

JLTP GBMF Modelling Support

G-BATS3 v2.3 Demand Model Development Report

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1. Introduction

BACKGROUND

- 1.1 This Demand Model Development Report has been prepared by Atkins Transport Planning under a commission to provide Consultancy Support for Transport Modelling for the four Unitary Authorities (UAs) in the West of England (WoE) sub-region: Bristol City Council (BCC), Bath and North East Somerset Council (B&NES), North Somerset Council (NSC) and South Gloucestershire Council (SGC).
- 1.2 A suite of models termed the Greater Bristol Modelling Framework (GBMF) has been developed covering the WoE's main urban areas. The model development phase has created new Variable Demand models, compliant with the latest Department for Transport (DfT) guidance (WebTAG) in order to assess a range of potential transport interventions in the sub-region. These potential interventions include demand management (and supporting complementary measures) and new public transport and highway schemes.
- 1.3 This report describes the development of the demand model element of the G-BATS3 model – the component of the GBMF that focuses on the main urban area of Bristol. The G-BATS3 modelling system consists of three key elements:
 - ◆ a highway model representing vehicle-based movements across the Greater Bristol Area for a typical 2006 morning peak hour (08:00 – 09:00), an average inter-peak hour (10:00 – 16:00) and an evening peak hour (17:00 – 18:00);
 - ◆ a public transport model representing bus and rail-based movements across the same area and time periods; and
 - ◆ a five-stage multi-modal incremental demand model that considers the impact on frequency choice, main mode choice, time period choice, destination choice, and sub mode choice in response to changes in generalised costs across the 24-hour period (07:00 – 07:00).
- 1.4 This demand model development report describes the overall modelling approach before discussing specific G-BATS3 v2.3 demand model and its validation in more detail. Further details of the G-BATS3 v2.3 Highway and Public Transport supply-side models may be found in their respective Local Model Validation Reports¹.
- 1.5 The G-BATS3 v2.3 demand model has been developed in close co-operation with the Department for Transport and their technical advice and support is acknowledged.

¹ JLTP G-BATS3 v2.3 Highway Local Model Validation Report (Atkins, March 2009) and JLTP G-BATS3 v2.3 Public Transport Local Model Validation Report (Atkins, March 2009).

CONTEXT

- 1.6 The Greater Bristol Modelling Framework (GBMF) encompasses three models namely:
 - ◆ **G-BATS3** - the Bristol Area Transport Studies model (as described here);
 - ◆ **G-BATH** - the Bath Highway Traffic Model (BHTM) and Bath Public Transport Model (BPTM); and
 - ◆ **G-NS** - the North Somerset Model.
- 1.7 Each of the three models, G-BATS3, G-BATH and G-NS, are free-standing models covering their respective areas of focus. The existing Greater Bristol Model (GBM), developed prior to the creation of GBMF, provides a more strategic (albeit historic) overview across all the modelled areas.
- 1.8 All three models have been developed to the same standard and functionality during their update to a 2006 base year and are fully compliant with the requirements for Variable Demand Modelling (TAG Unit 3.10), Modelling Public Transport Schemes (TAG Unit 3.11) and Modelling Road Pricing (TAG Unit 3.12). Further details may be found in the Inception Report (Atkins 2007²).
- 1.9 The overall structure of the models available under Greater Bristol Model Framework is shown below in Figure 1.1 and how they relate to the various models previously developed in the Greater Bristol area.

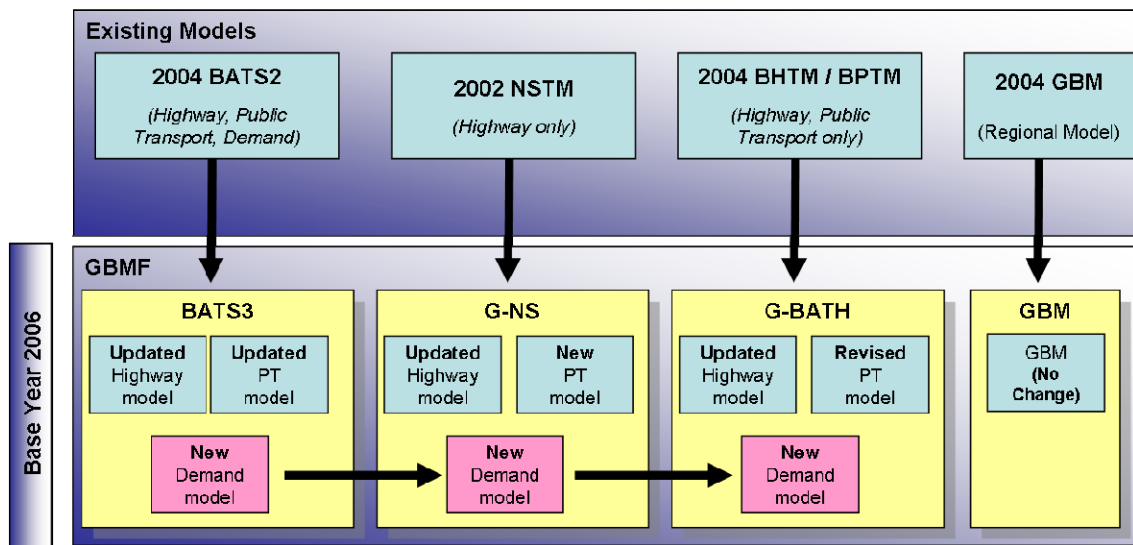


Figure 1.1 – Summary of Overall GBMF Model Evolution

² Joint Local Transport Plan - Consultancy Support for Transport Modelling: Inception Report (Atkins, February 2007)

KEY MODEL SPECIFICATION ISSUES

Modelling Software

- 1.10 A key feature of GBMF was the harmonisation of each of the local models to a consistent platform. The highway models have been upgraded to SATURN v10.8.17³ whilst the public transport and demand models use EMME/2 v9.2.

STRUCTURE OF REPORT

- 1.11 This draft MVR consists of five sections. Following this introductory section, Section two describes the structure of the G-BATS3 v2 demand model, its functional form and the sensitivity parameters adopted within each stage whilst Section three gives the details of the data collected and analysed for the G-BATS3 development. Section four provides the model convergence statistics and realism test results including the model elasticities. A summary of the model development is presented in Section Five.

MODEL VERSIONS

- 1.12 G-BATS2 Modelling System was developed in two stages. An interim version of the model – termed Version 1 (v1) - was created to support immediate modelling and appraisal needs while the full version of the model – termed Version 2 (v2) was developed. This report describes the development of the G-BATS3 v2.3 model with references made to the principal changes made from the interim v1 model.
- 1.13 Table 1.1 summarises the development history of the G-BATS3 v2 modelling system highlighting the differences in the various model components used.

Table 1.1 – Summary of Model Versions

Sub-Version	Sub-Model Components			Forecast Trip Ends ⁴
	Highway	Public Transport	Demand	
2.0	v2.0	v2.0	v2.0	TEMPRO-based
2.1				West of England Partnership / Draft RSS
2.2	Highway v2.2 Updated highway calibration / validation Migration to v10.8.17	PT v2.2 Updated to ensure consistency with v2.2 Highway Model	Demand v2.2 Recalibration of Demand Model Sensitivity Parameters	West of England Partnership / Draft RSS
2.3	Highway v2.3 No changes	PT v2.3 Updated PT model with latest RT Surveys	Demand v2.3 Re-calibration	West of England Partnership / Draft RSS

³ SATURN 10.8, User Manual by Dirck Van Vliet, Institute of Transport Studies (University of Leeds) and Ian Wright (Atkins), 2008. Website: www.saturnsoftware.co.uk

⁴ Greater Bristol Modelling Framework – Forecasting Report (Atkins, March 2009)

2. G-BATS3 Model System

INTRODUCTION

- 2.1 The G-BATS3 demand model was developed to evaluate a wide range of transport options that could be implemented in the West of England sub-region (aka Greater Bristol). This includes schemes such as road pricing and workplace parking as well as bus rapid transit, rail, park and ride, traffic management and road schemes.
- 2.2 The G-BATS3 v2.3 model represents travel choices across a typical 24-hour weekday period explicitly representing an AM peak period (07:00 – 10:00), an Inter-Peak period (10:00 – 16:00), a PM Peak period (16:00 – 19:00), and an off-Peak period (19:00 – 07:00). The model has a 2006 base year.
- 2.3 The G-BATS3 v2.3 is a variable demand model (VDM) in an incremental hierarchical form, pivoting off the base year, and estimating the choice between travel alternatives (frequency, modes, time periods, and destinations) depending on the change of generalised costs or disutility.
- 2.4 The G-BATS3 v2.3 uses a Production – Attraction (PA) formulation compliant to WebTAG guidance. A PA formulation with time period choice modelling was specifically developed for the G-BATS3 v2.3 demand model in consultation with the Department for Transport (DfT).
- 2.5 The G-BATS v2 model replaces the earlier interim V1 model. The principle differences between the G-BATS3 v1 and v2 models are that the G-BATS3 v1:
 - ◆ used the Origin-Destination (OD) formulation rather than PA-base;
 - ◆ represented a nine-hour period between 07:00-16:00 rather than the full 24-hour period;
 - ◆ used central Value of Times (VOT) for home-based other and non-home-based trips rather than VOT variation with trip lengths;
 - ◆ used sensitivity spreading parameters (lambdas) in the demand modelling structure throughout rather than the WebTAG tree structure parameters (lambdas in the lower levels and thetas in the higher levels);
 - ◆ used increased segmentation within the highway assignment with a significant detrimental impact on model runtimes; and
 - ◆ the demand model forecasted changes to external to external movements – in V2 these are treated as fixed.
- 2.6 All sub-model components for G-BATS have been developed to the common v2.3 standard as previously outlined in Table 1.1.

DfT Guidance

- 2.7 The design of the G-BATS3 v2.3 demand model closely follows the latest DfT WebTAG guidance (see below). The model development and refinement was supported by ongoing technical dialogue with Department through regular meetings, email correspondence, and telephone conversations.

2.8 The development of the demand model is fully in compliance with:

- ◆ TAG Unit 3.10 – Variable Demand Modelling (June 2006);
- ◆ TAG Unit 3.11 – Modelling of Public Transport Schemes (January 2006); and
- ◆ TAG Unit 3.12 – Design, Modelling and Appraisal of Road Pricing Schemes (February 2007).

The model was been developed in a modular fashion to enable subsequent adaptation in response to further updates.

2.9 The following paragraphs provide further details of the overall G-BATS3 model system and the inter-linkages with the demand model.

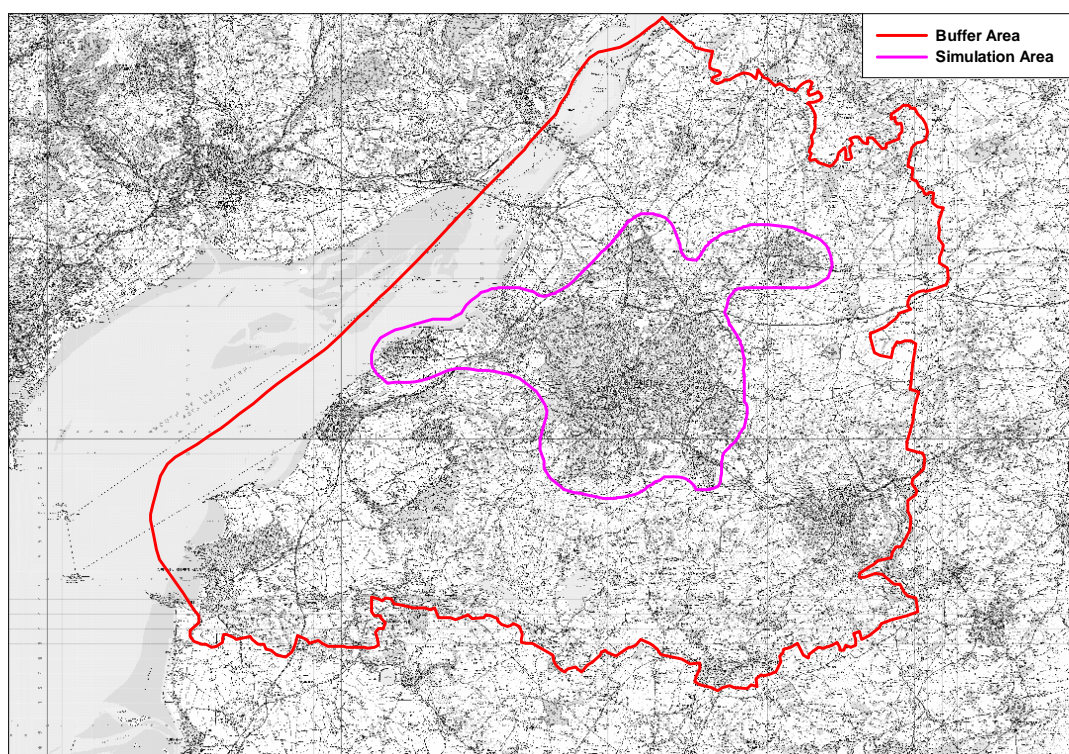
STUDY AREA & ZONING SYSTEMS

Study Area

2.10 The study area extends to cover the main urban areas of the WoE sub-region. The main focus of the BATS3 model is Bristol urban area. This area is bounded to the west by the M5, to the North by the M4 - with an extension along the A432 to Yate - to the east by the A4174 outer ring road - with an extension to include Keynsham and Cadbury Heath - and to the south by the edge of the Bristol City Boundary, running in an arc from the A4/A4174 junction to the A370 at Long Ashton

2.11 The study area of the G-BATS3 model is shown in Figure 2.1 below.

Figure 2.1 – G-BATS3 Study Area



Spatial Detail

2.12 WebTAG guidance emphasises that the size of zones in the highway assignment process is critical. They need to be sufficiently small to enable accurate routing to be predicted, yet sufficiently large to enable travel demand to and from the zone to be estimated with confidence. The same is true for the public transport assignments. Checks were undertaken on the zoning system and amendments made, where necessary, to provide appropriate levels of detail as noted below.

Zoning System

2.13 The G-BATS3 (2006) zoning system comprises of 600 zones in total covering the entire study area. A detailed zone system was developed to represent the Greater Bristol Urban area and its surroundings. The zone system includes four Park and Ride. Table 2.1 below summarises the number of zones within different geographical sub-areas of the study area whilst Table 2.2 shows a list of G-BATS3 Park and Ride zones.

Table 2.1 – Distribution of Zones across Study Area

Area	Zones
Bristol	274
North Somerset	62
B & NES	36
South Gloucestershire	162
Hinterland	34
Externals	12
Spare zones for Future	20
Total	600

Table 2.2 – G-BATS3 - Park & Ride Zones

Type	Description	Zone Number
Park & Ride	P&R A4 Portway (Avonmouth)	20190
Park & Ride	P&R Long Ashton	39390
Park & Ride	P&R Brislington	20890
Park & Ride	Bristol Parkway Rail Station P&R	42401

2.14 All three local models (ie G-BATS3, G-NS and G-BATH) use ward-based zoning systems to ensure compatibility with the various planning boundaries as well as the higher level GBM system.

