G-BATS4M Model Update

Demand Model Report

Prepared for

West of England Authorities

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Document History

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This document has been issued and amended as follows:

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1.0	08.05.15	Draft Demand Model Report	Katherine Williams/Jeff Tjiong	Chris Bushell	Chris Bushell
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Contents

SECTION 1

Introduction

1.1 Background

This report has been prepared by CH2M Hill as part of their commission to update to the Greater Bristol Area Transport Study (G-BATS) modelling suite for Bristol City Council (BCC), on behalf of the West of England authorities. The updated model is called the GBATS4 Metro Model (GBATS4M).

This report shows that the updated the Demand Model meets WebTAG guidance (TAG) in terms of structure, parameters used and realism tests, to demonstrate it is fit for purpose to test the impact of proposed future year schemes, in conjunction with the G-BATS4M Highway and Public Transport (PT) models.

1.2 This Report

The remainder of this report consists of the following sections:

- Section 2 – Model Usage and Design Considerations;
- Section 3 – Model Structure;
- Section 4 – Data Requirements; and
- Section 5 – Model Standards and Calibration.

SECTION 2

Model Usage and Design Considerations

2.1 Metro West

The GBATS4M modelling suite provides a tool with which to test the ability of future transport proposals to support forecast travel demand. At a general level this includes:

- Investigation of new development proposals; and
- Longer-term strategic planning of the transport network.

The specific purpose of the model is for assessing the MetroWest major scheme Phases 1 and 2.

2.2 Potential Alternative Uses

The GBATS4M modelling suite could (with further validation if necessary) also be used to forecast and assess a range of alternative potential interventions. While not a definitive list, the following future year schemes could potentially be assessed:

- Bristol Arena
- Temple Circus Roundabout / Redcliffe Way;
- Temple Quarter Enterprise Zone;
- Central Area Action Plan;
- Changes to bus operations;
- Park and Ride schemes;
- M4 Link;
- North Fringe VISSIM interface;
- Strategic wider area schemes; and
- Major development proposals in the wider urban area.

2.3 Model Design Considerations

The GBATS Demand Model is a complex, strategic five-stage model developed to cover the greater Bristol area. The model structure is consistent with the previous GBATS3 suite of models, including time period choice and segmentation by income groups, which provides flexibility in terms of potential to assess a wide range of schemes.

To support better control and ease of specifying model assumptions a new spreadsheet-based model user interface which contains all relevant model parameters has been built.

SECTION 3
Model Structure

3.1 Software

The Demand Model has been implemented using the EMME modelling software platform through a series of macros, containing the required executable commands and matrix calculations. The Demand Model macros interface with the Saturn highway and EMME PT model. A ‘front-end’ Excel spreadsheet has been developed to hold calibrated parameters and where the user can define certain run-specific inputs. This Excel file contains a number of macros written in Visual Basic, which perform file manipulations and call the EMME macros and SATURN assignments / network skim functions, as required to provide a fully automated and integrated interface between the G-BATS4M highway, PT and Demand models.

3.2 Zone system

The zone system used by the Demand Model is the same as that used by the G-BATS4 highway and PT models.

3.3 Temporal Scope

The Demand Model operation covers a 12 hour period interfacing with the G-BATS4 highway and PT assignment modelled hours as follows:

- AM peak hour: 0800-0900
- Inter-Peak (IP) modelled hour: average of 1000-1600; and
- PM peak hour: 1700 – 1800.

3.4 Segmentation

The Demand Model uses a greater level of segmentation than the highway and PT assignment models, in order to represent demand responses for different journey purposes and person types as advised by TAG.

The Demand Model segmentation is as follows:

By car availability

- Car available; and
- Non-car available

By household income

- Income Low: under £23,000
- Income Medium: £23,000 to £46,000
- Income High: over £46,000

These bands are based on latest TAG advice. Income segmentation is only applied to commute and other car available demand segments.

By journey purpose

- Commuting / Home based work (HBW)
- Home based and non-home based employer’s business (EMP)
- Home based and non-home based other trips (OTH)

This yields 10 demand segments as shown in Table 3.1.

TABLE 3.1
Demand Model Segmentation

Description	Demand Purpose	Car Available (CA)			Non Car Available (NCA)
		<£23,000	£23,000 to £46,000	> £46,000	
Commute	HBW	1	2	3	8
Other	OTH	4	5	6	9
Work	EMP	7			10

3.5 Cost Formulation

Generalised costs (GCs) are calculated in terms of minutes from highway and PT model time and distance skims as described below. The cost calculations in the Demand Model are expressed as changes in GCs from the base year.

Car

Time and cost skims are extracted separately for the highway model user classes: HBW, EMP and OTH, which vary with respect to value of time (VOT) assumptions.

