM supply model link flows are a reasonable representation of those in OmniTrans highway model.

8 Supply Model Forecasting Performance

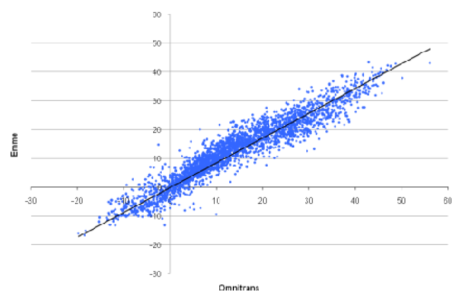
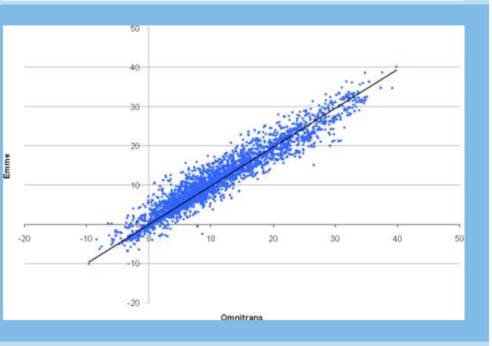
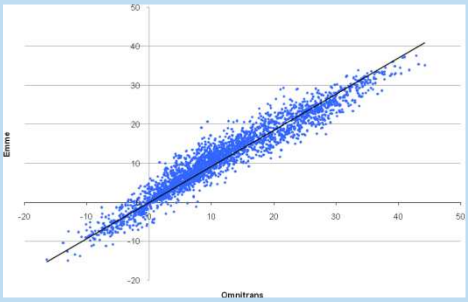
8 Supply Model Forecasting Performance

8.1 Cost Changes Over Time

Chapter 7 demonstrated that the base year TGDM highway supply model replicates the OmniTrans highway model (pure time) costs well. As the TGDM supply model is to be used for forecasting changing demand over time as a function of cost change, it is also important to demonstrate that TGDM can simulate those cost changes over time that could be generated by using the OmniTrans highway model.

Figure 8.1 provides a comparison of the cost changes over time produced when using TGDM and the OmniTrans highway model, between a base-year assignment and a 2028 assignment (OmniTrans highway model on the x-axis, TGDM on the y-axis).

Figure 8.1: Comparison of TGDM and OmniTrans highway model Cost Changes

Period	Base Year to 2028
Morning Peak	
Interpeak	
Evening Peak	

The cost data are matrix-based and reflect the costs taken from the assignment of base year (2006) and 2028 reference (pre-TGDM) assignments, i.e. the data used to derive the cost changes that are used in the first demand-supply iteration of TGDM.

Positive cost change values in the figures reflect higher congestion resulting from the higher 2028 demand. The few negative cost changes evident are inevitable as a result of some redistribution of traffic or transport scheme improvements in the *Core Scenario* network.

The linear regression statistics for the comparison between the OmniTrans highway model and TGDM cost changes are shown in Table 8.1.

Table 8.1: Linear Regression Statistics for Figure 8.1

	Base-2028		
	Morning Peak	**Inter Peak**	**Evening Peak**
Slope	0.86	0.99	0.93
r^2	0.90	0.91	0.92

These regression statistics demonstrate a very good correlation of cost changes between the two models.

9 Conclusions

9 Conclusions

TGDM is a full variable demand model, designed to be compliant with WebTAG guidance as of March 2009.

The sensitivity of TGDM is generally highly consistent with WebTAG guidance. The demand elasticities of the model to changes in car fuel cost, journey time and public transport fares are credible, varying by demand segment and time of day:

- The car fuel cost sensitivity of TGDM is consistent with current research and guidance. Interpeak and off peak model sensitivity is highest, reflecting lower levels of highway congestion which constrain the effects of the fuel cost change in the peak periods. The car journey time elasticity of TGDM is also consistent with WebTAG guidance, within the range of the values suggested for low to high modal competition.
- Overall public transport fare sensitivity is generally lower than that discussed in WebTAG, with variation between demand purposes. The sensitivity of rail demand to fare changes is a reasonable reflection of the ATOC rail fare elasticities. The bus fare elasticities lower than the range provided in the WebTAG guidance. This is attributed to a low average bus fare in the model.

The TGDM highway supply model responses satisfactorily reflect those of the full Omnitrans highway model. Whilst the use of the full OmniTrans highway model would, in principle, be preferable to the use of the internalised highway supply model, this is currently not practical on the grounds of software limitations and licensing. Some simplification was therefore required.

We have demonstrated that the TGDM supply model reproduces OmniTrans highway model link volumes and skimmed costs with accuracy, and we have demonstrated how cost changes over time, created within the TGDM highway supply model, compare well with those created in the OmniTrans highway model.

We have demonstrated that excellent demand-supply %Gap convergence is achieved, well in advance of that required by WebTAG. We are satisfied that this demonstrates that TGDM is converging to a level well-within WebTAG guidance, and such that economic benefit analysis of TGDM/ OmniTrans highway model results will prove robust and stable.

We therefore believe that the Thames Gateway Demand Model is fit for the purpose for which it will be used: that of forecasting demand responses to highway and public transport schemes in the Thames Gateway region.