2.15 Figure 2.2 shows the comparison between GBM and G-BATS3 zone system. Further information may be found in the corresponding Highway and PT LMVRs.

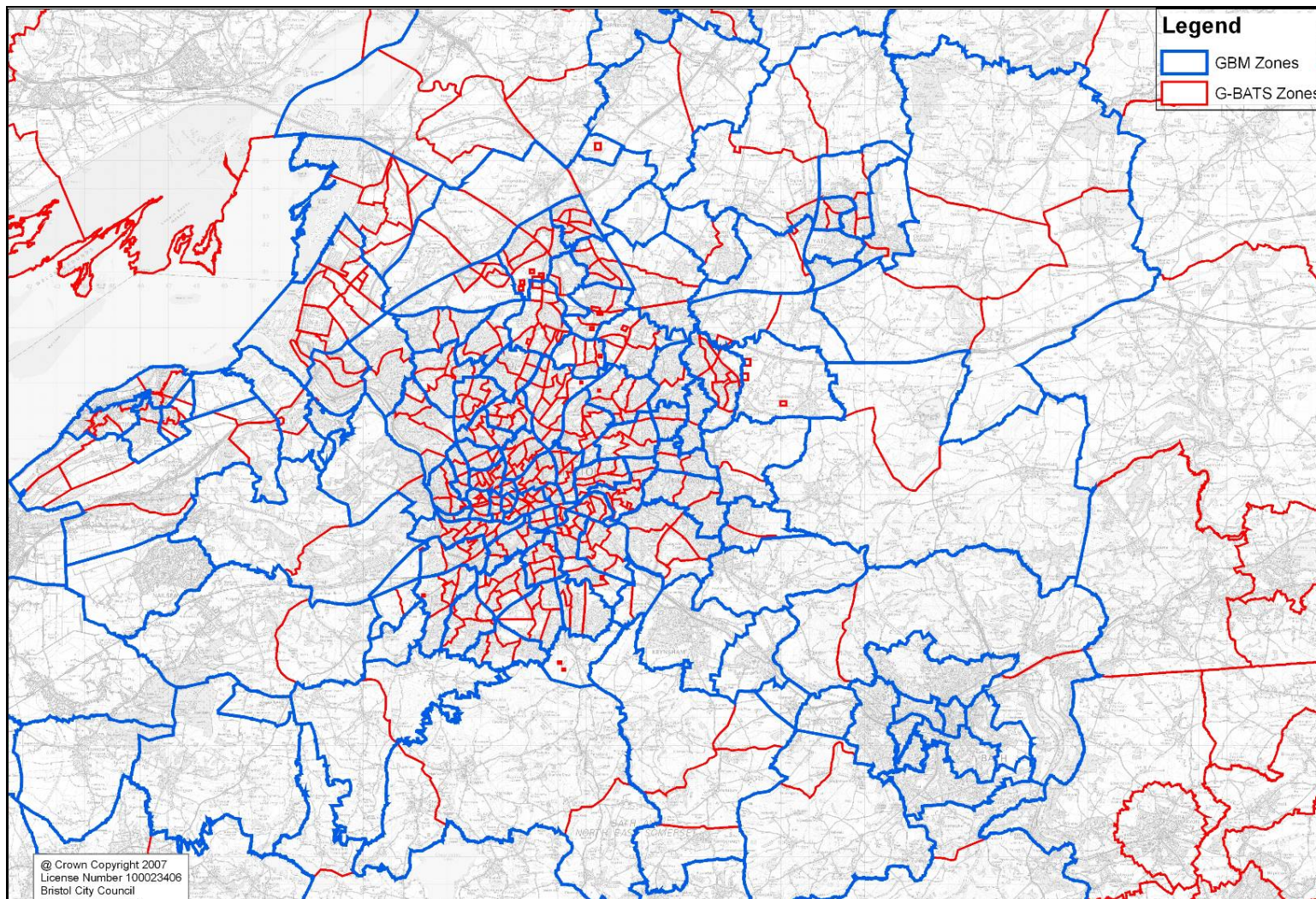


Figure 2.2 – GBM Zones and G-BATS3 Zones

ENHANCEMENTS TO THE EXISTING SUPPLY MODELS

Highway

- 2.16 The previous BATS2 highway model was validated to a 2004 base year. The BATS2 highway model has been updated to create the 2006 G-BATS3 v2.3 model using the following data:
- ◆ data on changes to the highway networks since 2004;
 - ◆ new demand data from RSI surveys conducted in 2006;
 - ◆ new traffic count data (2004-2006); and
 - ◆ new journey time data (2006-2007).
- 2.17 The G-BATS3 v2.3 model is compliant with the appropriate Design Manual for Roads and Bridges⁵ (DMRB) standards.

Public Transport

- 2.18 Similarly, the previous BATS2 public transport model was updated to create the G-BATS3 v2.2 public transport model. The principle changes comprised:
- ◆ the re-estimation of bus demand matrices using 2006 ticket data;
 - ◆ the re-estimation of rail demand matrices using 2006 ticket and survey data; and
 - ◆ reviewing and re-coding of all bus and rail services.

MODELLING SOFTWARE

- 2.19 This first phase of work has included the harmonisation of each of the local models to a consistent software platform. The highway models have been upgraded to SATURN v10.8.17⁶ whilst the public transport and demand models use EMME/2 v9.2.

TEMPORAL SCOPE

- 2.20 As already noted in paragraph 2.2, the G-BATS3 v2.3 is a 24-hour all-day demand model representing four time periods: the morning peak (AM), the Inter-peak (IP), the evening peak (PM) and the Off-Peak (OP) period, starting from 07:00 and concluding at 07:00 the following day.
- 2.21 The relationship between the various peak periods and peak hours within G-BATS3 v2.3 are defined as follows:
- ◆ AM peak period: 07:00 – 10:00;
 - ◆ AM peak hour (for assignment modelling only): 08:00 – 09:00;

⁵ Design Manual for Roads and Bridges (DMRB), Traffic Appraisals In Urban Areas, Volume 12a. Department of Transport, 1997.

⁶ SATURN 10.8, User Manual by Dirck Van Vliet, Institute of Transport Studies (University of Leeds) and Ian Wright (Atkins), 2008. Website: www.saturnsoftware.co.uk

- ◆ Inter-peak period: 10:00 – 16:00;
- ◆ Inter-peak hour (for assignment modelling only): 1/6th of 10:00 – 16:00;
- ◆ PM peak period: 16:00 – 19:00;
- ◆ PM peak hour (for assignment modelling only): 17:00 – 18:00; and
- ◆ Off Peak period: 19:00 – 07:00 (but without assignment).

Note that the AM and PM peak hours are not the average AM and PM peak periods.

- 2.22 The definition of the modelled time periods are based on TAG Unit 3.10.2 with macro time period choice (within the demand model) undertaken at the peak period level whilst a specific AM peak hour, inter-peak (IP) hour and PM peak hour are used in the assignment. The impact of peak spreading may be modelled within the peak periods if subsequently introduced.

SEGMENTATION

Within the Demand Model

- 2.23 TAG Unit 3.12.2 (para. 2.1.1. et al) provides guidance on the segmentation required for the modelling of road pricing. Accordingly, the G-BATS3 travel demands were segmented by car availability, journey purpose and household income as described below.

By person type

- ◆ car available (CA);
- ◆ non-car available (NCA)

By household income

- ◆ Income Low (IL): less than £17,500;
- ◆ Income Medium (IM): £17,500 to £35,000,
- ◆ Income High (IH): greater than £35,000.

By journey purpose

- home based work (HBW);
- home based other (HBO);
- non-home based other (NHBO);
- home based employer's business (HBEB); and
- non-home based employer's business (NHBEB).

Note the distinction made between home-based and non-home based purposes – this is required for adoption of PA-based modelling as each group requires a separate approach.

- 2.24 Table 2.3 cross-tabulates the segmentation undertaken within the demand model. Overall, there are 16 demand segments. Note that work trips (ie HBEB and NHBEB) and NCA trips are not segmented by income band in line with WebTAG.

2.25 Within the supply-side assignment models further aggregation of purposes was undertaken to reduce overall model runtimes as described below.

Table 2.3 - Demand model segmentation

Supply Purpose	Demand Purpose	Car Available (CA)			Non Car Available (CA)
		<£17,500	£17,500 to £35,000	> £35,000	
Commuting	HBW	8	9	10	15
Other	HBO	0	1	2	11
	NHBO	3	4	5	12
Work	HBEB	7			14
	NHBEB	6			13

Note: the numbers shown above refers to the segment ID used within the demand model.

Within the Highway Assignment

2.26 As noted above, the G-BATS3 supply model segmentation was undertaken in a more aggregated form than that adopted for the demand models to significantly reduce the model runtimes. Following discussions with DfT and its advisors, G-BATS3 v2.2 aggregates the five demand purposes into two supply-side purposes namely:

- ◆ Non Work (HBW+ HBO+NHBO); and
- ◆ Work (HBEB+NHBEB).

For completeness, G-BATS3 v1 aggregated the five demand purposes into three supply-side purposes with the common HB and NHB demand trips combined to form: (ie Commuting (HBW); (ii) Other (HBO+NHBO); and (iii) Work (HBEB+NHBEB).

2.27 The household income segmentation (ie *IL* below £17,500, *IM* £17,500 to £35,000 and *IH* above £35,000) applied to non work trips only. Work trips were combined together reflecting the allocation of costs of travel to their business.

2.28 Apart from cars, there are two further assignment segments for lights (LGV) and heavies (HGV). Altogether, there are six highway demand segments assigned in the SATURN model in the G-BATS3 v2.3 (there were nine segments in v1).

2.29 The six highway demand segments in the G-BATS3 v2.3 are:

- ◆ Car Non Work IL,
- ◆ Car Non Work IM,
- ◆ Car Non Work IH,
- ◆ Car Work,
- ◆ LGV; and
- ◆ HGV.

2.30 Note that the LGV and HGV segments are dealt with outside the demand model. As suggested by WebTAG, their demand assessment is undertaken using assumptions based on fixed exogenous growth.

Area Licensing Segmentation

- 2.31 G-BATS3 was also required to consider the impact of area-wide pricing mechanisms. TAG Unit 3.12.2 (para. 3.5.3) suggests that further segmentation between residents and non-residents may be required within both the demand and supply models.
- 2.32 A less complex approach was adopted to constrain the number of demand segments to manageable proportions following discussions with the Department. Area licensing was modelled as a combination of cordon pricing coupled with additional coding for the zonal connectors for all zones inside the cordon - all outbound (exiting) connectors in the SATURN network were coded with a toll equal to the proposed area licensing charge.

Cordon Based Charging

- 2.33 The modelling of cordon-based charging is straight-forward with the application of inbound (and/or outbound) link charges within the highway supply models.

Workplace Parking Charges

- 2.34 The outlined TIF package includes a number of parking control schemes such as those proposed for the workplace parking schemes in the North Fringe area.
- 2.35 WebTAG requires the parking modelling to be handled consistently between supply and demand models. In the G-BATS3 v2.3, workplace parking charges (if tested) are implemented by a highway network coding technique similar to the one used for the area licensing, ie the parking charge is hard-coded as tolls applied to relevant zonal connectors within SATURN networks. In this way any parking changes are incorporated into demand modelling via cost skims created after the highway assignments rather than through further segmentation.

Within the Public Transport Assignment

- 2.36 Within the EMME/2-based Public Transport assignment models, no distinction was necessary between journeys undertaken for different purposes, household income bands or car availability. Instead, the overall public transport demand was allocated (by logit-based choice mechanisms) to the various PT sub-modes, where available:
- ◆ Rail; and
 - ◆ Bus / BRT.

GENERALISED COST FORMULATION

Private Car

- 2.37 TAG Unit 3.10.2 (Para 1.10.8) defines the Generalised Cost for private car person and elements relating to:
- ◆ fuel cost;
 - ◆ in-vehicle time;

- ◆ parking costs;
- ◆ access/egress time; and
- ◆ tolls or other user charges.

2.38 The G-BATS3 follows the WebTAG formulae for the definition of generalised costs for cars: G_{car} , measured in units of time-minutes:

$$G_{car} = V_{wk} * A + T + D * VOC / (occ * VOT) + PC / (occ * VOT)$$

where:

- V_{wk} is the weight applied to walking time (assumed 0 currently);
- A is the total walk time to/from the car (minutes);
- T is the journey time spent in the car (minutes);
- D is the motorised journey length (kilometres);
- VOC is the vehicle operating cost (pence per km): including the fuel and non-fuel operating cost for work purpose but only the fuel operating cost for non-work purpose;
- occ is the occupancy (ie the number of people in the car) whom are assumed to share the cost;
- VOT is the appropriate Value of Time (pence per minute); and
- PC is the parking cost and tolls (if and when incurred), in monetary units (pence).

2.39 TAG Unit 3.5.6 provides guidance for estimating values of times and vehicle operating costs for general scheme appraisal and assessment whilst TAG Unit 3.12.2 Annex A provides guidance on segmentation and values of time for road pricing models. The evaluation of vehicle operating costs (VOC), values of time (VOT) and occupancy (occ) for G-BATS3 is undertaken by following the WebTAG guidance – further details may be found in Section 3.

Public Transport

2.40 TAG Unit 3.10.2 (Para 1.10.9) defines the Generalised Cost for public transport users and includes elements relating to:

- ◆ fares;
- ◆ in vehicle time;
- ◆ walking time to and from the service;
- ◆ waiting times;
- ◆ boarding penalties; and
- ◆ interchange penalty.