The GC calculation is of the form:

C_{ij} (car.^{p}) = T_{ij} + (f.c.D_{ij} + nf_{ij} + P_j)/($v^{(p)}$.$o^{(p)}$)

Where:

C_{ij} (car. p) = generalised cost by car between i and j, for segment p;
T = time in minutes (including in-vehicle time and walk access);
f = fuel cost in pence per litre;
c = fuel consumption in litres per kilometre;
nf = non fuel cost in p per kilometre (business trips only)
D = highway distance in km;
P = parking charge in pence obtained from local data (taken as half per trip);
v(p) = value of time for segment p in pence per minute; and
o(p) = car occupancy for segment p.
Fuel consumption is estimated using a function of the form:

$L = a/v + b + c.v + d.v^2$

Where:

L = consumption, expressed in litres per kilometre;
v = average speed in kilometres per hour; and
a, b, c, d are parameters defined for each vehicle category.

The non-fuel elements of vehicle operating costs (VOC) are combined in a formula of the form;

C = a1 + b1/V,

Where;

C = cost in pence per kilometre travelled,
V = average link speed in kilometres per hour,
a1 is a parameter for distance related costs defined for each vehicle category, and
b1 is a parameter for vehicle capital saving defined for each vehicle category (this parameter is only relevant to working vehicles).

Bus / rail

Public transport GCs are calculated for each purpose, differing in respect of VOT. They are derived as follows:

$C_{ij}^{(pt.p)} = f.D_{ij}/v^{(pt)} + I_{ij} + w.W_{ij} + x.X_{ij} + a.A_{ij}$

Where:

$C_{ij}^{(pt.p)}$= generalised cost by public transport between i and j for purpose segment (p);
f = fare per kilometre in pence;
D = travel distance in km;
$v^{(pt)}$ = value of time for segment p in pence per minute;
I = in-vehicle time in min;
w = wait time weight;
W = wait time in min;
x = transfer penalty in min;
X = number of transfers;
a = access and egress time weight; and
A = access and egress time in min.
Weights applied for walking and waiting are in line with TAG advice.

Park and Ride (submode)

P&R GCs are calculated as follows:

$C_{ij}^{(P\&R.p)} = C_{ik}^{(car.\ p)} + C_{kj}^{(bus.\ p)}$

Where:

$C_{ij}^{(P\&R.p)}$ = GC by P&R for purpose segment (p)
k = P&R site zone

Change in Generalised Cost

The changes in GC that drive the demand response calculations are calculated as follows:

$\Delta C_{ij}^{m(p.t)} = (C_{ij}^{m(p.t)} - C^0_{ij}{}^{m(p.t)})$

Where:

$\Delta\ C_{ij}^{m(p.t)}$= change in generalised cost for mode m, segment p and time period t;
$C_{ij}^{m(p.t)}$ = test cost for mode m, segment p and time period t; and
$C^0_{ij}{}^{m(p.t)}$ = base cost for mode m, segment p and time period t.

Where costs are used in demand response calculations that relate to alternatives considered ‘lower’ in the model hierarchy, these are composite costs calculated using logsum equations, as advised in TAG.

3.6 Demand responses

Demand response calculations are undertaken for travel demands and costs translated into Production-Attraction (PA) format in accordance with TAG, using OD to PA factors derived from survey data.

Calculations are undertaken for each demand response following incremental logit model form as outlined below, with future test travel costs pivoted off the base year model.

In order to preserve the integrity of the validated highway / PT model origin-destination (OD) assignment matrices, the implied demand changes in PA form are translated to OD form and used to incrementally adjust the assignment matrices.

Demand responses are as follows:

- Trip frequency
- Main mode choice (car vs PT)
- Time period choice
- Destination choice

- Sub-mode choice (car vs P&R and rail vs bus/BRT)

Appendix A provides the model formulation for demand responses and cost calculations using standard TAG notation.

The Demand Model does not explicitly model slow modes (walk / cycle), but models trip frequency instead in accordance with TAG.

Main mode choice is only applied to ‘car available’ trips.

Time period choice is only applied to ‘other’ trips, in line with TAG advice that commute and employer’s business trips will have limited flexibility in terms of timing.

The destination choice response is handled for each mode / time period separately.

For HBW trips, the destination choice model is doubly constrained by balancing the travel demands according to the calculated zonal trip productions/attractions.

Sub-mode choice calculations are undertaken to forecast change in sub-modes with the same general model form as main mode choice, as follows:

- Main mode PT has sub-modes: bus/BRT and rail
- Main mode car has sub-modes: car only and P&R.

3.7 Park and Ride

P&R is modelled as a sub-mode choice of the car main mode to forecast P&R site usage for the seven car available demand segments on a PA basis. Three separate park-and-ride sites are covered within the model area, as follows:

- A4 Bath Road (~1300 car parking spaces)
- A4 Portway (~500 car parking spaces)
- A370 Long Ashton (~1500 car parking spaces)

Parking capacity restraint are not modelled explicitly in the Demand Model to avoid the complexities of a full modelling of parking which would be viewed as disproportionate as per the TAG guidance on modelling parking and park and ride.