Appendix A: Alternative TGDM Choice Structure

Appendix A: Alternative Choice Structure

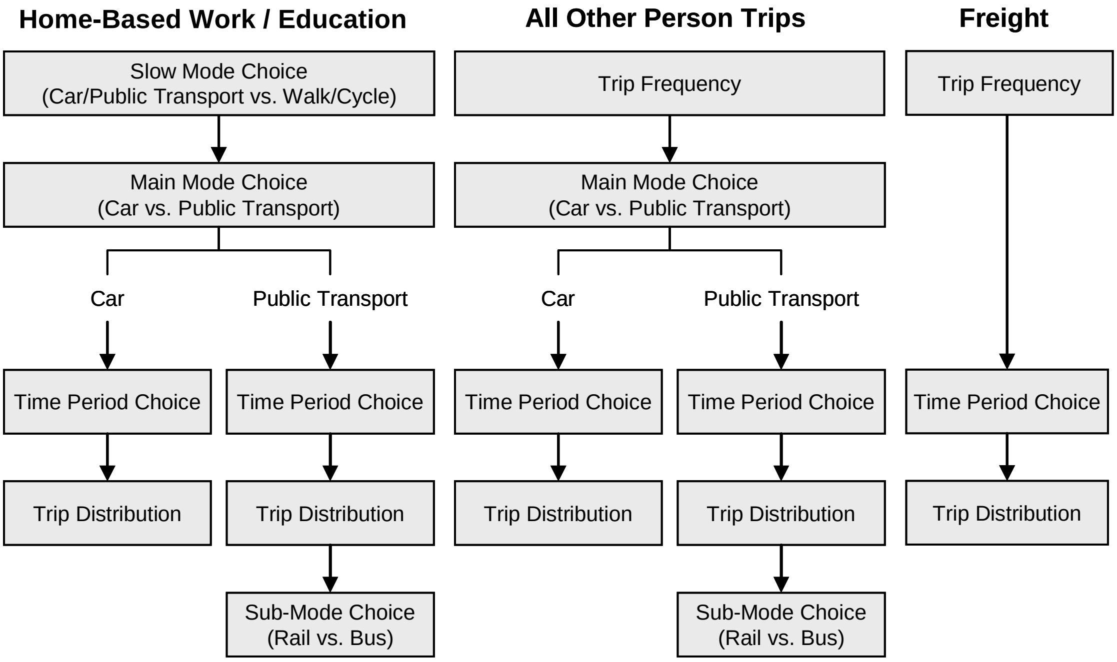
Context

The main choice structure within TGDM is ordered:

- trip frequency;
- time period choice;
- main mode choice;
- trip distribution; and
- public transport (sub-)mode choice.

Another choice structure, which switches the order of time period choice and main mode choice (which have identical sensitivity in TGDM in any case), exists in the model, and is coded for use with the HBW demand segment. Testing has been carried out to verify that, with time period choice and main mode choice having the same sensitivity, identical results are obtained by the two choice structures. The alternative choice structure is illustrated in Figure A1.

Figure A1: Alternative TGDM Choice Structure



Alternative TGDM Choice Structure Functions

Trip Frequency

$$\hat{D}_{**i*} = \sum\nolimits_{tmj} D_{tmij}\ e^{\theta_f \Delta C_{**i*}} \quad \text{where} \quad \Delta C_{**i*} = \log_e\left(\frac{\sum_{tmj} D_{tmij} e^{\theta_m \Delta C_{*mi*}}}{\sum_{tmj} D_{tmij}} \right)$$

Main Mode Choice

$$\hat{D}_{*mi*} = \hat{D}_{**i*} \frac{\sum_{tj} D_{tmij} e^{\theta_m \Delta C_{*mi*}}}{\sum_{tmj} D_{tmij} e^{\theta_m \Delta C_{*mi*}}} \quad \text{where} \quad \Delta C_{*mi*} = \log_e\left(\frac{\sum_{tj} D_{tmij} e^{\theta_t \Delta C_{tmi*}}}{\sum_{tj} D_{tmij}} \right)$$

Time Period Choice

$$\hat{D}_{tmi*} = \hat{D}_{*mi*} \frac{\sum_{j} D_{tmij} e^{\theta_t \Delta C_{tmi*}}}{\sum_{tj} D_{tmij} e^{\theta_t \Delta C_{tmi*}}} \quad \text{where} \quad \Delta C_{tmi*} = \log_e\left(\frac{\sum_{j} D_{tmij} e^{-\lambda_d C_{tmij}}}{\sum_{j} D_{tmij}} \right)$$

Trip Distribution and Public Transport Mode Choice

The formulation is identical with that used for the main choice structure given in Sections 3.10 and 3.11.

Alternative TGDM Choice Structure Parameter Values

Only the time period choice and main mode choice parameters are different. The main mode choice parameters in this structure are all equal to 1, whilst the time period choice parameters are given in the table below, and are identical to the main mode choice parameters used in the main choice structure.

Table A1: TGDM Time Period Choice Theta Values for Alternative Structure

Purpose	Theta
HBW	0.68
HBEB	0.45
HBO	0.53
NHBEB	0.73
NHBO	0.81
HGV	1.00
LGV	1.00