2.41 The WebTAG formula for PT generalist cost G_{PT} , measured in units of time (minutes) is given as:

$$G_{PT} = V_{wk} * A + V_{wt} * W + T + F/VOT + I + B$$

where:

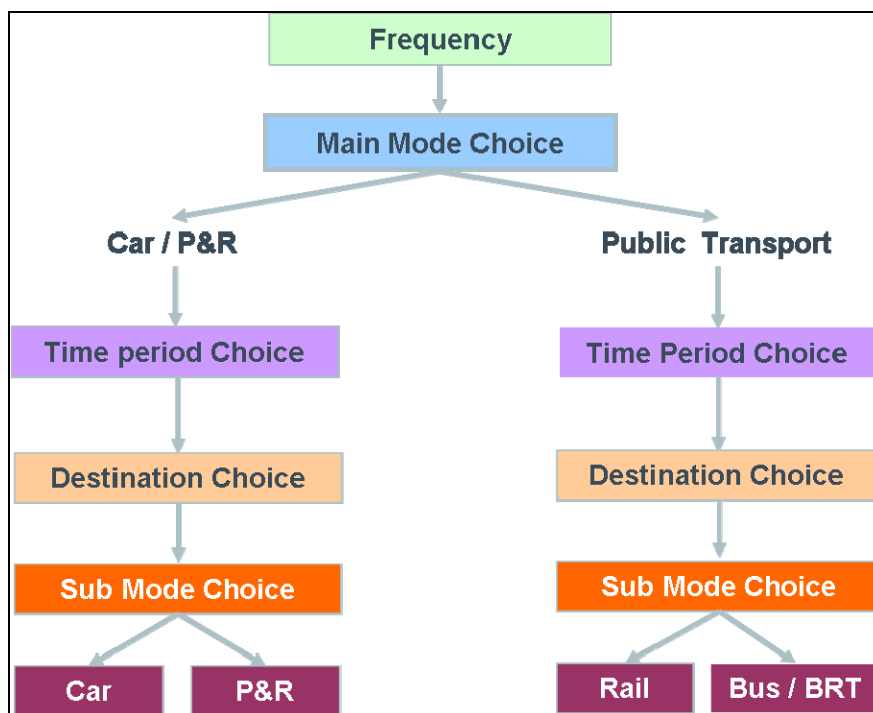
- V_{wk} (=2.45) is the weight applied to time spent walking;
- A is the total walking time to and from the service;
- V_{wt} (=2.5) is the weight applied to time spent waiting;
- W is the total waiting time for all services used on the journey;
- T is the total in-vehicle time;
- F is total fare;
- VOT is the appropriate Value of Time, in pence per minute;
- B is a boarding penalties (where applied); and
- I (=10 minutes) is the interchange penalty if the journey involves transferring from one service to another.

2.42 The above weights 2.45 and 2.5 are obtained through the base calibration / validation work for the walk and waiting times, respectively.

DEMAND MODEL STRUCTURE

2.43 The GBMF demand models have the same hierarchical logit choice structure as shown below in Figure 2.3. Compliant to WebTAG, an incremental demand modelling approach was adopted which responds to changes from the base generalised costs, measured in generalised minutes.

Figure 2.3 - Demand model choice structure



- 2.44 The sub mode choice between bus, BRT and LRT (if any) is undertaken by the public transport assignment, ie they are within the same segmentation within the demand model.
- 2.45 The P&R sub mode is a highway sub mode which means that P&R generally extracts more patronage from cars. The P&R extraction from bus-all-the-way is modelled implicitly by the main mode choice, up and down the demand model hierarchical tree via the destination choice and the time period choice as shown in Figure 2.3.
- 2.46 An overview of the model stages, functional forms (eg OD/PA and Car-Available / Non-Car Available) and time periods is listed below in Table 2.4 for each of the six stages for G-BATS3 v2.2 demand modelling. Note that: (i) Stages 1 to 5 are undertaken within the demand model whilst Stage 6 is provided through the separate highway and public transport supply-side models; and (ii) the PT sub-mode is undertaken within the demand model.

Table 2.4 – G-BATS3 v2.2 Demand Model Overview

Stage	Model	Temporal Scope	Form	Person Type
1	Frequency Modelling	24-hour	PA Tripends	All (CA & NCA)
2	Main Mode Choice	24-hour	PA Tripends	CA
3	Time Period Choice	Translate 24-hour to AM (3hr), IP (6hr), PM (3hr) and OP (12hr) periods	PA Tripends	CA & NCA
4	Destination Choice	3hr (AM), 6hr (IP), PM (3hr) and OP (12hr)	Translate PA Tripends to PA matrices	All (CA & NCA)
5	Sub Mode Choice	3hr (AM), 6hr (IP), PM (3hr) and OP (12hr)	PA matrices	All (CA & NCA)
6	Assignment	1-hour	OD matrices	All (CA & NCA)

- 2.47 The frequency modelling (Stage 1) is undertaken for HBO and NHBO trips only as suggested by WebTAG. The main mode choice (Stage 2) between car and PT operates for Car Available (CA) person type only. The demand model operates at the 24-hour level until the time of day choice (Stage 3) is undertaken. For destination choice modelling (Stage 4), the demand model considers all four time periods AM/IP/PM/OP for all person types in parallel. The resulting PA matrices are converted into OD matrices after the sub mode choice (Stage 5) and before the individual highway and PT assignments (Stage 6) are undertaken.

MODEL FORMULATION

Incremental Logit-based

- 2.48 The choice modelling on various demand responses follows an incremental approach as required by WebTAG, pivoted off from the base year situation. The logit-based formulation is described below for each of the five demand modelling stages. That

said, the various parameter values have been re-estimated following advice from the DfT in conjunction with further model development work. The parameter values described below all relate to the version 2.3 model.

- 2.49 The G-BATS3 v2.3 demand model is implemented in terms of utilities and composite utilities consistent to the WebTAG hierarchical logit (HL) formulation, different from the ones used in previous versions where disutilities (or generalised costs) were used. The formulas given below are specified in terms of the WebTAG HL tree structure, ie using lambda parameters for the lower level sub-mode choice and destination choice but using theta parameters⁷ for the upper level time period choice, main mode choice and the top frequency modelling.
- 2.50 The logsum composite cost enables an average weighted cost to be calculated across the lower level choices made within the logit choice model. In operation, the logsum composite costs at a particular level are estimated by collapsing (ie aggregating) the lower level choices and the associated costs. This process enables either costs to be combined for use in higher levels in the tree-structure or splitting the resulting demand for use in the lower levels.
- 2.51 It is also noted that the same sensitivity parameters are used for person types within the various household income segments. This applies to all parameter values given below for destination choices and mode/time period choices.

Frequency Modelling

- 2.52 G-BATS3 v2.3 does not explicitly model slow modes and WebTAG suggests that some form of frequency modelling should be undertaken within the demand model. WebTAG does not provide illustrative parameters for frequency other than noting its position within the demand model structure. The guidance suggests that the lambda values for the frequency parameters should be set during the realism tests and adjusted, through an iterative process, in order to achieve the target elasticities. This iterative process was undertaken during the development of the model.
- 2.53 The formula for the frequency modelling is as follows:

$$T_{ipc} = T_{ipc}^0 e^{\theta_{freq} \Delta U_{ipc}}$$

where:

- i = production end; p: purpose; c: person type
- T_{ipc}^0 : reference zonal production over *i.p.c*;
- T_{ipc} : output zonal production over *i.p.c*;
- θ_{freq} : frequency choice structure parameter; and
- $\Delta U_{ipc} = \ln(\sum_m T_{ipcm}^0 e^{\theta_m \Delta U_{ipcm}} / T_{ipc}^0)$: logsum of lower level main mode choice.

⁷ Theta is the ratio of the upper level and lower level lambda parameters.

2.54 WebTAG recommends that frequency modelling is undertaken for HBO and NHBO purposes only. The frequency modelling structure parameter is 0.05 for both of the two purposes and both of the person types CA and NCA, derived from the realism testing.

Main Mode Choice

2.55 WebTAG (Unit 3.10.2, para. 1.7.12) suggests that the main mode choice between cars and public transport for car available travellers should be placed just below the frequency modelling in the choice hierarchy, whilst the time period choice should be placed after the mode choice.

2.56 The formula for the main mode choice is as follows:

$$T_{ipcm} = T_{ipc} \frac{T_{ipcm}^0 e^{\theta_m \Delta U_{ipcm}}}{\sum_k T_{ipck}^0 e^{\theta_m \Delta U_{ipck}}}$$

where:

- i = production end; p : purpose; c : person type; m : main mode (car or PT);
- T_{ipcm}^0 : reference zonal production tripends over $i.p.c.m$;
- θ_m : main mode choice tree structure parameter
- T_{ipc} : input zonal production tripends over $i.p.c$ from the above frequency stage;
- $\Delta U_{ipcm} = \ln(\sum_t T_{ipcm}^0 e^{\theta_t \Delta U_{ipcm}^t} / T_{ipcm}^0)$: logsum of lower level time period choice.

2.57 The main mode choice tree structure parameters for the G-BATS v2⁸ are given below in Table 2.5 – they are exactly the median WebTAG thetas shown in Unit 3.10.3. Realism test results presented in Section 4 show that these parameters lead to satisfactory elasticities, after the Value of Time (VOT) variation with distance has been introduced for non-work trips (see the following para 2.78 – 2.84 for details).

Table 2.5 - Main Mode / Time Period Choice Parameters

Purpose	WebTAG Theta (Median)	G-BATS3 v2.2 Theta
HBO	0.53	0.53
NHBO	0.81	0.81
NHBEB	0.73	0.73
HBEB	0.45	0.45
HBW	0.68	0.68

⁸ Parameters are defined as implemented in v2.3 of the model

2.58 The use of the same parameter for main mode and time period choice implies that the choices are undertaken simultaneously. Note that the same theta parameters were used for both Car Available (CA) and Non-Car Available (NCA) person types as recommended by WebTAG, reflecting the limited volume of robust local data available.

Macro Time Period Choice

2.59 WebTAG (Unit 3.10.2, para. 1.7.13) suggested that macro time period choice parameter values should be similar in magnitude to main mode choice parameter values. The sensitivity parameters used for the macro time period choice were set to the same value as used in main mode choice – in mathematical terms, they are modelled simultaneously in a multinomial form.

2.60 The formula for the time period choice between the four periods (ie AM, IP, PM and OP period) is as follows:

$$T_{ipcm} = T_{ipcm} \frac{T_{ipcm}^0 e^{\theta_t \Delta U_{ipcm}}}{\sum_k T_{ipcmk}^0 e^{\theta_t \Delta U_{ipcmk}}}$$

where

- t: time period;
- T_{ipcm}^0 : reference zonal production tripends over *i.p.c.m.t*;
- T_{ipcm} : input zonal production tripends over *i.p.c.m* from the above mode choice stage;
- θ_t : time period choice tree structure parameter;
- $\Delta U_{ipcm} = \ln(\sum_j T_{ijpcmt}^0 e^{\lambda_{dist} \Delta U_{ijpcmt}} / T_{ipcm}^0)$: logsum of lower level, singly constrained destination choice for HBO, NHBO, NHBEB, and HBEB purposes; and
- $\Delta U_{ipcm} = \ln(\sum_j B_{jp} T_{ijpcmt}^0 e^{\lambda_{dist} \Delta U_{ijpcmt}} / T_{ipcm}^0)$: logsum of lower level, doubly constrained destination choice for HBW purpose only.

2.61 However, the estimation of the logsum ΔU_{ipcm} for the doubly constrained distribution was not as straightforward - further details are provided below.

Destination Choice

2.62 WebTAG (Unit 3.10.2, para, 1.7.11) recommended that the destination choice should be modelled as singly (origin) constrained distribution for trips with HBO, NHBO, NHBEB or HBEB purposes. In contrast, WebTAG recommended that the destination choice for HBW needed to be modelled as doubly (ie origin-and-destination) constrained distribution. To meet this requirement, a rectangular furnishing procedure was developed to undertake the HBW distribution modelling.

2.63 The formula for the singly constrained destination choice was:

$$T_{ijpcmt} = T_{ipcmt} \frac{T_{ijpcmt}^0 e^{\lambda_{dist} \Delta U_{ijpcmt}}}{\sum_k T_{ikpcmt}^0 e^{\lambda_{dist} \Delta U_{ikpcmt}}}$$

where

- j = attraction end;
- T_{ijpcmt}^0 : reference PA matrix over p, c, m, t ,
- T_{ipcmt} : input zonal production tripends over i, p, c, m, t from the above time period choice;
- λ_{dist} : destination choice sensitivity parameter;
- T_{ijpcmt} : output PA matrix over p, c, m, t , and
- $\Delta U_{ijpcmt} = \ln(\sum_s T_{ijpcmts}^0 e^{\lambda_{sub} \Delta U_{ijpcmts}} / T_{ijpcmt}^0)$: logsum of lower level sub-mode choice.

2.64 All distribution models, irrespective of whether they are singly or doubly constrained, satisfied the following row constraints:

$$T_{ipcmt} = \sum_j T_{ijpcmt}.$$

2.65 For doubly constrained distribution, another set of column constraints was also introduced:

$$\sum_{imtc} T_{ijpcmt} = \sum_{imtc} T_{ijpcmt}^0.$$

2.66 The rectangular furnishing procedure adopted guarantees that the above two sets of constraints are always satisfied. In other words, each zone attracts a fixed amount of (total) trips for each person type within a purpose.

2.67 The formula for the doubly constrained distribution was

$$T_{ijpcmt} = T_{ipcmt} \frac{B_{jp} T_{ijpcmt}^0 e^{\lambda_{dist} \Delta U_{ijpcmt}}}{\sum_k B_{kp} T_{ikpcmt}^0 e^{\lambda_{dist} \Delta U_{ikpcmt}}}$$

where

- j = attraction end;
- T_{ijpcmt}^0 : reference PA matrix over p, c, m, t ,
- T_{ipcmt} : input zonal production tripends over i, p, c, m, t ,
- λ_{dist} : destination choice sensitivity parameter;

- B_{jp} : attraction balance factors for purpose p and destination j , estimated via the rectangular Furnessing procedure;
- T_{ijpcmt} : output PA matrix over $p.c.m.t$;
- $\Delta U_{ijpcmt} = \ln(\sum_s T_{ijpcmts}^0 e^{\lambda_{sub} \Delta U_{ijpcmts}} / T_{ijpcmt}^0)$: logsum of sub mode choice

2.68 Note that the attraction balance factors were estimated via inner loops between this distribution stage and the above time period choice and main mode choice. This was necessary because that trip-ends from the above two stages were a function of the logsum (or B_{jp}) of this doubly constrained stage, which in turn, was a function of the Furnessing procedure for B_{jp} , dependent on the resulting forecasted trip-ends from the above two stages.

2.69 The initial values for the inner loops were:

$$T_{ijpcmt} = \sum_j T_{ijpcmt}^0, \alpha_{ijpcmt} = 1, \text{ and } B_{jp} = 1.$$

Within the inner loops, before the logsum is evaluated, the attraction balance factors were normalised such that $\sum_j B_{jp} = N$, where N = number of zones with non-zero attractions.

2.70 The destination choice sensitivity parameter values are presented below, derived from the realism tests described in section 4. As shown below in Table 2.6, the v2.3 model uses the median WebTAG illustrative lambdas specified in Unit 3.10.3 for the distribution modelling, with the only exception of the highway HBW demand segment whose lambda is slightly above the media value. Again, the same lambdas are used for both CA and NCA PT users inside the demand model.

