Salisbury Transport Model

Demand Model Report

May 2009

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Document History

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1. Introduction

Background

1.1 Wiltshire Council (WC) commissioned Atkins to develop Transport Models for Salisbury in September 2008. The commission was a response to a need to test the impact of significant proposed development in the Salisbury area.

1.2 This Demand Model Validation Report forms deliverable 2.4 of the commission and it describes the development and validation of the Salisbury Transport Model's Demand Model (SDM). The purpose of this report is to demonstrate that the demand model meets WebTAG criteria and can be used for reliable transport forecasts in the future.

Context

Planning

1.3 The Secretary of State's modifications to the South West Spatial Strategy shows that Salisbury City is required to accommodate a 8,700 new dwellings and provide 13,500 new employment opportunities by 2026. A range of potential sites have been identified. The strategy identifies sites in and around Salisbury, including potentially major changes in land use through the redevelopment of Churchfields and new developments to the north-west and south of the City.

1.4 As such, the Salisbury Transport Model must be able to:

- identify the impact on the transport network of locating development in each of the strategic residential and employment sites;
- identify the potential for maximising the use of public transport, walking and cycling for movements to from and within sites;
- identify the potentially significant switches in travel patterns arising from major changes in employment type and location;
- assess the potential impact on movements to/from Salisbury arising from the location of development outside Salisbury and Wilton; and
- support the District Council through the Local Development Framework (LDF) process and any subsequent statutory processes.

Modelling Approach

1.5 Our response to these needs is to develop a fully up-to-date and appropriately validated area-wide traffic model of the Salisbury and Wilton area, supported by a demand model that is capable of representing the effect of mode switching and re-distribution of travel patterns as land uses change (macro modelling) and a detailed micro-simulation model of specific areas to view the impact of changes to land use and transport provision in more detail (micro modelling).

1.6 The "macro-level" multi-modal model of Salisbury that represents movements to the city from its rural hinterland; through traffic, particularly that using the A36; and public transport movements including rail and park-and-ride.

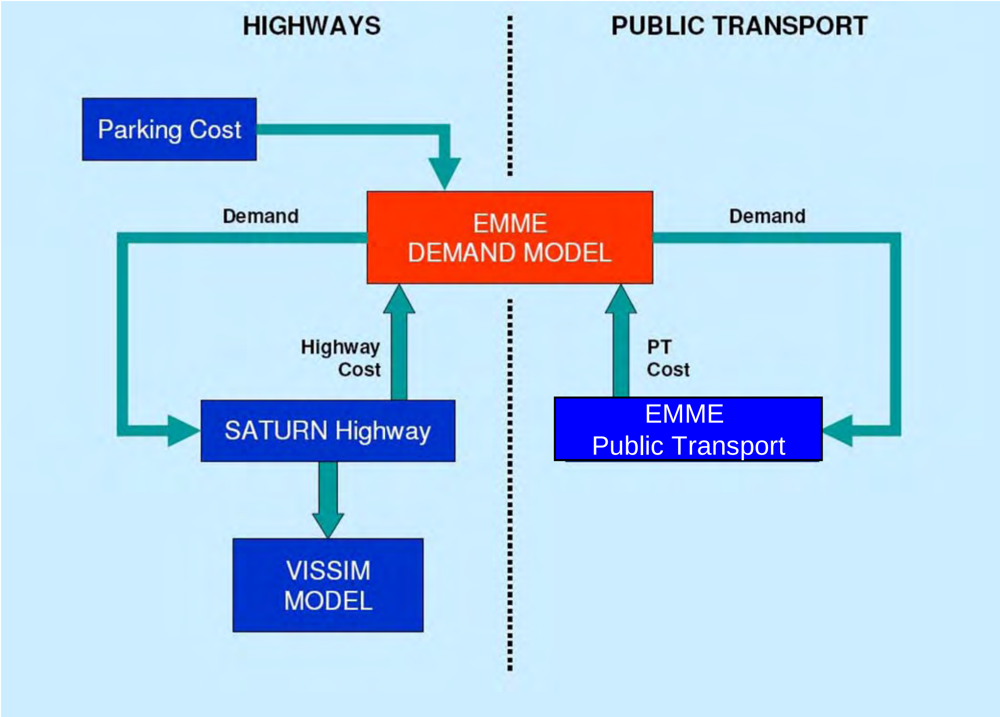
1.7 This model will be able to represent the impact of land use changes on travel demands and network performance – specifically being able to asses the impact of different development locations, scales of development and type of development including the impact of sustainable development principles. The model must also assess the impact of different trip distribution patterns arising from in-commuting from the City's hinterland.