The P&R sub-model is implemented in the following sequential steps:

1. Utilising the triple-index operation feature in Emme modelling software to determine the minimum park-and-ride journey cost and “best” P&R site for all PA pairs in the base year. The minimum P&R cost is computed based a combination of the journey cost for the car-only and bus sub-modes :

   $\text{Min}(GC\_P\&R_{pq}^{min}) = \text{Min}_k(GC\_Car_{pk}^{min} + GC\_Bus_{kq}^{min})$

   Where:

   p = trip production
   q = trip attraction
   k = P&R site
   GC_P&R = generalised cost for the entire P&R journey
   GC_Car = generalised cost for the car-leg of the P&R journey, which includes perceived parking costs at the P&R site
   GC_Bus = generalised cost for the bus-leg of the P&R journey

2. Prepare reference P&R trip productions and attractions and then distribute them through a matrix furness process. It is assumed that any P&R trip on a PA basis is essentially made by car leg to P&R site first, followed by a bus leg of the journey leaving the P&R site. As such, total number of trip productions and trip attractions can be computed using the following functions:

$P\&RTrip\_PA_p = CarTrip\_OD_{ik} + Transposed(CarTrip\_OD_{kj})$

$P\&RTrip\_PA_q = BusTrip\_OD_{kj} + Transposed(BusTrip\_OD_{ik})$

Where:

p = reference trip production
q = reference trip attraction
i = reference trip origin
j = reference trip destination
k = P&R site
P&RTrip_PA = reference P&R trip vector, either production or attraction, on a PA basis
CarTrip_PA = reference car trip OD pairs to/from P&R sites, on a PA basis
BusTrip_PA = reference bus trip OD pairs to/from P&R sites, on a PA basis

The matrix furness process balances the reference P&R trip productions and attractions based on distributional pattern as in the validated car-only PA demand matrices. The furness process is controlled to the trip productions (i.e., the car trip totals to/from P&R sites).

3. Generate incremental P&R productions and attractions at the P&R sub-model stage of the hierarchical logit model using the following function:

$$T_{ij}^{mts} = T_{ij}^{mt} \frac{T_{ij}^{0\,mts} e^{-\lambda_{sub} \Delta C_{ij}^{mts}}}{\sum_k T_{ij}^{0\,mtk} e^{-\lambda_{sub} \Delta C_{ij}^{mtk}}}$$

Where for each demand segment:

k = numeration of sub-modes

T_{ij}^{mts} = adjusted trips by submode

T_{ij}^{mt} = adjusted trips by submode from demand response at higher hierarchy

$T_{ij}^{0\,mts}$= reference trips by submode

ΔC_{ij}^{mts}= change in generalised cost for a given submode

λ_{sub}=P&R logit choice parameter

4. Split the adjusted P&R trips (PA) produced by the incremental model into car and bus legs using the trip-index operation in Emme, assuming these incremental trips would access the best P&R site with minimum combined P&R journey cost as in the base year condition.

3.8 Other Demand

Goods vehicles and external to external car / PT trips have been excluded from the above demand response calculations in the Demand Model. Rather for future years, growth for goods vehicles will be based on DfT regional traffic forecasts. Growth for external to external car / PT trips will be based on Tempro.

SECTION 4

Model Parameters

4.1 WebTAG Parameters

Model parameters have been used as follows:

- Initial parameters and scaling factors for each demand response to be obtained from TAG unit 3.10.3, then adjusted during model calibration, as shown in Tables 4.1 and 4.2; and
- Value of time (VOT) and Vehicle operating cost (VOC) from TAG unit 3.5.6, as shown in Tables 4.3 and 4.4.

TABLE 4.1

TAG M2 Table 5.1 - Illustrative Destination Choice Parameters (Lambda)

CAR	MIN	MEDIAN	MAX
Home-based work	0.054	0.065	0.113
Home-based employers business	0.038	0.067	0.106
Home-based other	0.074	0.090	0.160
Non-home-based employers business	0.069	0.081	0.107
Non-home-based other	0.073	0.077	0.105
PT	**MIN**	**MEDIAN**	**MAX**
Home-based work	0.023	0.033	0.043
Home-based employers business	0.030	0.036	0.044
Home-based other	0.033	0.036	0.062
Non-home-based employers business	0.038	0.042	0.045
Non-home-based other	0.032	0.033	0.035

TABLE 4.2

TAG M2 Table 5.2 - Illustrative Main Mode Choice Scaling Parameters (Theta)

TRIP PURPOSE	MIN	MEDIAN	MAX
Home-based work	0.50	0.68	0.83
Home-based employers business	0.26	0.45	0.65
Home-based other	0.27	0.53	1.00
Non-home-based employers business	0.73	0.73	0.73
Non-home-based other	0.62	0.81	1.00

TABLE 4.3

Value of Time by Income, Purpose and Vehicle Type (p/min)

TRIP PURPOSE / VEHICLE TYPE	Low Income	Medium Income	High Income
Home-based work - Car	6.91	10.22	15.23
Home-based other - Car	8.94	10.90	13.18
Employers business - Car	42.81	42.81	42.81
Employers business - Bus	26.30	26.30	26.30
Employers business - Rail	50.56	50.56	50.56

Calculated from TAG Tables A1.3.1 and M2.1 for VOT adjusted to 2013 prices and values in Table A1.3.2 and the retail price index.