Table 2.6 - Destination Choice Sensitivity Parameters

Purpose	WebTAG		G-BATS V2 ⁹	
	Highway (Median/Maximum)	PT (Median)	Highway	PT (CA / NCA)
HBO	-0.090 / -0.160	-0.036	-0.090	-0.036
NHBO	-0.077 / -0.105	-0.033	-0.077	-0.033
NHBEB	-0.081 / -0.107	-0.042	-0.081	-0.042
HBEB	-0.067 / -0.106	-0.036	-0.067	-0.036
HBW	-0.065 / -0.113	-0.033	-0.085	-0.033

⁹ Parameters are defined as implemented in V2 of the model

Sub-Mode Choice

- 2.71 After destination choice, the sub-mode choices were undertaken for highway and public transport users independently.
- 2.72 Park and Ride (P&R) users appeared in the single nest of sub mode choices (as previously shown in Figure 2.3), to facilitate the sub-mode switching in forecast years between highway and P&R only.
- 2.73 WebTAG does not provide explicit values to be used for the sub-mode choice. The earlier GBM model used a value of -0.1 – derived from previous analytical work - and this value was retained for the G-BATS3 demand modelling.
- 2.74 The formula for the sub mode choice in the G-BATS3 demand model was:

$$T_{ijpcmts} = T_{ijpcmt} \frac{T_{ijpcmts}^0 e^{\lambda_{sub} \Delta U_{ijpcmts}}}{\sum_s T_{ijpcmts}^0 e^{\lambda_{sub} \Delta U_{ijpcmts}}}$$

where

- s: sub-mode such as rail, bus, BRT, P&R;
 - $T_{ijpcmts}^0$: reference PA matrix over p,c,m,t;
 - T_{ijpcmt} : input PA matrix over p,c,m,t from the above destination choice;
 - λ_{sub} : sub-mode choice sensitivity parameter (= -0.1);
 - $T_{ijpcmts}$: output PA matrix over p.c.m.t.s;
 - $\Delta U_{ijpcmts} = \lambda_{sub} (C_{ijpcmts} - C_{ijpcmts}^0)$: the change of utilities over the base year at the lowest level of the hierarchy.
- 2.75 Note that the bottom level $\Delta U_{ijpcmts}$ were subject to damping factoring to overcome the oversensitivity for long distance trips. This arose because the elasticity of logit formulation scales with the utility - longer distance trips exhibited larger cost differences.
 - 2.76 The cost dampening function was applied to the change of generalised costs for all the demand segments operating at this lowest level of the hierarchy,. The form of the damping function adopted was in inverse proportion to the square root of zonal distances:

$$CostChangeDampingFactor = 0 < \frac{\sqrt{30}}{\sqrt{distance}} < 1$$

Value of Time (VOT) Variation with Distance

- 2.77 In previous versions of the G-BATS3 demand model before v2.2, unrealistically larger elasticities were derived for long distance trips given the inherent nature of

logit formulation. VOT variation with distance for non-work trips has been introduced to enable the model to replicate recommended WebTAG elasticities.

- 2.78 When the information is available on the distribution of income and distance of trips in a study area, para 11.4.2 in TAG Unit 3.12.2 gives a formula to estimate local VOTs for road pricing modelling. However, the average household income information is not available for the development of the G-BATS3 demand model.
- 2.79 Following discussion with the Department for Transport and its advisor, an alternative version of the WebTAG formula is applied without the local income data requirement. The expression for the VOT variation by distance for non-work trips is:

$$VOT = \max \left(VOT_C \left[\frac{D}{D_0} \right]^{\eta_s}, VOT_C \left[\frac{D_C}{D_0} \right]^{\eta_s} \right)$$

where:

- VOT : value of time used in G-BATS3 v2.2 for non-work trips;
- VOT_C : central value of time given in Table 3.3 of Section 3 for non-work trips
- D: length of trip (see the following paragraph); and
- D_0 , D_C , and η_s : parameters.

- 2.80 Evaluation of the above formula¹⁰ gives rise to a matrix of VOTs by distance for non-work trips. The trip length D actually represents a matrix of uncongested distance between zone pairs, skimmed from the base year inter-peak highway network after assignment.
- 2.81 The distance elasticity parameter (η_s) is given in para 11.4.4 of TAG Unit 3.12.2: 0.314 for HBO/NHBO trips and 0.421 for commuting trips, together with the distance parameter D_0 as 7.58 miles (12.2 kilometres). The reason to use D_C (=4km) is to deal with intra-zonal or short distance trips as the G-BATS3 demand model contains a large number of intra-zonal trips with estimated distances generally very short (<4km, approximately).
- 2.82 Table 2.7 below presents a summary of the VOTs used for the G-BATS3 v2.3 demand model, where the VOT variation by distance is represented by the matrix average, minimum and maximum.

¹⁰ Note: $\text{Max}(x,y)$ is the maximum value of x and y

Table 2.7 - VOT Variation with Distance

Purpose	Car Available (HBO/NHBO)			Non Car Available	
	Income Low	Income median	Income High	HBW	HBO/NHBO
Central Value	7.08	9.14	10.98	6.66	5.49
Matrix Average	8.40	10.84	13.02	8.57	6.51
Matrix Minimum	4.99	6.44	7.74	4.16	3.87
Matrix maximum	26.80	34.60	51.57	39.69	20.78

Units: pence / minute

2.83 It is noted that the VOT variation by distance has been applied to all non-work purposes for non-car available users, but only to the HBO and NHBO demand segments for car available users. Initially, the CA HBW demand segment was also applied but the outturn elasticities appeared too low in realism tests. After discussions with the Department, the central VOT values were assumed to be the same as for the CA HBW demands.

MODELLING PARK AND RIDE

Overall Approach

2.84 Modelling park and ride (P&R, a highway sub mode) raises a number of issues as it requires linking highway and public transport elements of the model. This section sets out the modelling methodologies implemented in the G-BATS3 demand model.

2.85 There are four key stages in the v2 P&R modelling approach:

- ◆ Derivation of park and ride generalised costs;
- ◆ Estimation of park and ride demand in the demand model;
- ◆ Site allocation of park and ride demand to competing sites; and
- ◆ Assignment of highway and PT legs of park and ride trips to the networks.

Deriving Park and Ride Generalised Costs

2.86 The highway and PT network models are used to define the generalised cost for a park and ride journey between zone to zone pairs.

2.87 P&R sites are defined in the model as individual zones. In the base case there are four existing bus (or rail) P&R zones as listed below:

- ◆ A4 Portway (Avonmouth): bus P&R site;
- ◆ Brislington: bus P&R site;
- ◆ Long Ashton: bus P&R site; and
- ◆ Bristol Parkway: bus / rail P&R site.

-
- 2.88 A number of P&R zones are reserved for potential future applications -- it is possible to define different park and ride sites for those identified as “proposed” providing the new zone is appropriately located in the highway and PT networks.
 - 2.89 The highway network model (SATURN) is used to determine travel times and costs from production zones to each park and ride zone. The PT network model (EMME/2) is used to determine travel times and costs from the park and ride zones to each attraction zone.
 - 2.90 A park and ride generalised cost for a given production to attraction zone movement is determined by taking the minimum combination of highway plus PT costs – also taking into account a parking charge, PT fare and site specific constant.
 - 2.91 In model application only those sites considered active are used in the process (ie even though additional zones are defined for possible sites – they are only used if a site is assumed in place in a given forecast model run).
 - 2.92 It is noted that this process is undertaken to derive park and ride generalised costs for all demand segments (purpose and income groups) and modelled time periods.
 - 2.93 Park and ride site choice is not restricted at this level by the definition of site catchment areas – though this is done at a subsequent stage of processing (see below). This means that all production zones that can access to a P&R site are assumed to have a choice of every park and ride site in determining the minimum generalised cost combination of highway and PT. However, some restrictions¹¹ on the movements for which park and ride is a valid movement are applied to avoid illogical movements (eg travellers driving outbound from the city centre to access a park and ride site on the edge of the urban area).

Application in the Demand Model

- 2.94 The park and ride generalised costs derived as described above – for the lowest generalised cost highway + park and ride combination - are used in the demand model. The demand model conforms to WebTAG standards.
- 2.95 As previously shown in Figure 2.3, the demand model has a hierarchical structure. Park and ride appears in the bottom of the car nest of the main mode choice – and is not treated as a PT sub-mode. Earlier versions of the model attempted to include park and ride in the car and PT nests – but in discussion with DfT this was changed. Car access to rail stations is included in the representation of rail and – with the single exception of Bristol Parkway - is not explicitly modelled as park and ride in the same way as bus-based park and ride. Because of the special characteristics of Bristol Parkway the rail-based park and ride mode using this station is modelled explicitly, though bus-based options are also assumed available. It is noted that the other three existing sites in G-BATS3 v2.3 are modelled as bus-based park and ride.

¹¹ In other words, a decision is taken for each model zone to determine whether it may use P&R services or not in order to prevent illogical movements occurring. For the zones that are permitted to use P&R services, each zone is allocated either to a particular park & ride site or sets of park & ride sites within the P&R choice sub-module. The demand from the zone cannot use any other P&R site(s) outside this allocation. The restrictions are specified in the P&R catchment ensembles.

2.96 The demand model structure passes composite costs up from the lower levels of the next to higher levels – thereby park and ride generalised costs influence destination choice, time period choice and main mode choice described in the above.

Park and Ride Site Allocation

2.97 Outside the main demand model an independent park and ride site choice module is implemented. As described above the main demand model works using the generalised cost estimated for the least cost park and ride site. However, some overlap of site catchment areas occurs now and can be expected to occur with new site locations. The allocation model therefore takes the park and ride demand from the main demand model and examines the generalised cost of travel to different potential sites for every production-attraction pair. This model is especially important when a number of sites are close alternatives.

2.98 The distribution of park and ride between competing sites is modelled by using a logit-based function depending on the average generalised cost between the zones in each catchment area to the available sites and between these sites to the central business district (CBD):

$$D_{prq} = D_{pq}^c \frac{e^{-\theta_1 C_{pr}^{car} - \theta_2 w_r - \theta_3 C_{rq}^{PT}}}{\sum_k e^{-\theta_1 C_{pk}^{car} - \theta_2 w_k - \theta_3 C_{kq}^{PT}}}$$

where:

- r = Park & Ride site under consideration;
- k = all Park & Ride sites
- $\theta_1 = 0.02$, $\theta_2 = 0.02$, and $\theta_3 = 0.01$;
- D_{pkq} : P&R trips from p to q using site r ;
- D_{pq}^c : input aggregated P&R matrix from the above highway and PT sub mode choice;
- C_{pr}^{car} : average generalised car costs from origin p to site r ;
- C_{rq}^{PT} : average generalised PT costs from site r to final destination q
- w_r : the total cost of parking at site r including site penalties (currently assumed to equate to a cost of six generalised minutes), bus fare and site specific constants).

2.99 It is noted that this model is applied as an absolute model – whereas the main demand model is incremental. The site choice mechanism is implemented by using the EMME/2 matrix convolution methodology. The actual demand using a particular site is calculated based on the average generalised costs of the car leg (C_{pr}^{car}) and PT leg (C_{rq}^{PT}), and parking charges and penalties (w_r) at the sites as given in the above

formula. The average costs used in modelling were the average generalised costs across all segmentation, ie site choices are done at aggregate level.

- 2.100 In running the allocation model the choice set of available park and ride sites for given production zones is restricted using catchment areas. This is to ensure the allocation process is realistic and because of the attributes of multinomial models when they exist a number of close alternatives (the so-called red bus-blue bus problem) which can give rise to illogical results. Currently, the catchment areas set-up for the sites for which zones are reserved in the model. Catchment areas can be refined particularly if new sites are to be considered.

Assignment of Highway and PT networks

- 2.101 The subsequent output from the site choice module consists of separate car-leg highway matrices and PT-leg bus matrices. These car-leg and bus-leg demands were person PA trips which were then added into the relevant car and PT PA matrices, before converting to highway vehicle OD trips and bus person OD trips for assignment. The PA to OD factors were derived from the 2006 RSI data for each of the appropriate demand on model segments (ie income, purpose and period).

INTRODUCING PA-BASED TIME PERIOD CHOICE

- 2.102 The introduction of PA-based modelling with the explicit consideration of time period choice is complex, particularly when (as shown in Figure 2.3), time period choice is undertaken after main mode choice but before destination choice. The key technical challenge, with the demand model, was how the demand and costs arising from the return leg of home-based trip may be estimated when the timing of the return leg is dependent on the outward journey. In other words, if an outward home-based trip retimed from the morning peak period to the corresponding inter-peak period in response to the introduction of a morning peak road pricing, when would the corresponding return leg be undertaken?
- 2.103 Within the demand model, the key issue was to determine the appropriate travel demand and associated costs of return-legs of home based trips in a coherent and consistent manner given that the return-leg journeys were constrained by the nature of their outward journeys. Whilst WebTAG recommends that this functional form should be adopted, it does not provide any guidance on how it may be implemented.
- 2.104 For this study, a new PA-based formulation with time period choice was proposed and a Technical Note submitted to DfT for approval. The fundamental assumption underpinning the approach was the use of fixed return proportions whereby *for outward trips leaving home within each time period, the proportions of trips returning in subsequently time periods remain fixed by purpose over the base year and future forecast years*. In other words, if AM tolls were applied and certain trips shifted to the IP period (for example), the return leg of these transferred outward trips would have the same return patterns as those already established in the base inter-peak period.
- 2.105 Accordingly, for the PA formulation, only the outward from-home trips in each time period are explicit variables within the demand model. The return-leg demands were calculated from the initial outward-leg demands factored by the associated return

proportions. The return proportions were derived from information supplied by DfT and further details are provided in Section 3.

2.106 Following peer review, the Department accepted the methodology for use in GBMF to enable the adoption of PA-based modelling with time period choice.

2.107 The following paragraphs describe the innovative fixed-return proportion method for modelling PA-based time period choice. The two key assumptions underpinning the formulation were that:

- ◆ the return proportions are fixed in forecasting mode;
- ◆ the time of a day choice starts with the AM Peak period and that trips departing over the course of the day will all return before the commencement of the following AM Peak period the next day. In other words, for each outbound from-home trip, there would be an equivalent trip returning home during the day and the sum of outward journeys equals to the sum of return journeys.

Details of the PA Formulation

Time Period Specification

2.108 We denote the modelled time period as (t), outward from-home time period as (s), and return to-home time period as (r), respectively.

2.109 The four time periods (t) in a 24-hour day in G-BATS3 v2.2 are:

- ◆ t=am: 07:00 – 10:00;
- ◆ t=ip: 10:00 – 16:00;
- ◆ t=pm: 16:00 – 19:00; and
- ◆ t=op: 19:00 – 07:00;

2.110 For a given time period t, the outward from-home time period (s) is the same as t:

- ◆ $s = t$ for $t \in \{\text{am}, \text{ip}, \text{pm}, \text{op}\}$.