1.8 Our approach to this "macro-level" model, collectively referred to as the Salisbury Transport Model (STM) is developed using:

- an EMME demand model representing modal switching and redistribution effects and is referred to as the Salisbury Demand Model (SDM);
- a SATURN to represent the highway network and highway travel demands, referred to as the Salisbury Highway Model (SHM); and
- an EMME model representing the public transport network with individual bus, rail and park and ride services coded and is referred to as the Salisbury Public Transport Model (SPTM).

1.9 The linkages between the modelling framework is shown in Figure 1.1.

Figure 1.1 - Modelling Components and Linkages



Scope of Report

1.10 This draft Demand Model Validation report consists of seven chapters. Following this introductory chapter:

- Chapter Two outlines the demand model specification;
- Chapter Three describes the demand model formulation;
- Chapter Four provides details of the data used in the model;
- Chapter Five presents the results of the model validation; and
- Chapter Six provides a concluding summary.

2. Model Specification

Introduction

2.1 The aim of this chapter is to describe the specification of the Salisbury Demand Model (SDM) ahead of more detailed description in subsequent chapters. This chapter specifies the:

- spatial detail;
- temporal scope;
- vehicles and trip purposes; and
- provides an overview of the demand models.

Spatial Detail

Zones

2.2 In the first instance the existing zone system from the 2001 version of the SDM were adjusted to TEMPRO (Trip End Model Presentation PROgramme) boundaries. This stage is necessary for forecasting future year trip rates from the National Trip End Model data extracted from TEMPRO (**Error! Reference source not found.**and **Error! Reference source not found.**).

2.3 Following the review of TEMPRO boundaries each existing zone was considered for current land use and likely public transport catchments. As an example a supermarket site is expected to have different trip patterns to a residential area. If combined within an existing zone, different land uses were divided into two separate zones (Figure 2.3).

2.4 The zoning in areas also being modelled in micro-simulation was carefully considered for the loading of trips to the network. Trips within the micro-simulation model are loaded at the location of zone to network connectors in the SATURN network. To accommodate this, zones must be of a suitable size that connections to the network give an accurate representation of trips in the micro-simulation model. As a general principle smaller zones are required in such cases (Figure 2.4).

Sector System

2.5 It is often easier to visualise the trip matrix in a condensed form. For the Salisbury Transport Model the following sectoring system is used (and is shown in Figure 2.5):

- Salisbury City Centre;
- Salisbury urban area;
- Salisbury District Council;
- Wiltshire; and
- Rest of Britain.

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Figure 2.1 - National Zoning System