TABLE 4.4
Vehicle Operating Costs

VOC Type	Value
Fuel cost - Non-work (p/litre)	51.20
Fuel cost - Business (p/litre)	40.96
Fuel Consumption Parameter a	0.964023
Fuel Consumption Parameter b	0.041448
Fuel Consumption Parameter c	-0.000045
Fuel Consumption Parameter d	0.000002
Non Fuel Cost Parameter a1 (p/km)	5.25
Non Fuel Cost Parameter b1 (p/hr)	143.73

Values from TAG Tables A1.3.7, A1.3.8 and A1.3.14

4.2 OD to PA Factors

OD to PA and purpose split factors have been applied to derive matrices segmented by purpose for use in the Demand Model have been derived from roadside interview and PT survey data for car and PT trips respectively. The factors are shown in Tables 4.5 and 4.6.

TABLE 4.5
Highway OD to PA Factors

PURPOSE/DIRECTION	AM	IP	PM
Home-based work Out	0.98	0.50	0.05
Home-based work Return	0.02	0.50	0.95
Home-based other Out	0.88	0.49	0.54
Home-based other Return	0.12	0.51	0.46
Employers business	1.00	1.00	1.00

TABLE 4.6
PT OD to PA Factors

PURPOSE/DIRECTION	AM	IP	PM
Home-based work Out	0.95	0.30	0.06
Home-based work Return	0.05	0.70	0.94
Home-based other Out	0.88	0.49	0.15
Home-based other Return	0.12	0.51	0.85
Employers business	1.00	1.00	1.00

4.3 Car Occupancy and Availability

Car occupancy factors have been derived from local roadside interview survey data. Table 4.7 shows the values used for each time period and purpose.

TABLE 4.7
Car Occupancy

PURPOSE	AM	IP	PM
Home-based work	1.22	1.19	1.16
Home-based other	1.65	1.62	1.58
Employers business	1.30	1.22	1.27

Car availability factors have been derived from PT survey data. This is more appropriate than population-based car availability data, such as census data, as it is the PT demand in particular that is segmented according to car availability. Table 4.8 shows the PT car availability factors.

TABLE 4.8
PT Car Availability Factors

PURPOSE	Car Available	No Car Available
Home-based work	0.58	0.42
Home-based other	0.48	0.52
Employers business	0.59	0.41

4.4 PT Fares

Rail fares have been derived from MOIRA data. Bus fares have been derived from local operator data.

Table 4.9 shows the PT fares used together with the weight and transfer penalties used from TAG M3.2. The PT fares used are weighted averages that include concessionary fares and use of season tickets.

TABLE 4.9
PT Fares

Sector	Value
Bus fare (p/km)	26.70
Rail fare (p/km)	15.00
Wait time weight	2.00
Walk time (Aux) weight	2.00
Transfer Penalty (min)	10.00

4.5 Parking Charges

Parking charges have been obtained from published data. Weighted average parking charges have been calculated per zone within the city centre, based on parking usage data, the number of spaces of each parking type (public, private non-residential and on-street parking) and length of stay data. The parking charges are then used in the highway generalised cost calculations.

Table 4.10 shows half the cost of parking in the city centre zones, which were sectored into 3 areas, Temple Meads/Redcliffe, Broadmead/Cabots Circus/Colston and Waterfront/Floating Harbour/Queens Square. Work parking charges were based on long stay (>5 hours) parking costs and free spaces, whereas the other and employer's business parking charges were based on short stay (<5 hours) parking costs and free spaces.

TABLE 4.10
Parking Charges (in pence, half the cost of parking)

Sector	Home-based work	Home-based other	Employers business
1	676	360	360
2	285	216	216
3	527	225	225

SECTION 5
Model Calibration

5.1 Calibration

An initial run of the Demand Model was undertaken using median TAG demand response parameters. Demand Model parameters were then adjusted with small increments until a final set of parameter values were reached which produce model behaviour satisfying the realism tests criteria to demonstrate demand responses lie within TAG elasticity ranges.

The realism tests applied are specified in TAG unit 3.10.4 to test model response to changes in travel costs. These have been undertaken for 10% increases in the following:

- Car fuel cost;
- Car journey times;
- PT fares; and
- Bus Fares.

The arc elasticity formula recommended by TAG was used for calculating the resulting realism test outputs:

$e = \log(T^1) - \log(T^0) / \log(C^1) - \log(C^0) = \log(T^1) - \log(T^0) / \log(1.1)$

where the subscripts 0 and 1 indicate values before and after the change in cost respectively, and for:

- Car fuel cost elasticity: T = car-kms travelled and C = fuel costs;
- Car journey time elasticity: T = car trips and C = journey time;
- PT fare elasticity: T = PT trips and C = bus and rail fares; and
- Bus fare elasticity: T = Bus trips and C = bus fares.