2.111 For each time period t (or s), there are multiple corresponding return time periods (r) as defined below:

- ◆ $r \in \{\text{am}, \text{ip}, \text{pm}, \text{op}\}$, if $t = \text{am}$;
- ◆ $r \in \{\text{ip}, \text{pm}, \text{op}\}$, if $t = \text{ip}$;
- ◆ $r \in \{\text{pm}, \text{op}\}$, if $t = \text{pm}$; and
- ◆ $r \in \{\text{op}\}$ if $t = \text{op}$.

2.112 The above relationship is illustrated below in Table 2.8 where symbol \surd indicates available returning time periods for each outward time period:

Table 2.8 - Returning Time Period Specification

		Return To-Home time period (r)			
		AM	IP	PM	OP
Outward From-Home Period (s)	AM	√	√	√	√
	IP		√	√	√
	PM			√	√
	OP				√

Demand Model Variable Notations

- 2.113 We use “p.c.m” or “pcm” to represent segmentation used in the G-BATS3 v2.2 with combination of purpose (p), person type (c) (household income band and CA/NCA), and mode (m). This is consistent to the formula presented in the early part of this section for Incremental Hierarchical Logit (IHL) formulation.
- 2.114 Table 2.9 below provides the notations of variables used for the PA specification (which is arranged according to the appearance of variables in the following text).

Table 2.9 - Notation Used in PA Formulation

Notation	Description	Source Data
$Pout_{Ijpcmt}^0$	Given time period t, reference outward from-home trip proportion by p.c.m for origin sector I and destination sector J. These factors are used only once in creating base PA trips.	RSI data
$Pr et_{pcmsr}^0$	Given time period s, fixed to-home proportion for trips returned in time period r by p.c.m. These factors are only segmented by p.c.m – not enough data is available to populate all ij pairs in a matrix from. (Not sure at this stage if sector based factors are achievable).	RSI data and NTS data
$T_{Ijpcms}^{(RSI)}$	The total of from-home trips from 2006 RSI by p.c.m in time period s from origin sector I to destination sector J (directional from-home).	RSI data
$T_{Ijpcmt}^{(RSI)}$	The total of from-home and to-home trips from RSI by p.c.m in time period t from origin sector i to destination sector j (non directional).	RSI data
$T_{ijpcmt}^{(OD)0}$	Reference OD assignment matrices from origin i to destination j in time period t by p.c.m (non directional).	Calibrated/validated base assignment matrices
$T_{ijpcms}^{(OD)0}$	Reference outward OD trips from origin i to destination j in time period s by p.c.m (directional from-home).	
$T_{ijpcmt}^{(PA)0}$	Reference production-attraction (PA) trips from production zone i to attraction zone j in time period t by p.c.m.	
$C_{ijpcmt}^{(PA)0}$	Reference production-attraction (PA) costs from production zone i to attraction zone j in time period t by p.c.m.	
$C_{ijpcms}^{(OD)0}$	Skimmed base OD generalised costs of travel for outward trips in time period s from origin i to destination j by p.c.m (directional from-home).	
$C_{ijpcmt}^{(OD)0}$	Given time period t, skimmed base OD generalised costs of travel for trips returning home in time period r from origin i to destination j by p.c.m (directional to-home)	
$T_{ijpcm24}^{(PA)0}$	Reference 24hr PA trips from production zone i to attraction zone j by p.c.m.	Fixed

Notation	Description	Source Data
$C_{ijpcmt}^{(PA)}$	PA costs of travel for time period t converted from relevant OD outward and return costs from production zone i to attraction zone j by $p.c.m.$	
$C_{ijpcms}^{(OD)}$	Skimmed OD generalised costs of travel for outward trips in time period s from origin i to destination j by $p.c.m$ (directional from-home).	
$C_{ijpcmr}^{(OD)}$	Given time period t , skimmed OD generalised costs of travel for trips returning home in time period r from origin i to destination j by $p.c.m$ (directional to-home)	
$\Delta C_{ijpcmt}^{(PA)}$	The change of PA costs from the forecast year over the base year from production zone i to attraction zone j in time period t by $p.c.m.$	WebTAG
CC	Composite costs (logsums) over IHL	WebTAG
λ	A series of IHL Spreading parameters over FMTD stages	Subject to realism tests
$T_{ijpcmt}^{(PA)}$	Latest production-attraction (PA) trips from production zone i to attraction zone j in time period t by $p.c.m.$	Output directly from the demand model
$T_{ijpcms}^{(OD)}$	Estimated OD outward trips from origin i to destination j in time period s by $p.c.m$ (directional from-home).	
$T_{ijpcmr}^{(OD)}$	Given time period t , estimated OD return trips that happen in time period r from origin i to destination j by $p.c.m$ (directional to-home).	
$T_{ijpcmt}^{(OD)}$	Given time period t , the latest total OD trips estimated in the current demand/supply loop from origin i to destination j in time period t by $p.c.m$ (non directional).	Send to the assignment stage

Create Outward and Return Proportion

2.115 For a given time period t , the reference proportion of outward from-home trips over total trips was calculated via RSI data, which should only be used once to create reference PA matrices by time period and by all other segmentation:

$$Pout_{ijpcmt}^0 = \frac{T_{ijpcms}^{(RSI)}}{T_{ijpcmt}^{(RSI)}} \quad (1)$$

2.116 Return reference proportions were assumed fixed over the forecasting years for each time period s . These factors for the G-BATS v2 are presented in of the next section (supplied by DfT and tuned locally). For a given time period s , reference proportions for trips returning home in time period r were subject to the following constraint:

$$\sum_r Pret_{pcmsr}^0 = 1 \quad (2)$$

Create Reference PA Costs and Demands

2.117 For a given time period t , reference demands and costs were calculated by the following two formula respectively:

$$T_{ijpcmt}^{(PA)0} = T_{ijpcms}^{(OD)0} = T_{ijpcmt}^{(OD)0} Pout_{ijpcmt}^0 \quad (3)$$

$$C_{ijpcmt}^{(PA)0} = (C_{ijpcms}^{(OD)0} + \sum_{r \geq s} (C_{ijpcmr}^{(OD)0})' \text{Pr et}_{pcmsr}^0) / 2 \quad (4)$$

where $r \geq s$ means that r ranges from the outward from-home time period (s) up to the last time period (op) in a day, and the ()' means a transpose. In other words, the costs defined in (4) are a weighted average of the outward and return legs.

- 2.118 The daily 24-hour reference demand was the sum of the time period PA demands (which account for only an half of total OD demands):

$$T_{ijpcm24}^{(PA)0} = \sum_t T_{ijpcmt}^{(PA)0} \quad (5)$$

Convert OD Costs to PA

- 2.119 For each demand/supply loop, the skims from the OD-based assignment by time period (t) were converted to PA costs for feeding into the demand model. With the same formulation as given by (4), the PA costs in forecasting considered both outward and return journeys simultaneously as a weighted sum given below:

$$C_{ijpcmt}^{(PA)} = (C_{ijpcms}^{(OD)} + \sum_{r \geq s} (C_{ijpcmr}^{(OD)})' \text{Pr et}_{pcmsr}^0) / 2, \quad (6)$$

where $r \geq s$ means that r ranges from the outward from-home time period (s) up to the last time period (op) in a day.

- 2.120 By adding the relevant return costs, say, any AM tolls will be appropriately allocated to further to-home trips occurring in the same and subsequent time periods (ie IP, PM and OP), and therefore the impact of AM tolls will be distributed across all time periods rather than incorrectly allocated to the AM demand calculation only.

Incremental Demand Modelling

- 2.121 For an IHL-based demand modelling, the change of PA costs at the bottom level of hierarchy was simply defined as

$$\Delta C_{ijpcmt}^{(PA)} = C_{ijpcmt}^{(PA)} - C_{ijpcmt}^{(PA)0} \quad (7)$$

- 2.122 Based on $\Delta C_{ijpcmt}^{(PA)}$, the composite costs ie the structured logsums over the various stages of the demand model were calculated in the standard way:

$$CC = f(\Delta C_{ijpcmt}^{(PA)}, T_{ijpcmt}^{(PA)0}, \lambda) \quad (8)$$

- 2.123 Based on the CC and others, the demand model calculated a new set of PA outward-leg demands for each demand/supply loop, or simply

$$T_{ijpcmt}^{(PA)} = f(CC, T_{ijpcmt}^{(PA)0}, \lambda)$$

Convert PA Demands to OD for assignment

- 2.124 The outward PA demands $T_{ijpcmt}^{(PA)}$ output from the demand model were then converted to the OD form for assignment. The outward from-home OD demands are simply the latest PA demands output from the demand model:

$$T_{ijpcms}^{(OD)} = T_{ijpcmt}^{(PA)} \quad (9)$$

2.125 Return-leg demands were constrained by relevant outward from-home trips that take place in previous time periods. As indicated above, for example, the PM return demands corresponded to proportions of trips travelling out in the AM period, IP period, and PM period respectively.

2.126 For given time period (t), the formula to calculate to-home demands is given below by applying the fixed return proportions over the latest outward from-home trips:

$$T_{ijpcmr}^{(OD)} = \sum_{s \leq r} \text{Pr et}_{pcmsr}^0 (T_{ijpcms}^{(OD)})', \quad (10)$$

where $s \leq r$ means that s ranges from the first time period (AM) up to the current time period t.

2.127 Finally, the OD assignment demands were simply the sum of from-home and to-home trips:

$$T_{ijpcmt}^{(OD)} = T_{ijpcms}^{(OD)} + T_{ijpcmr}^{(OD)} \quad (11)$$

Final Comments

2.128 The demand model calculated the outward estimates of the PA demand directly by the Incremental Hierarchical Logit technique. The return-leg demands were implicitly considered via the outward journeys in the following way:

- ◆ Return OD costs were incorporated in formulas (4) and (6) above, ie the PA costs are taken as the average OD costs between the outward and return journeys;
- ◆ Return-leg trips were collected by formula (10) from their relevant outward legs using fixed return proportions. Therefore, any reduction of AM trips resulting from say, the introduction of AM tolls, would have been mapped onto the corresponding return legs.

MODELLING THE OFF-PEAK PERIOD

2.129 The off-peak (OP) time period (ie 19:00 – 07:00) was modelled within the G-BATS v2 demand model rather than by assignment to enable the 24-hour model to be developed. A representation of the off-peak costs and demands were needed for the PA-based modelling as defined by the formulas (4) to (11) presented earlier in this section.

2.130 WebTAG does not provide any guidance on how the OP period should be represented. Accordingly, a number of assumptions were made to enable off-peak demand and costs to be estimated for use in the model, reflecting both the limited data available and non-accumulation of scheme benefits within this period. The assumptions were:

- ◆ OP car users travelled at free-flow conditions in the base year;
- ◆ the change of OP costs was equal to the change in Inter-Peak costs in the same forecasting year; and

- ◆ the use of nominal OP base demands were assumed, consisting of 5% of the corresponding IP base demands.

2.131 These assumptions ensured that the switch to the OP period from any of the AM, IP, and PM is always limited and restrictive, for example, the change of OP outward demand was very small in response to the introduction of AM peak tolling. In other words, the introduction of tolling would shift outbound demands to the inter peak period (10:00 -16:00) rather than the off peak period (19:00 to 07:00). It is also worth noting that there were also the practical limitations with the software and the impact on model runtimes.

DEMAND AND SUPPLY MODEL OUTPUTS

2.132 The output from the demand model after the sub-mode choice (stage 5) included two sets of updated matrices for use in the highway and PT assignments namely:

- ◆ Highway AM peak hour OD matrices (08:00 – 09:00), Inter-Peak average hour matrices (10:00 – 16:00), and PM peak hour OD matrices (17:00 – 18:00), segmented by car user class in vehicles; and
- ◆ Public Transport AM peak hour OD matrices (08:00 – 09:00), Inter-Peak average hour matrices (10:00 – 16:00), and PM peak hour OD matrices (17:00 – 18:00), aggregated over person types and journey purposes and PT mode.

2.133 The output from the PT and Highway assignment models were a set of cost skimming matrices, produced by the assignment model to feedback into the demand model, namely:

- ◆ Highway matrices: skimmed time, distance, and toll matrices; and
- ◆ PT matrices: demand by mode, skimmed in-vehicle time, wait time, penalties, and number of interchanges.

2.134 Both highway and PT skims were converted from OD format into the equivalent PA format within the demand model along with the conversion of PA demand matrices into OD matrices.

3. Data Sources and Analysis

INTRODUCTION

- 3.1 A large volume of data was accumulated for the development of G-BATS3 model system. Much of the data was already available but a number of additional surveys were undertaken to support the model development. These included additional traffic surveys such as manual classified volume count and turning count surveys, Roadside Interview Surveys (to collect local income data), journey time surveys, passenger counts and network inventory. In addition, a range of secondary data sources were also available including Wayfarer bus ticketing data and LENNON rail ticketing data for the use in public transport model for example.
- 3.2 These data sources are described in more detail in the separate G-BATS3 v2.3 Highway and Public Transport Local Model Validation Reports.
- 3.3 The development of the G-BATS3 v2.3 demand model involved the derivation of local factors from these datasets and, in particular, the income band factors, Value of Time (VOT) and SATURN time and distance coefficients (ie PPM and PPK), PA factors and occupancy factors. The results from this analysis are described in more detail below.

DEMAND MODELLING FACTORS

- 3.4 One of the principle data sources for the demand model was the 2006 RSI survey data undertaken specifically for the GBMF study, supplemented by other data sources such as TEMPRO and the National Travel Survey where necessary. The 2006 RSI surveys were undertaken to collect up-to-date travel patterns to strengthen existing demand matrices as well as providing additional household income data. Altogether, 15 sites were surveyed in the Bristol area (with a further 14 undertaken in Bath) during June / July 2006.
- 3.5 The following factors were derived from the 2006 RSI survey data:
 - ◆ Household income band factors;
 - ◆ Purpose splitting factors; and
 - ◆ Car occupancy factors by purpose, household income band, and time period.
- 3.6 Table 3.1 provides the local household income band factors by purpose and time period for the base year 2006.

Table 3.1 – Demand Segmentation Factors by Purpose / Income

Purpose	AM	IP	PM
HBO <£17500	0.058	0.154	0.157
HBO £17,500- £35,000	0.101	0.263	0.352
HBO >£35,000	0.041	0.036	0.17
Total HBO	0.20	0.453	0.679
NHBO <£17500	0.018	0.054	0.048
NHBO £17,500- £35,000	0.031	0.092	0.108
NHBO >£35,000	0.012	0.012	0.052
Total NHBO	0.061	0.158	0.208
NHBEB	0.031	0.026	0.019
HBEB	0.08	0.168	0.031
HBW <£17500	0.107	0.044	0.010
HBW £17,500- £35,000	0.348	0.109	0.038
HBW >£35,000	0.173	0.041	0.015
Total HBW	0.628	0.194	0.063
Total	1.00	1.00	1.00

3.7 Table 3.2 gives highway car occupancy factors for the base year 2006 by purpose, income and time period. Note that no distinction was made between home-based and non home-based trips.

Table 3.2 – Highway Car Occupancy Factors

Time Period / Segment	Commuting	Work	Other
<i>AM Peak</i>			
< £17,500	1.18	Not Applicable	1.57
£17,500 - £35,000	1.19		1.48
> £35,000	1.10		1.65
<i>Average</i>	1.16	1.26	1.54
<i>Inter-Peak</i>			
< £17,500	1.19	Not Applicable	1.56
£17,500 - £35,000	1.19		1.59
> £35,000	1.19		1.57
<i>Average</i>	1.19	1.21	1.58

Time Period / Segment	Commuting	Work	Other
<i>PM-Peak</i>			
< £17,500	1.38	Not Applicable	1.46
£17, 500 - £35,000	1.33		1.49
> £35,000	1.31		1.46
<i>Average</i>	1.34	1.32	1.47

3.8 Table 3.3 and Table 3.4 present the base year 2006 VOT parameters for demand modelling and highway assignment respectively, based on the values given in TAG Units 3.5.6 and 3.12.2 and the other parameters presented above.

Table 3.3 – 2006 Value of Time by Person-Type

Demand Segment	Purpose	Value of Time (pence / minute)
Car Available	Commuting (HBW) <£17,500	5.62
	Commuting (HBW) £17,500 - £35,000	9.15
	Commuting (HBW) >£35,000	13.32
	Other (HBO+NHBO) <£17,500	7.08
	Other (HBO+NHBO) £17,500 - £35,000	9.14
	Other (HBO+NHBO) >£35,000	10.98
	Work (HBEB+NHBE)	43.13
Non-Car Available	Commuting (HBW)	6.66
	Other (HBO+NHBO)	5.49
	Work (HBEB+NHBE)	20.00

Table 3.4 – 2006 PPM / PPK by Vehicle

Purpose	AM		IP		PM	
	Pence / Min.	Pence / Km	Pence / Min.	Pence / Km	Pence / Min.	Pence / Km
Non Work <£17,500	8.49	6.48	10.30	5.84	10.25	5.88
Non Work £17,500 - £35,000	11.60	6.48	13.67	5.84	13.47	5.88
Non Work >£35,000	15.50	6.48	16.56	5.84	16.08	5.88
Work	53.10	13.48	51.25	12.33	54.73	14.25
LGV	20.15	14.58	20.15	13.63	20.15	12.13
HGV	17.48	35.78	17.48	35.72	17.48	35.72

- 3.9 The values between Table 3.2, Table 3.3 and Table 3.4 are compatible between the person VOTs and vehicle PPMs. In calculating the PPMs of Table 3.4 WebTAG driver and passenger values were used accordingly with time-period specific occupancies given in Table 3.2; whilst in calculating the person VOTs of Table 3.3 WebTAG average car user values were used.
- 3.10 Note that the base year values provided in the two tables above were adjusted within the demand model for the different forecast years by applying the relevant growth factors, as specified in TAG Unit 3.5.6.
- 3.11 Table 3.5 summarises the 2006 from-home / to-home factors derived from the 2006 RSI surveys. These base year values are assumed to be constant across all the forecast years.

Table 3.5 - From-home / To-home Factors

Demand Segment	AM	IP	PM
HBW <£17,500	0.93 / 0.07	0.51 / 0.49	0.10 / 0.90
HBW £17,500 - £35,000	0.96 / 0.04	0.55 / 0.45	0.12 / 0.88
HBW >£35,000	0.98 / 0.02	0.57 / 0.43	0.07 / 0.93
HBO <£17,500	0.86 / 0.14	0.64 / 0.36	0.53 / 0.47
HBO £17,500 - £35,000	0.86 / 0.14	0.65 / 0.35	0.55 / 0.45
HBO >£35,000	0.79 / 0.21	0.63 / 0.37	0.60 / 0.40
HBEB	0.97 / 0.03	0.54 / 0.46	0.22 / 0.78

3.12 The factors to convert demand from the peak hour to peak period (or inverse for the reverse), derived from the 2006 RSI surveys, are presented below in Table 3.6 by time period and segmentation.

Table 3.6 - Peak Hour to Peak Period Factors

Demand Segment	AM	IP*	PM
<i>Car</i>			
HBW <£17,500	2.18	6.00	2.13
HBW £17,500 - £35,000	2.09	6.00	2.30
HBW >£35,000	2.00	6.00	2.58
Other (HBO+NHBO) <£17,500	4.25	6.00	3.14
Other (HBO+NHBO) £17,500 - £35,000	3.38	6.00	3.14
Other (HBO+NHBO) >£35,000	2.35	6.00	3.23
Non Work <£17,500	2.69	6.00	2.58
Non Work £17,500 - £35,000	2.30	6.00	2.62
Non Work >£35,000	2.07	6.00	2.85
Work (HBEB+NHBE)	2.74	6.00	3.43
<i>Bus</i>			
All purposes	2.50	6.00	2.15
<i>Rail</i>			
All purposes	2.70	6.00	2.15

Note: By definition, the model system represents an average hour in the Inter-peak period.

3.13 Local household survey data was not available and the car availability person type factors were derived for the PT segmentation using the 2006 Avon Rail Surveys. Table 3.7 presents the Car-available (CA) and non-Car available (NCA) splitting factors for rail and bus users in the 2006 base year (ie assuming that bus users have the same equal split as rail users).

Table 3.7 - CA / NCA Splits for Rail & Bus Users

Demand Segment	AM	IP	PM
CA / NCA	0.651 / 0.349	0.559 / 0.441	0.716 / 0.284

3.14 Similarly, data for PT income segmentation was not available. Following discussions with the DfT, it was assumed that highway income segmentation factors may be transferred to car-available PT users (ie the PT income segmentation uses the same proportions as that used for highway for each of the purposes).

BASE YEAR HIGHWAY MATRIX DEVELOPMENT

Data Sources

3.15 The G-BATS3 highway matrices were developed using several data sources including:

- ◆ BATS2 Model 2004 Validated Matrices;
- ◆ OD data from RSI surveys undertaken in 2006; and
- ◆ Traffic counts and journey time survey data (2004 to 2007).

Segmentation

3.16 The calibration and validation of the highway model was undertaken for two user classes “Lights” (ie cars plus LGVs) and “Heavies” (ie HGVs) reflecting the absence of routing data available to support further segmentation either by income and/or purpose.

Assignment Coefficients

3.17 The PPK (Pence per Kilometre) and PPM (Pence per Minute) parameters for SATURN calibration and validation work are presented in Table 3.8. The parameters were normalised for use in the assignment. The PPM values are weighted values based on the numbers presented in Table 3.4, in particular, WebTAG VOT values and VOC parameters and the 2006 RSI survey for occupancies and trip purpose information.

Table 3.8 - SATURN PPK / PPM Values

Time Period	User Class	PPM	PPK
AM (08:00 – 09:00)	Lights	16.99	8.18
	Heavies	17.48	35.78
IP (10:00 – 16:00)	Lights	20.36	8.00
	Heavies	17.48	35.72
PM (17:00 – 18:00)	Lights	16.05	7.04
	Heavies	17.48	35.72

Synthetic Infilling

3.18 An infilling process was undertaken to highway (and Public Transport) demand matrices to smooth the ‘lumpiness’ of the original SATURN highway models using the methodology suggested by WebTAG (Unit 3.10.3, para. 1.5.21). The process used a weighted average of observed and synthetic matrices to remove potentially empty cells within the demand matrices with a greater weight given to cells where there are more observed trips than expected from a locally-calibrated synthetic model.

3.19 WebTAG recommends that the relative weights should reflect the accuracy of the two forms of estimates if this information is available. Alternatively, WebTAG recommends the adoption of a 90% / 10% split between the observed and synthetic forms as used for G-BATS3. Further details may be found in the G-BATS3 v2.3 Highway Local Model Validation Report.

Fixed Returning Proportions

3.20 Table 3.9 presents G-BATS3 v2.3 returning proportions for three home-based purposes. DfT supplied national tour information derived from NTS datasets from which returning proportions were derived. The national average values were subsequently adjusted to reflect the travel demand in the Bristol area traffic. To ensure consistency with the calibrated base year supply models, a substantial volume of analytical work was undertaken to ensure consistency between the base year validated matrices and the outward/return proportions. The final return factors were very close to the national average values except HBEB – there was some variation for this (small) purpose in the three time periods. Following discussions with the DfT, the same return proportions were used across the corresponding PT modes, reflecting the similar returning traffic patterns found in the NTS/TEMPRO datasets.

Table 3.9 - Fixed Returning Proportions

	HBW	HBO	HBEB
AM Outward			
<i>AM Return</i>	0.03	0.26	0.06
<i>IP Return</i>	0.20	0.55	0.55
<i>PM Return</i>	0.67	0.15	0.31
<i>OP Return</i>	0.10	0.04	0.08
Total	<i>1.00</i>	<i>1.00</i>	<i>1.00</i>
IP Outward			
<i>IP Return</i>	0.26	0.70	0.81
<i>PM Return</i>	0.49	0.25	0.16
<i>OP Return</i>	0.25	0.05	0.03
Total	<i>1.00</i>	<i>1.00</i>	<i>1.00</i>
PM Outward			
<i>PM Return</i>	0.48	0.58	0.40
<i>OP Return</i>	0.52	0.42	0.60
Total	<i>1.00</i>	<i>1.00</i>	<i>1.00</i>
OP Outward			
<i>OP Return</i>	<i>1.00</i>	<i>1.00</i>	<i>1.00</i>
Total			

3.21 Table 3.10 summarises the overall matrix totals per peak by the highway assignment segment for cars following the application of the segmentation and fixed return proportion factors (and consequently resulting in some small differences in the overall totals compared to those reported in the G-BATS3 v2.3 Highway LMVR).

Table 3.10 - Validated Highway Base Year Demand by Segment (Cars only)

Purpose	AM Peak	Ave IP	PM Peak
Non Work IL <£17,500	21,774	22,099	24,155
Non Work ILM £17,500 - £35,000	57,888	40,428	55,733
Non Work IH >£35,000	27,132	8,116	26,962
Non Work Total	106,794	70,643	106,850
Work Total	13,435	16,579	5,817
Total Car	120,229	87,222	112,667

BASE YEAR BUS MATRIX DEVELOPMENT

3.22 The G-BATS3 v2.3 bus demand matrices were created in a similar process to the highway demand matrices by updating the 2004 BATS2 matrices using synthetic infilling from the 2006 Wayfarer data. This was followed by the application of a matrix estimation process to adjust the matrix to a series of bus counts collected on key routes and city centre cordons. Further details may be found in the G-BATS3 v2.3 Public Transport Local Model Validation Report.

3.23 Table 3.11 provides the 2006 base year bus trip totals per peak period by person type and purpose. No income data was available for PT segmentation and, following discussions with the Department, the observed income segmentations from the highway demand segments were applied.

Table 3.11 - 2006 Base Bus Matrix Totals (Person)

Purpose		AM Peak Period (3hr)	Inter-Peak Period (6hr)	PM Peak Period (3hr)
Car Available	HBW IL <£17,500	2,981	1,299	2,230
	HBW IM £17,500 - £35,000	10,010	3868	7,310
	HBW IH >£35,000	5,080	1,736	3,607
	HBW Sub-Total	18,071	6,903	13,147
	Other IL <£17500	2,352	6,442	2,187
	Other IM £17,500 - £35,000	4,085	11,137	4,563
	Other IH >£35,000	1,536	1,806	1,879
	Other Sub-Total	7,973	19,385	8,629
	Work Sub-Total	3,317	5,836	1,613
	Total Car Available (CA)	29,361	32,124	23,389
Non Car Available	HBW	9,381	4,327	7,104
	Other	4,331	14,557	4,162
	Work	1,778	4,330	953
	Total Non Car Available (NCA)	15,490	23,214	12,219
Total (CA + NCA)		44,851	55,338	35,608

BASE YEAR RAIL MATRIX DEVELOPMENT

- 3.24 The G-BATS3 v2.3 rail demand matrices were created from three key data sources:
- ◆ 2006 Avon Rail Surveys enabling detailed rail demand matrices to be created by time period for all rail movements originating in the Greater Bristol area;
 - ◆ 2006 LENNON ticketing data providing overall, all-day constraints on rail movements from each station, and
 - ◆ PLANET Strategic Model supplying through (ie External – External) movements.
- 3.25 Further details may be found in the G-BATS3 v2.3 Public Transport Local Model Validation Report.
- 3.26 Table 3.12 illustrates the 2006 Base Year person trip totals per peak period in terms of demand segmentation based on the highway purpose and income band segmentation factors.

Table 3.12 - 2006 Base Rail Matrix Totals (Person)

Purpose		AM Peak Period (3hr)	Inter-Peak Period (6hr)	PM Peak Period (3hr)
CA	HBW IL <£17,500	918	249	630
	HBW IM £17,500 - £35,000	3,083	789	2,103
	HBW IH >£35,000	1,564	378	1,051
	HBW Sub-Total	5,565	1,416	3,784
	Other IL <£17500	724	805	1,658
	Other IM £17,500 - £35,000	1,258	1,394	796
	Other IH >£35,000	473	287	432
	Other Sub-Total	2,455	2,486	3,204
	Work Sub-Total	1,021	804	415
	Total Car Available (CA)	9,041	4,706	7,420
NCA	HBW	2,889	809	1,988
	Other	1,334	1,751	1,335
	Work	547	550	230
	Total Non Car Available (NCA)	4,770	3,110	3,553
Total (CA + NCA)		13,811	7,816	10,971

BASE YEAR PARK AND RIDE

Base Year P&R Matrix Development

3.27 The Park and Ride distribution was taken from the 2004 BATS2 model and growthed to the observed passenger counts using the Park and Ride onboard counts survey collected by BCC in 2006. Table 3.13 shows the matrix totals for the base year matrices outbound from home to the city centre for each time period. Note that it was assumed that the volume of outbound trips from the P&R sites to the city centre was insignificant in the evening peak. However, the model included trips returning to the P&R site in the evening.

Table 3.13 - 2006 Base Year P&R Matrix Totals (persons)

	AM Peak Hour	Average IP Hour	PM Peak Hour
P&R (Inbound) Totals	1,167	246	0

Base Year P&R Charges and Site Constants

- 3.28 Currently the parking charge is set to zero and all charges are modelled by bus fares. These are set at a £1.30 daily charge (2006 prices) – though this can be varied on an individual site basis.
- 3.29 Site specific constants can also be defined. They influence the choice of park and ride site in the absolute site allocation logit model described in Section 2.
- 3.30 For the base model the site specific factors have been defined so as to acceptably match the allocation of park and ride demand to each existing site based on independently observed AM peak hour entry flows. The constants and the resultant fit to the observed data are shown in Table 3.14 below.