Table 5.1 shows a summary of the realism test changes required to the demand model, the measure of demand change and the resulting output criteria.

TABLE 5.1
Realism Test Summary

Test	Adjustment	Measure of cost change	Measure of demand change	Criteria
Car Fuel Cost	Increase PPK in SATURN and fuel cost (p/l) in demand model by 10%	Fuel cost pence / litre	Car km for each time period and UC calculated from sum of trips x distance skim (need to skim all time periods) - matrix based and network based. Exclude ext-ext and ex-int trips.	By purpose -0.1 to -0.4 (business closer to -0.1 and Other closer to -0.4). Average -0.25 to -0.35
Car Journey Time	Increase the journey time skims by 10% in the highway GC calculation for each UC - calculated on a single iteration of the demand model	Identify weighted average car journey time from the model across all OD pairs	Car trips for each time period and UC for matrix based and for network based the new assigned car journey times.	0 to -2.0
PT fares	Increase average PT fare / km by 10%	PT fare pence / km	Total PT trips (bus + rail) for each time period and UC - exclude ext-ext trips	-0.2 to -0.9
Bus Fares	Increase average Bus fare / km by 10%	Bus fare pence / km	Total bus trips each time period and UC - exclude ext-ext trips	-0.4 to -0.9

5.2 Convergence

As part of the calibration process model convergence using the GAP statistic calculation is checked to ensure the model is sufficiently stable as specified in TAG M2. The recommended criterion for measuring convergence between demand and supply models is the demand/supply gap calculated by:

$(\sum_a C(X_a^n)|D(C(X_a^n))-X_a^n|/\sum_a C(X_a^n)\ X_a^n)*100$

Where:

X_a^n is cell a in the previous assignment matrix for iteration n;

$C(X_a^n)$ is cell a in the generalised costs resulting from assigning that matrix;

$D(C(X_a^n))$ is cell a in the matrix output by the demand model based on costs $C(X_a^n)$; and

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

TAG requires a high level of convergence to be achieved, where the %Gap should be lower than 0.2%. If this cannot be achieved then a more relaxed criterion related to the projected benefits of a scheme can be used. Table 5.2 shows the GAP values achieved for each of the realism tests.

TABLE 5.2
Realism Test Convergence Results (%)

Iteration number	Bus Fares	PT Fares	Car Fuel
1	1.49	5.54	1.66
2	0.38	0.41	0.58
3	0.46	0.26	0.42
4	0.40		0.23
5	0.26		

The convergence results show that the achieved GAP value is slightly higher than the recommended 0.2. Performing additional demand model loops did not result in lower GAP values. However, during model calibration, the realism test results indicated a high degree of stability hence the level of convergence is considered sufficient for the purposes of model calibration.

5.3 Calibrated Parameters

During model calibration, the demand response sensitivity parameters were adjusted to meet the realism test criteria. This section provides a comparison between the calibrated model parameters and the illustrative parameter ranges in TAG.

Destination Choice

Table 5.3 shows the destination choice parameters used to calibrate the demand model. These are all within the illustrative TAG range (see Table 4.1) with the exception of the parameters used for employer's business trips. These values required to calibrate the model are slightly higher than the maximum illustrative TAG values.

TABLE 5.3

Calibrated Destination Choice Parameter Values (Lambda)

TIME PERIOD / PURPOSE	CAR	PT
AM - Home-based work	0.081	0.033
AM - Home-based other	0.104	0.036
AM - Employers business	0.134	0.056
IP - Home-based work	0.081	0.033
IP - Home-based other	0.104	0.036
IP - Employers business	0.134	0.056
PM - Home-based work	0.075	0.033
PM - Home-based other	0.104	0.036
PM - Employers business	0.134	0.056

Time of Day Choice

Table 5.4 shows the time of day choice parameters used for home-based other. In accordance with TAG M2 advice the sensitivity of the time period choice parameters are the same as those used for main mode choice.

TABLE 5.4

Calibrated Time of Day Choice Parameters (Lambda)

MODE	VALUE
Car	0.033
PT	0.033

Main Mode Choice

Table 5.5 shows the main mode scaling parameters used. These values fall within the illustrative TAG ranges (see Table 4.2). These scaling parameters were then applied to the average of the car and PT destination choice parameters shown in Table 5.2 above. The resulting main mode choice parameters are shown in Table 5.6.

TABLE 5.5

Calibrated Main Mode Choice Scaling Parameters (Theta)

PURPOSE	VALUE
Home-based work	0.59
Home-based other	0.47
Employers business	0.59

TABLE 5.6

Calibrated Main Mode Choice Parameters (Lambda)

PURPOSE	VALUE
Home-based work	0.033
Home-based other	0.033
Employers business	0.056

Trip Frequency

Trip frequency elasticity parameters for both car available and no car available, all modes and income segments has been set to 0.005 to avoid unrealistic model sensitivity.