Table 3.14 - Bristol Base P&R Site Allocation Calibration (AM Peak Period)

Site	Site Constant (min)	Volumes (Period)		Proportions	
		Observed	Modelled	Observed	Modelled
A4 Portway (Avonmouth)	35	90	136	12%	17%
Brislington	5	383	400	52%	49%
Long Ashton	35	269	273	36%	34%
Total		742	809	100%	100%

Note: An informal Park & Rail is also available at Bristol Parkway Station but without any dedicated P&R facilities and any reliable survey data on passenger volumes. In this case, P&R is simply modelled as the cheapest mode (ie by bus or rail) versus car in terms of overall generalised cost.

BASE YEAR BUS FARES

- 3.31 Public transport fares are excluded from the EMME/2 assignment module and were incorporated into PT generalised cost calculations within the G-BATS3 demand model.
- 3.32 The 2006 base year bus fares were derived from an updated version of the original 2004 BATS2 fares matrix. The BATS2 bus fares matrix was calculated according to the number of bus boardings and the number of fares zones crossed derived from published fares information with the same matrix was used for both the AM and Inter-peak periods. For G-BATS3, this fares matrix was reviewed against current fares along twenty key routes across Bristol. For each of these typical journeys, the single and return fares were provided by BCC public transport team, supplemented by information on multi-journey tickets available on the First website. Adjustments were made to the BATS2 bus fare matrix to create the equivalent G-BATS3 version.
- 3.33 Further details may be found in the G-BATS3 v2.3 Public Transport Local Model Validation Report.

BASE YEAR RAIL FARES

- 3.34 Rail fares are calculated based on the function of skimmed rail OD distances and connected bus interchanges using the same formulas derived from the GBM model namely:

$$AM / PM \text{ fare} = (0.4 + 0.09583 * \text{Distance}) + 1.08 * \text{number of bus boardings}$$

$$IP \text{ fare} = (0.4 + 0.07403 * \text{Distance}) + 1.08 * \text{number of bus boardings}$$

- 3.35 Note that both bus and rail fares are factored up in forecast years in real terms with the annual growth factors being 0.01096 and 0.01053 respectively.
- 3.36 The bus fare growth factor was derived using historical fare data taken from Bulletin of Public Transport Statistics which shows the annual changes in bus fare receipts between 1990/91 to 2001/02. The rail fare growth factor was derived from data published in National rail Trends, for non London and South East operators.
- 3.37 Following discussions from the DfT, the impact of rail crowding was not considered in the G-BATS3 v2.3 modelling system.
- 3.38 Further details may be found in the G-BATS3 v2.3 Public Transport Local Model Validation Report.

4. Demand Model Validation

INTRODUCTION

- 4.1 The validity of the demand model has been assessed by undertaking a series of realism tests. The main purpose of realism tests is to demonstrate that the chosen model parameters (either locally calibrated or adopted from the nationally recommended parameters) replicate long-term elasticities derived from empirical observations and/or best practice. The target elasticities for the realism tests, as defined by WebTAG, are:
- ◆ *Car Fuel cost* - recommended elasticity between -0.1 to -0.4, with an overall target value of -0.3 across all segments;
 - ◆ *Car journey time* - recommended elasticity less than -2.00; and
 - ◆ *PT fare* - recommended elasticity between -0.1 to -0.4 (short-term) and up to 0.9 (longer-term).
- 4.2 WebTAG recommends the use of locally calibrated demand parameters if they are available from Revealed Preference and Stated Preference data. If these are not available, as with G-BATS3, WebTAG recommends the use of illustrated sensitivity parameters provided in TAG Unit 3.10.3. In either case, the robustness of the demand model validation needs to be demonstrated through the application of a set of realism tests.
- 4.3 Based on the previous G-BATS3 versions, the v2 demand model has been developed to further enhance the performance of the model's demand sensitivities to more closely reproduce the Department's view on model sensitivities for models of this nature. Specifically, v2 has introduced value of time variation with trip distance for HBO and NHBO demand segments, as explained in Section 2.
- 4.4 This section presents the G-BATS3 v2.3 demand model elasticities derived from the realism tests, by using the sensitivity parameters and tree structure parameters presented in Section 2.

CONVERGENCE BETWEEN SUPPLY-DEMAND

- 4.5 The five-stage G-BATS3 v2.3 demand model employs an iterative method to achieve convergence between the assignment models (ie SATURN highway and EMME/2 PT) and the EMME/2-coded demand model. Convergence was achieved by passing costs from the assignment models to the demand model and subsequently passing trips from the five-stage demand model to the assignment models; the process terminated once the convergence criterion has been met.
- 4.6 Two convergence algorithms were implemented within G-BATS3 v2.3 to create a stable converged solution between the cycling of demand and supply responses. The convergence algorithms were: (i) the method of successive average (MSA); and (ii) the average method which simply used the mean value between previous results and the current new estimates. The testing work undertaken identified that the

simple average method provided a more stable (and quicker) solution and this was adopted for the modelling system.

4.7 The recommended criterion by TAG Unit 3.10.4, for measuring convergence between demand and supply models, is the demand/supply gap over all segments as defined by:

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

where:

- X_{ijctm} is the current flow vector or matrix from the model
- $C(X_{ijctm})$ is the generalised cost vector or matrix obtained by assigning that matrix
- $D(C(X_{ijctm}))$ is the flow vector or matrix output by the demand model, using the costs $C(X_{ijctm})$ as input
- $ijctm$ represents origin i, destination j, demand segment/user class c, time period t and mode m.

4.8 It is also important that the demand model achieved a high level of supply-demand convergence as described in more detail below. WebTAG suggested that convergence level as measured by %GAP, should be lower than 0.2% (or, if that cannot be achieved, a more relaxed criterion related to the projected benefits of a scheme). Following discussions with DfT, a higher %GAP value was accepted for realism tests only. The realism test runs were undertaken using a maximum of nine iterations which typically provided %GAP values under 0.5%. Table 4.1 gives an example of the %GAP values for the G-BATS3 v2.3 forecast tests - note that to achieve this level of convergence required around 16 hours of CPU time on a high performance, quad-core workstation.

Table 4.1 - Example of Convergence for the G-BATS3 v2.3 Rapid Transit Tests (2031)

Demand / Supply Iteration	%GAP
1	305.1553%
2	77.3332%
3	24.1602%
4	9.2163%
5	6.2551%
6	3.9545%
7	2.4879%
8	1.9298%
9	1.1155%

Demand / Supply Iteration	%GAP
10	0.7597%
11	0.5109%
12	0.3042%
13	0.2197%
14	0.1662%

REALISM TESTS

- 4.9 During the initial G-BATS3 v1 development work, the WebTAG-based illustrative sensitivity parameters from the minimum to maximum were all tested. The realism tests undertaken identified that the range of median parameters were the most appropriate for the Bristol area (with respect to the demand hierarchy form presented in Figure 2.3).
- 4.10 The demand response parameters presented in Chapter two were the result of finer tuning of the WebTAG illustrative parameters when the VOT variation is introduced – these were achieved by an iterative process of tuning the parameters values to achieve the target elasticities described above.
- 4.11 The arc elasticity formulation recommended by WebTAG was used for the realism testing is:

$$e = \frac{\log(T^1) - \log(T^0)}{\log(C^1) - \log(C^0)} = \frac{\log(T^1) - \log(T^0)}{\log(1.1)},$$

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

- ◆ *Car fuel cost elasticity:* *T* represents the car-kms travelled whilst *C* represents fuel costs;
- ◆ *PT fare elasticity:* *T* represents PT trips and *C* represents fares.

- 4.12 The realism tests were undertaken assuming:
- ◆ a 10% increase of fuel prices for the car fuel cost elasticity test; and
 - ◆ a 10% increase of bus and rail fare for the public transport fare elasticity test.

Car Fuel Cost Elasticities

Network Level

- 4.13 The Car fuel cost elasticities in terms of car vehicle kilometres with respect to (w.r.t) fuel costs, are shown below in Table 4.2, presented by segmentation of highway assignment user classes, ie by household income and by purpose work/non-work.

Note that it was not possible to separately calculate the elasticities for “commuting” and “other” purposes (nor the non-work categories) at network level as they were combined together for assignment purposes.

- 4.14 The network-based fuel cost elasticities in Table 4.2 are given for each of the three peak hours. As requested by the Department, the annual average fuel cost elasticities are reported in the last column by applying the G-BATS3 annualisation factors as follows (ie including weekday and weekend travel):

$$253*(AM_distance*f_am+IP_distance*f_ip+PM_distance*f_pm) + 104* IP_distance*2$$

where: f_am , f_ip and f_pm are the hour-to-period factors by user class presented in Table 3.6 for AM, IP, and PM periods respectively. (Note: (i) that equation estimates the 12-hour factor rather than an annual average as the remaining factors will cancel out in the evaluation of annual average elasticity; and (ii) the expansion factors are used by the TUBA appraisal reflecting 253 week days and 104 weekend days assumed to be represented by the inter-peak volumes).

- 4.15 Table 4.2 also distinguishes between the various network areas (ie simulation, buffer link and buffer centroid connectors). The simulation area covers the entire built-up area of Bristol as previously illustrated in Figure 2.1. The elasticity values presented are obtained by direct calculation on SATURN network statistics reported in output

Table 4.2 – G-BATS3 v2.3 Car Fuel Cost Elasticity (WebTAG: -0.1 to -0.4)

PCU-Kms w.r.t Fuel Cost	AM	IP	PM	Annual
<i>UC1 Car – Non Work IL</i>				
Simulation Area	-0.26	-0.21	-0.25	-0.23
Buffer Area (B)	-0.51	-0.31	-0.41	-0.38
Buffer Area (BCC)	-0.47	-0.30	-0.41	-0.36
Total	-0.44	-0.28	-0.37	-0.34
<i>UC2 Car – Non Work IM</i>				
Simulation Area	-0.18	-0.15	-0.17	-0.16
Buffer Area (B)	-0.21	-0.20	-0.19	-0.20
Buffer Area (BCC)	-0.14	-0.17	-0.16	-0.16
Total	-0.18	-0.18	-0.18	-0.18
<i>UC3 Car – Non Work IH</i>				
Simulation Area	-0.10	-0.12	-0.12	-0.11
Buffer Area (B)	-0.02	-0.08	-0.08	-0.06
Buffer Area (BCC)	0.07	-0.02	-0.07	0.00
Total	-0.01	-0.07	-0.09	-0.05
Car – Total Non Work				
Simulation Area	-0.17	-0.17	-0.18	-0.17
Buffer Area (B)	-0.22	-0.22	-0.21	-0.22
Buffer Area (BCC)	-0.15	-0.20	-0.20	-0.19
Total	-0.19	-0.20	-0.20	-0.20

PCU-Kms w.r.t Fuel Cost	AM	IP	PM	Annual
<i>UC4 Car - Work</i>				
Simulation Area	0.02	-0.03	-0.02	-0.02
Buffer Area (B)	-0.07	-0.10	-0.09	-0.09
Buffer Area (BCC)	-0.09	-0.09	-0.10	-0.09
Total	-0.06	-0.08	-0.08	-0.07
Total Cars				
Simulation Area	-0.15	-0.14	-0.17	-0.15
Buffer Area (B)	-0.21	-0.20	-0.21	-0.20
Buffer Area (BCC)	-0.14	-0.18	-0.19	-0.17
Total	-0.17	-0.18	-0.19	-0.18

- 4.16 Table 4.2 demonstrates a correct pattern of fuel cost elasticities by user class or household income, such that the highest income groups exhibited the lowest elasticities whilst the poorest groups exhibited the highest elasticities due to their lowest VOTs.
- 4.17 It was not possible to separately calculate the elasticities for “commuting” and “other” purposes for the non-work trips at network level as they were combined together in order to reducing the SATURN assignment runtimes.

Matrix Level

- 4.18 The matrix-based vehicle-km fuel cost elasticities are presented below in Table 4.3 with the elasticities reported by time period, by ‘super’ sector (ie Internal or External), and by purpose (ie HBW / HBO / NHBO / Work). Figure 4.1 shows the four geographical sectors making up the ‘Internal’ super sector (ie sectors 1 to 4 representing Bristol Central / Inner / Outer, and Greater Bristol) and the ‘External’ super sector (ie sector 5).
- 4.19 It is noted that the demand model does not consider the impact on external to external trips with Table 4.3 only including internal to internal demands and internal to external demands (I to I&E).
- 4.20 It is noted that the network-based elasticities in Table 4.2 are smaller than the values presented below in Table 4.3. This difference arises because that the fuel cost elasticities at the network level include external to external (E-E) movements and external to internal (E-I) movements whereas the matrix-based calculations are able to exclude E-E trips (as they are inelastic) and E-I demands (are only partially modelled).

Table 4.3 - G-BATS3 v2.3 Matrix-based Fuel Cost Elasticities

Time Period	Movement Type	HBW	HBO	NHBO	Non-Work (Total)	Work	All
AM	I to I&E	-0.29	-0.38	-0.39	-0.32	-0.12	-0.30
IP	I to I&E	-0.23	-0.27	-0.42	-0.29	-0.10	-0.26
PM	I to I&E	-0.14	-0.22	-0.42	-0.23	-0.06	-0.22
All-Day	I to I&E	-0.23	-0.28	-0.41	-0.28	-0.10	-0.26

4.21 Looking at the matrix-based fuel cost elasticities by purpose, Table 4.3 shows sensibly that:

- ◆ HBO and NHBO trips exhibit higher elasticities than the doubly-constrained HBW trips; and
- ◆ Work trips exhibit the lowest elasticities as they have the highest values of time.

Commentary

Fuel Cost Elasticity by Time Period

4.22 Looking at the matrix-based fuel cost elasticities by time period, Table 4.3 shows that the fuel cost elasticity is greatest in the AM peak and the IP is the next most sensitive with the PM peak the least sensitive.

4.23 The traditional view, drawn from experience of models previously developed, is that travel in the IP is expected to most sensitive to changes in fuel costs than the AM peak primarily because fuel costs typically form a large proportion of generalised costs for IP journeys and that the IP period has a higher proportion of discretionary travel.

4.24 The WebTAG demand modelling approach adopted for GBMF has greater functionality and different choice structures compared to the traditional approach upon which the above conventional view of relative levels of sensitivity is drawn. The GBMF also represents demand in a PA format (as explained in section 2) using a pseudo-tour based to in order to link outward / return journeys across the three time periods.

4.25 Taken together, it is considered that the formulation of the model means that the relative sensitivities across time periods could reasonably be expected to be different compared with past experience.