5.4 Realism Test Results

Car Fuel Cost Elasticities

The network based car fuel elasticities in terms of car vehicle kilometres with respect to fuel costs are shown in Table 5.7 and the matrix based car fuel elasticities are shown in Table 5.8. The tables show the elasticities according to the highway model segmentation, i.e. by household income and purpose. The results are also shown by time period and annual average.

TABLE 5.7
Network Based Car Fuel Elasticity

Time Period	Home base work + other			Employer's Business
	Low Income	Medium Income	High Income	
AM	-0.31	-0.18	-0.14	-0.07
IP	-0.29	-0.20	-0.14	-0.06
PM	-0.29	-0.20	-0.14	-0.06
Annual Average	-0.29	-0.20	-0.14	-0.06
	-0.18			

TABLE 5.8
Matrix Based Car Fuel Elasticity

Time Period	Home base work + other			Employer's Business
	Low Income	Medium Income	High Income	
AM	-0.29	-0.20	-0.15	-0.07
IP	-0.36	-0.28	-0.22	-0.07
PM	-0.39	-0.29	-0.22	-0.08
Annual Average	-0.35	-0.27	-0.21	-0.07
	-0.25			

The results demonstrate that the car fuel elasticities reduce as income increases due to a higher value of time in the higher income bands, for home-based work and other trips. The elasticities for these purpose/income segments, for both network and matrix based, fall within the TAG M2 Table 6.2 recommended ranges.

The employer's business purpose displays elasticities slightly weaker than -0.1, for both the network and matrix based tests which reflects the higher value of time for this demand segment.

Whilst the annual average value for the network based test lies out of range of -0.25 to -0.35, the pattern of elasticities across income groups and purposes follows the expected pattern, with the annual average reduced by the lower response values for home based work / other high income and employer's business trips. The network based annual average is within the suggested range.

Car Journey Time Elasticities

The outturn car journey time elasticities from the demand model should be no stronger than -2.0, from one iteration of the model. Table 5.9 shows the car journey time elasticities on a network basis while Table 5.10 shows them on a matrix basis. The tables show the elasticities by the highway model segmentation, i.e. by household income and purpose. The results are also shown by times period and annual average.

TABLE 5.9
Network Based Car Journey Time Elasticity

Time Period	Home base work + other			Employer's Business
	Low Income	Medium Income	High Income	
AM	-0.16	-0.13	-0.08	-0.01
IP	-0.10	-0.08	-0.07	-0.02
PM	-0.13	-0.09	-0.08	-0.02
Annual Average	-0.11	-0.09	-0.07	-0.02
	-0.09			

TABLE 5.10
Matrix Based Car Journey Time Elasticity

Time Period	Home base work + other			Employer's Business
	Low Income	Medium Income	High Income	
AM	-0.15	-0.15	-0.18	-0.08
IP	-0.11	-0.11	-0.13	-0.08
PM	-0.15	-0.15	-0.17	-0.10
Annual Average	-0.12	-0.12	-0.15	-0.08
	-0.13			

The results show that the model responses within the TAG M2 recommended range.

PT Fare Elasticities

The outturn PT fare elasticities from increasing both rail and bus fares by 10% should fall with the range of -0.2 to -0.9. Table 5.11 shows the matrix based PT fare elasticities, by purpose and time period, and the annual average.

TABLE 5.11
PT Fares Elasticity

Time Period	Home base work + other			Employer's Business
	Low Income	Med Income	High Income	
AM	-0.88	-0.69	-0.50	-0.75
IP	-0.72	-0.62	-0.48	-0.47
PM	-0.98	-0.78	-0.57	-0.48
Annual Average	-0.82	-0.68	-0.51	-0.50
	-0.67			

The results show that all but the PM low income home based work and other demand segment meet the TAG criteria, which is only 0.08 outside the recommended range.

Bus Fare Elasticities

The outturn bus fare elasticities from increasing bus fares only by 10% should fall with the range of -0.4 to -0.9. Table 5.12 shows the matrix based bus fare elasticities, by purpose and time period, with the annual average calculated. This shows realism test results broadly within the expected range and showing the expected relative differences between income groups.

TABLE 5.12

Bus Fares Elasticity

Time Period	Home base work + other			Employer's Business
	Low Income	**Med Income**	**High Income**	
AM	-0.46	-0.36	-0.25	-0.85
IP	-0.50	-0.42	-0.31	-0.42
PM	-0.50	-0.39	-0.27	-0.44
Annual Average	-0.49	-0.40	-0.29	-0.46
	-0.39			

Overall, the realism test results are generally within the expected ranges in line with TAG advice and reflect the correct pattern of responses with high income segments showing lower sensitivity to fuel costs and PT fare changes.

SECTION 6

Summary

The G-BATS4M Demand Model has been developed primarily to assess the Metro West Phases 1 and 2.

The demand model is a five-stage multi-modal incremental model that calculates trip frequency choice, main mode choice, time period choice, destination choice and sub mode choice with regards to changes in generalised cost for both the highway and PT models. The G-BATS4M Demand Model follows the current TAG guidance with respect to this structure of model.

The demand model iterates between the hourly-based SATURN highway and EMME PT supply models and the 12 hour demand model, using factors derived from local data collected from surveys.

The calculated Gap values for convergence based on current TAG guidance are close to the target value of 0.2% and the model provides stable realism test results in relation to minor changes in input parameters. Hence sufficient convergence has been achieved for demand model calibration. Further steps may be undertaken during scheme testing to either reduce the GAP value or check projected scheme benefits in relation to model stability to verify that model convergence is not adversely affecting assessment results.

The destination choice lambda parameters and main mode scaling theta parameters are mostly within the illustrative TAG value ranges, with the exception of the employer's business destination choice parameters, which are slightly higher than the maximum illustrative TAG values.

In general the realism test results are within the expected ranges in line with TAG advice and reflect the correct pattern of responses with high income segments showing lower sensitivity to fuel costs and PT fare changes.

Appendix A
Demand Model Formulation

OTH	HBW	EMP
Trip Frequency		
Negative Exponential	**Negative Exponential**	**Negative Exponential**
$T_i = T_i^0 e^{-\lambda_{freq}\Delta C_i}$ $\Delta C_i = \frac{1}{-\lambda_{mode}} ln \sum_m \frac{T_i^{0\,m}}{T_i^0} e^{-\lambda_{mode}\Delta C_i{}^m}$ *m: numeration over main modes*	$T_i = T_i^0 e^{-\lambda_{freq}\Delta C_i}$ $\Delta C_i = \frac{1}{-\lambda_{mode}} ln \sum_m \frac{T_i^{0\,m}}{T_i^0} e^{-\lambda_{mode}\Delta C_i{}^m}$ *m: numeration over main modes*	$T_i = T_i^0 e^{-\lambda_{freq}\Delta C_i}$ $\Delta C_i = \frac{1}{-\lambda_{mode}} ln \sum_m \frac{T_i^{0\,m}}{T_i^0} e^{-\lambda_{mode}\Delta C_i{}^m}$ *m: numeration over main modes*
Main Mode Choice (m)		
Logit	**Logit**	**Logit**
$T_i{}^m = T_i \frac{T_i^{0\,m} e^{-\lambda_{mode}\Delta C_i{}^m}}{\sum_k T_i^{0\,k} e^{-\lambda_{mode}\Delta C_i{}^k}}$ *k: numeration over main modes* $\Delta C_i{}^m = \frac{1}{-\lambda_{tod}} ln \sum_t \frac{T_i^{0\,mt}}{T_i^{0\,m}} e^{-\lambda_{tod}\Delta C_i{}^{mt}}$ *t: numeration over time periods* *must satisfy:* $0 < \frac{-\lambda_{mode}}{-\lambda_{tod}} \le 1$	$T_i{}^m = T_i \frac{T_i^{0\,m} e^{-\lambda_{mode}\Delta C_i{}^m}}{\sum_k T_i^{0\,k} e^{-\lambda_{mode}\Delta C_i{}^k}}$ *k: numeration over main modes* $\Delta C_i{}^m = \sum_t \frac{T_i^{0\,mt}}{T_i^{0\,m}} \Delta C_i{}^{mt}$ *t: numeration over time periods*	$T_i{}^m = T_i \frac{T_i^{0\,m} e^{-\lambda_{mode}\Delta C_i{}^m}}{\sum_k T_i^{0\,k} e^{-\lambda_{mode}\Delta C_i{}^k}}$ *k: numeration over main modes* $\Delta C_i{}^m = \sum_t \frac{T_i^{0\,mt}}{T_i^{0\,m}} \Delta C_i{}^{mt}$ *t: numeration over time periods*
Time of Day (m,t)		
Logit	**Factor**	**Factor**