4.26 The impact of this pseudo-tour based formulation is indicated by Table 2.8 whereby more time period choices for HB “tours” are available for those departing home in the AM period than those departing home in subsequent time periods (which are restricted to switching to later time periods). For example, in the IP period demand can only switch to the later PM and OP periods but not to the AM period and the PM period demands can only re-time to the following OP period.

- 4.27 The main mode choice in the later time periods after the AM period is also implicitly restricted in GBMF since the mode-switching response is placed above the time period choice. For example, the departure-in-AM car tours are able to switch to the departure-in-IP bus tours in appropriate but not vice versa.
- 4.28 In summary, the fundamental reason for the fuel cost elasticities being higher in the AM than in the IP period is the diminishing set of choice alternatives in the IP and then PM peak periods. Given that the choice sets are not the same between different time periods the fuel cost elasticities are not therefore strictly comparable.

Car Trip Elasticities

- 4.29 The estimation of car trip elasticities of with respect to fuel cost, is not required by WebTAG. However, they are a useful measure to understand the behaviours of the model in forecasting mode. The car trip elasticities are shown below in Table 4.4 by time period and purpose. The results show that, overall, the trip elasticities were very small with trip re-distribution as the primary response to increasing fuel cost rather than switching mode – this reflects the hierarchical structure of the model shown in Figure 2.3.

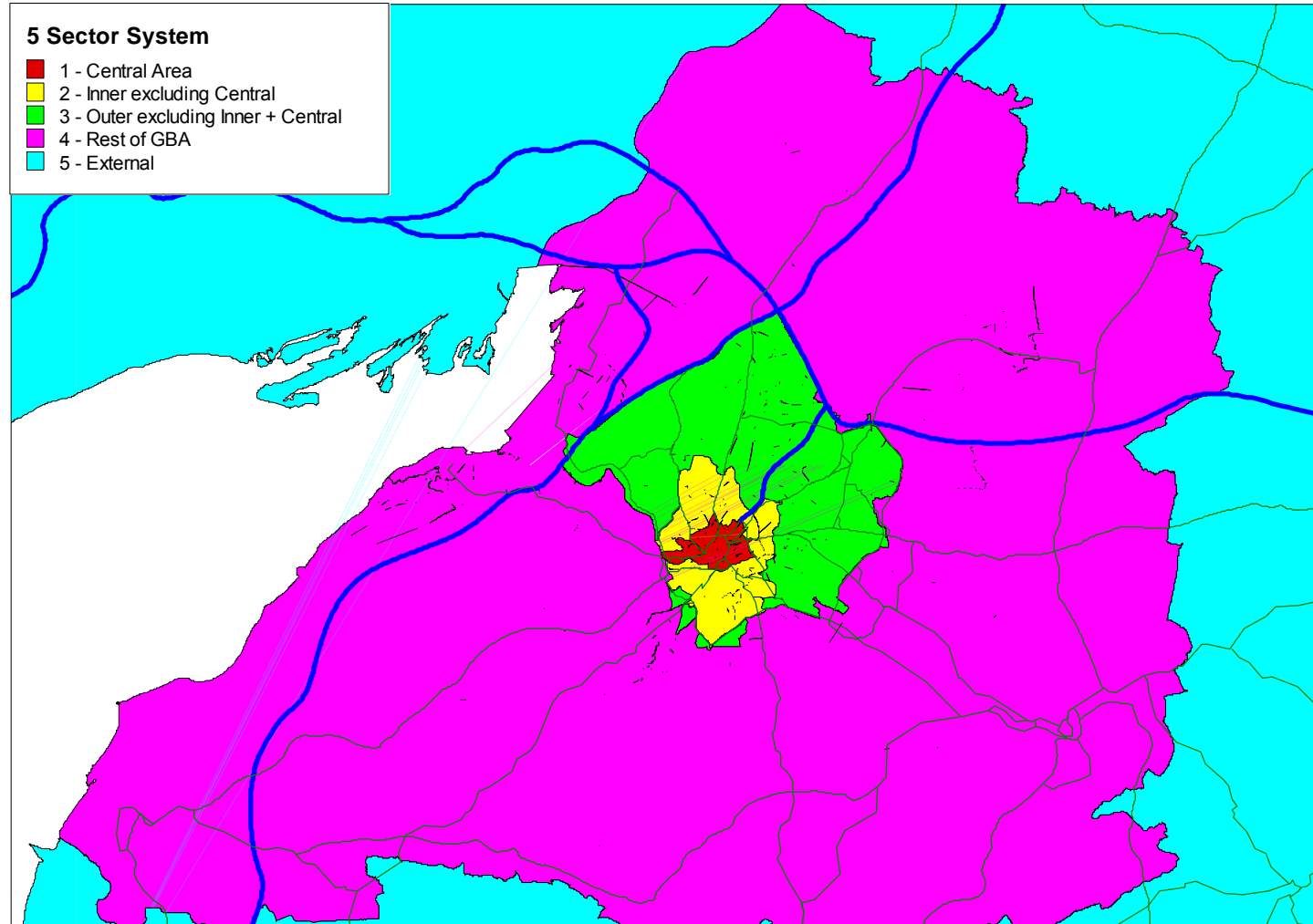
Table 4.4 - G-BATS3 v2.3 Car Trip Fuel Cost Elasticities

Time Period	HBW	HBO	NHBO	Work	All
AM	-0.02	-0.03	-0.02	0.01	-0.02
IP	-0.01	-0.01	-0.01	0.01	-0.01
PM	-0.02	-0.03	-0.04	0.00	-0.02

Summary

- 4.30 The car vehicle-kilometre elasticities shown in the above tables demonstrate the G-BATS3 v2.3 demand model replicates network-wide, published elasticities of the impact of fuel cost on vehicle kilometres. The annual average fuel cost elasticity -0.26 in Table 4.3 is lower than the national average of -0.3, reflecting the higher income characteristics of the study area. The analysis demonstrates that the G-BATS3 v2.3 modelling system is a robust tool for the forecasting of highway demand.

Figure 4.1 - Five Sector Reporting System



Car Journey time Elasticities

- 4.31 The car elasticity of vehicle-kms with respect to journey times may be derived from the aforementioned car fuel cost elasticities, by multiplying each of them by their relevant ratios between car journey costs and fuel costs. The journey time elasticities are presented below in Table 4.5.
- 4.32 Table 4.5 shows that the majority of the journey time elasticities were less than -2.00 as recommended by WebTAG - the two exceptions were for the discretionary / lower income segments in outer buffer areas (ie outside the main urban areas of Bristol) for the IP and PM respectively. The overall journey time elasticities for the three time periods are -0.59, -0.64, and -0.69 respectively.

Table 4.5 - G-BATS3 v2.3 Car Journey Time Elasticity (WebTAG: <-2.00)

PCU-KMs w.r.t Journey Tme	AM	IP	PM
<i>UC1 Car – Non Work IL</i>			
Simulation Area	-0.89	-0.76	-0.88
Buffer Area (B)	-1.74	-1.12	-1.47
Buffer Area (BCC)	-1.59	-1.09	-1.49
Total	-1.50	-1.03	-1.34
<i>UC2 Car – Non Work IM</i>			
Simulation Area	-0.61	-0.56	-0.61
Buffer Area (B)	-0.73	-0.72	-0.70
Buffer Area (BCC)	-0.48	-0.63	-0.59
Total	-0.62	-0.65	-0.64
<i>UC3 Car – Non Work IH</i>			
Simulation Area	-0.33	-0.42	-0.45
Buffer Area (B)	-0.07	-0.28	-0.30
Buffer Area (BCC)	0.24	-0.08	-0.24
Total	-0.02	-0.24	-0.31
Car – Total Non Work			
Simulation Area	-0.59	-0.60	-0.63
Buffer Area (B)	-0.76	-0.79	-0.77
Buffer Area (BCC)	-0.52	-0.71	-0.70
Total	-0.64	-0.72	-0.71
<i>UC4 Car - Work</i>			
Simulation Area	0.08	-0.10	-0.07
Buffer Area (B)	-0.26	-0.35	-0.33
Buffer Area (BCC)	-0.29	-0.33	-0.36
Total	-0.19	-0.29	-0.28
Total Cars			
Simulation Area	-0.51	-0.51	-0.60
Buffer Area (B)	-0.70	-0.71	-0.74
Buffer Area (BCC)	-0.49	-0.64	-0.68
Total	-0.59	-0.64	-0.69

PT Fare Elasticities

- 4.33 The PT fare elasticities derived from the PT realism test should reflect WebTAG elasticities between -0.1 and -0.4 (short-term) up to -0.9 (longer-term). Matrix-based PT fare elasticities were calculated by internal / external sector. Table 4.6 below presents the fare elasticities for car available PT travellers for “I to I&E” movements whilst Table 4.7 shows the corresponding fare elasticities for Non-Car Available PT travellers.
- 4.34 Table 4.6 shows that all of the elasticities of public transport demand (number of trips) w.r.t PT fare increase were less than -0.9 (with only work trips slightly less than -0.1). The overall elasticity for CA users is 0.44 within the range of values recommended by WebTAG.

Table 4.6 - G-BATS3 v2.3 Matrix-based CA PT Fare Elasticities (WebTAG: up to -0.9)

Time Period	Movement Type	HBW	HBO	NHBO	Non-Work (Total)	Work	All
AM	I to I&E	-0.70	-0.32	-0.67	-0.61	-0.08	-0.55
IP	I to I&E	-0.50	-0.30	-0.64	-0.40	-0.07	-0.34
PM	I to I&E	-0.40	-0.32	-0.70	-0.39	-0.06	-0.38
All Day	I to I&E	-0.55	-0.31	-0.67	-0.48	-0.07	-0.44

- 4.35 Non-car available (NCA) PT demands are captive to PT. Looking at the daily level the “Total” fare elasticities by purpose are all small negative numbers. Compared to fare elasticity values in Table 4.6, the elasticities in Table 4.7 reflect very limited choice available for captive PT users.
- 4.36 Looking at the NCA “I to I&E” movement in Table 4.7, there appear some positive fare elasticities for HBW in the IP, PM and OP periods. The NCA HBW demand segment is modelled with a doubly-constrained distribution as suggested by WebTAG; the upper level time period choice is the only other response available which has virtually no impact when the PT fare is increased by 10%. The fare realism test re-distributes longer distance NCA HBW trips to shorter distance trips – internal trips (“I to I”) increased but “E to I” and “I to E” trips decreased. Consequently, the overall all-day net impact is balanced when all movements are considered as shown in Table 4.7 with the “Total” fare elasticity of NCA HBW is (almost) zero.

Table 4.7 - G-BATS3 v2.3 Matrix-based NCA PT Fare Elasticities (WebTAG: up to -0.9)

Time Period	Movement Type	HBW	HBO	NHBO	Non-Work (Total)	Work	All
AM	I to I&E	-0.00	-0.07	-0.12	-0.03	0.01	-0.02
	Total ¹²	-0.02	-0.07	-0.12	-0.04	0.01	-0.03
IP	I to I&E	0.29	-0.03	-0.03	0.04	0.01	0.04
	Total	0.04	-0.03	-0.03	-0.02	0.00	-0.01
PM	I to I&E	0.47	-0.06	-0.18	0.28	0.03	0.26
	Total	0.00	-0.07	-0.18	-0.03	0.00	-0.03
Total	I to I&E	0.24	-0.05	-0.09	0.12	0.01	0.10
	Total	-0.01	-0.05	-0.09	-0.02	0.00	-0.01

4.37 The majority of the PT fare elasticities presented in Table 4.6 and Table 4.7 are within the range of WebTAG target values, by using the median WebTAG PT lambdas and thetas specified in TAG unit 3.10.3. The analysis demonstrates that the G-BATS v2.3 demand model is appropriate for the assessment of public transport demand forecasting.

¹² 'Total' movement type includes "I to I&E" and "E to I"

5. Summary

- 5.1 The G-BATS3 v2.3 demand model was developed to assess the transport impacts of a range of potential transport interventions in the West of England sub-region.
- 5.2 The G-BATS3 v2.3 demand model is a five-stage multi-modal incremental model that consider the impact on frequency choice, main mode choice, time period choice, destination choice, and sub mode choice in response to changes in generalised costs.
- 5.3 The G-BATS3 v2.3 demand model represents travel demand over a 24-hour period and was developed from the previous G-BATS3 v1 9-hour demand model. The G-BATS3 v2.2 is a Production Attraction (PA)-based model with explicit time period choice modelling based on the use of fixed return proportions derived from national average values obtained from the DfT NTEM/TEMPRO datasets.
- 5.4 The G-BATS3 v2.3 demand model is fully compliant with the latest WebTAG guidance (June 2006), functioning at the same zoning level as that of highway and PT supply models, ie composed of 600 zones, which ensures consistency between costs and demands at each stage of the demand sub-modules.
- 5.5 The G-BATS3 v2.3 demand model iterates between the hourly-based AM, IP and PM supply models and the 24-hour demand model. Two convergence algorithms were implemented namely the MSA algorithm and the average algorithm to achieve convergence in the demand/supply interactions with the latter selected based on the performance testing. The G-BATS3 v2.3 demand model achieves the required levels of convergence stipulated by WebTAG albeit at the expense of a substantial CPU commitment (ie runtime of around 12 to 16 hours).
- 5.6 VOT variation with trip length has been introduced into the G-BATS3 v2.3 demand model for car available HBO and NHBO trips, and non car available non-work purposes including HBW. This technique has helped greatly for achieving WebTAG required elasticities especially for longer distance trips due to the nature of the logit-based demand modelling framework.
- 5.7 The sensitivity lambdas and thetas adopted in the G-BATS3 v2.3 were all equal to the WebTAG median parameters, with only the exception of the highway HBW segment whose distribution lambdas are slightly larger than the median values (but still comfortably within the range of illustrative values). Overall, the realism tests undertaken have identified a set of demand response parameters that replicated both the local conditions as well as conforming to the recommended hierarchical tree structure by WebTAG, that is, FMTD (Frequency, Mode, Time period, and Destination choice).
- 5.8 The derived car fuel cost elasticity, car journey time elasticity and PT fare elasticity, established through the realism tests, have been reported by purpose, person type (household income), time period and spatial locations. The substantial majority of the outturn elasticity values are within WebTAG recommended ranges.

- 5.9 Moreover, the realism tests also sensibly demonstrate that lower household incomes exhibited higher demand response elasticities. The tests also show that discretionary trips (HBO/NHBO) exhibited higher elasticities than non-discretionary compulsory trips (HBW/EB).
- 5.10 The demand model has been developed in close co-operation with the Department for Transport and its adviser: their technical advice and support is acknowledged.
- 5.11 On this basis, the model is considered to be fit for the purposes described in Section 1, para. 1.2 - as demonstrated through the realism tests - and may be used with confidence to forecast the demand responses of possible demand management schemes and other major transport schemes within the study area.