$T_i{}^{mt} = T_i{}^m \frac{T_i^{0\,mt} e^{-\lambda_{tod}\Delta C_i{}^{mt}}}{\sum_k T_i^{0\,mk} e^{-\lambda_{tod}\Delta C_i{}^{mk}}}$ *k: numeration over time periods* $\Delta C_i{}^{mt} = \frac{1}{-\lambda_{dest}} ln \sum_j \frac{T_{ij}^{0\,mt}}{T_i^{0\,mt}} e^{-\lambda_{dest}\Delta C_{ij}{}^{mt}}$ *j: numeration over all attractions* *must satisfy:* $0 < \frac{-\lambda_{tod}}{-\lambda_{dest}} \le 1$	$T_i{}^{mt} = T_i{}^m \frac{T_i^{0\,mt}}{\sum_k T_i^{0\,mk}}$ *k: numeration over time periods* $\Delta C_i{}^{mt} = \frac{1}{-\lambda_{dest}} ln \sum_j \frac{B_j^0 T_{ij}^{0\,mt}}{T_i^{0\,mt}} e^{-\lambda_{dest}\Delta C_{ij}{}^{mt}}$ *j: numeration over all attractions*	$T_i{}^{mt} = T_i{}^m \frac{T_i^{0\,mt}}{\sum_k T_i^{0\,mk}}$ *k: numeration over time periods* $\Delta C_i{}^{mt} = \frac{1}{-\lambda_{dest}} ln \sum_j \frac{T_{ij}^{0\,mt}}{T_i^{0\,mt}} e^{-\lambda_{dest}\Delta C_{ij}{}^{mt}}$ *j: numeration over all attractions*
Destination Choice (m,t,j)		
Singly constrained	**Doubly constrained**	**Singly constrained**
$T_{ij}{}^{mt} = T_i{}^{mt} \frac{T_{ij}^{0\,mt} e^{-\lambda_{dest}\Delta C_{ij}{}^{mt}}}{\sum_k T_{ik}^{0\,mt} e^{-\lambda_{dest}\Delta C_{ik}{}^{mt}}}$ *k: numeration of all destinations* $\Delta C_{ij}{}^{mt} = \frac{1}{-\lambda_{sub}} ln \sum_s \frac{T_{ij}^{0\,mts}}{T_{ij}^{0\,mt}} e^{-\lambda_{sub}\Delta C_{ij}{}^{mts}}$ *s: numeration over all sub-modes* *must satisfy:* $0 < \frac{-\lambda_{dest}}{-\lambda_{sub}} \le 1$	$T_{ij}{}^{mt} = T_i{}^{mt} \frac{B_j T_{ij}^{0\,mt} e^{-\lambda_{dest}\Delta C_{ij}{}^{mt}}}{\sum_k B_k T_{ik}^{0\,mt} e^{-\lambda_{dest}\Delta C_{ik}{}^{mt}}}$ *Attractions **extracted from the reference case ("Do-Min") matrix** are normalized to the trip end total of the productions from the time of day choice stage above.* *k: numeration of all destinations* *B: attraction-based balancing factors, estimated iteratively in this destination choice stage by Emme* $\Delta C_{ij}{}^{mt} = \frac{1}{-\lambda_{sub}} ln \sum_s \frac{T_{ij}^{0\,mts}}{T_{ij}^{0\,mt}} e^{-\lambda_{sub}\Delta C_{ij}{}^{mts}}$ *s: numeration over all sub-modes* *must satisfy:* $0 < \frac{-\lambda_{dest}}{-\lambda_{sub}} \le 1$	$T_{ij}{}^{mt} = T_i{}^{mt} \frac{T_{ij}^{0\,mt} e^{-\lambda_{dest}\Delta C_{ij}{}^{mt}}}{\sum_k T_{ik}^{0\,mt} e^{-\lambda_{dest}\Delta C_{ik}{}^{mt}}}$ *k: numeration of all destinations* $\Delta C_{ij}{}^{mt} = \frac{1}{-\lambda_{sub}} ln \sum_s \frac{T_{ij}^{0\,mts}}{T_{ij}^{0\,mt}} e^{-\lambda_{sub}\Delta C_{ij}{}^{mts}}$ *s: numeration over all sub-modes* *must satisfy:* $0 < \frac{-\lambda_{dest}}{-\lambda_{sub}} \le 1$
Sub mode choice (m,t,j,s)		
Logit	**Logit**	**Logit**
$T_{ij}{}^{mts} = T_{ij}{}^{mt} \frac{T_{ij}^{0\,mts} e^{-\lambda_{sub}\Delta C_{ij}{}^{mts}}}{\sum_k T_{ij}^{0\,mtk} e^{-\lambda_{sub}\Delta C_{ij}{}^{mtk}}}$ *k: numeration of sub-modes* $\Delta C_{ij}{}^{mts} = C_{ij}{}^{mts} - C_{ij}^{B\,mts}$	$T_{ij}{}^{mts} = T_{ij}{}^{mt} \frac{T_{ij}^{0\,mts} e^{-\lambda_{sub}\Delta C_{ij}{}^{mts}}}{\sum_k T_{ij}^{0\,mtk} e^{-\lambda_{sub}\Delta C_{ij}{}^{mtk}}}$ *k: numeration of sub-modes* $\Delta C_{ij}{}^{mts} = C_{ij}{}^{mts} - C_{ij}^{B\,mts}$	$T_{ij}{}^{mts} = T_{ij}{}^{mt} \frac{T_{ij}^{0\,mts} e^{-\lambda_{sub}\Delta C_{ij}{}^{mts}}}{\sum_k T_{ij}^{0\,mtk} e^{-\lambda_{sub}\Delta C_{ij}{}^{mtk}}}$ *k: numeration of sub-modes* $\Delta C_{ij}{}^{mts} = C_{ij}{}^{mts} - C_{ij}^{B\,mts}$