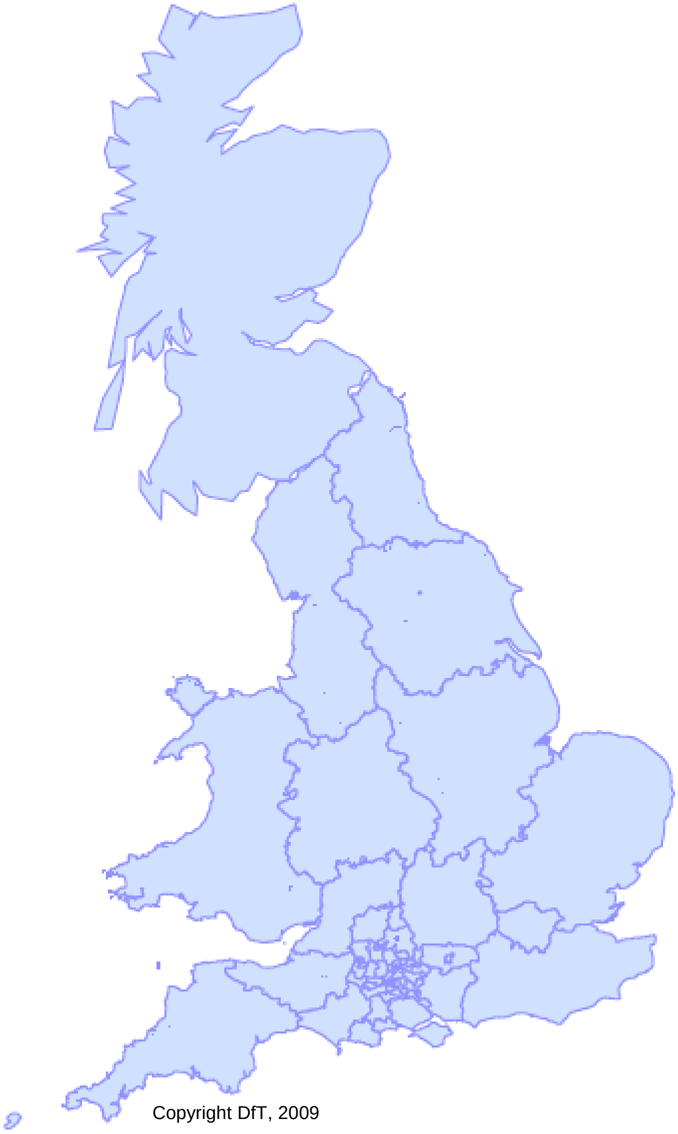


Figure 2.2 - Zoning System Within Wiltshire

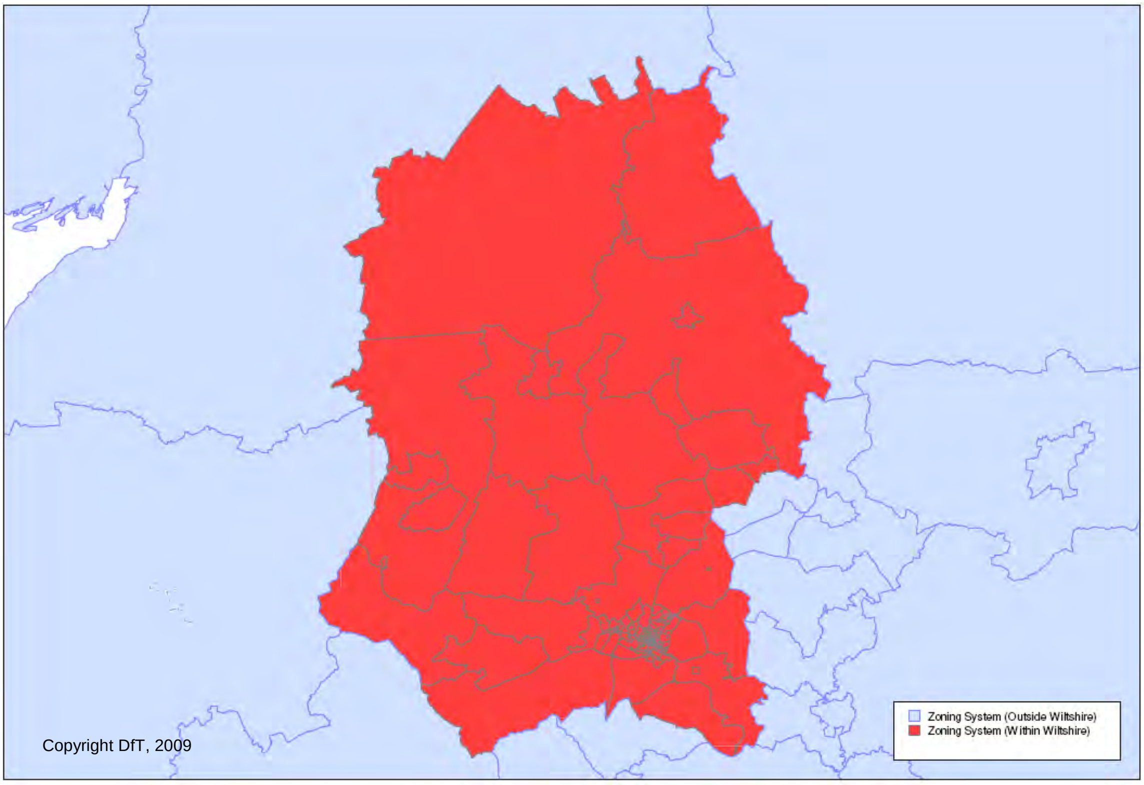


Figure 2.3 – Zoning System Within Salisbury District

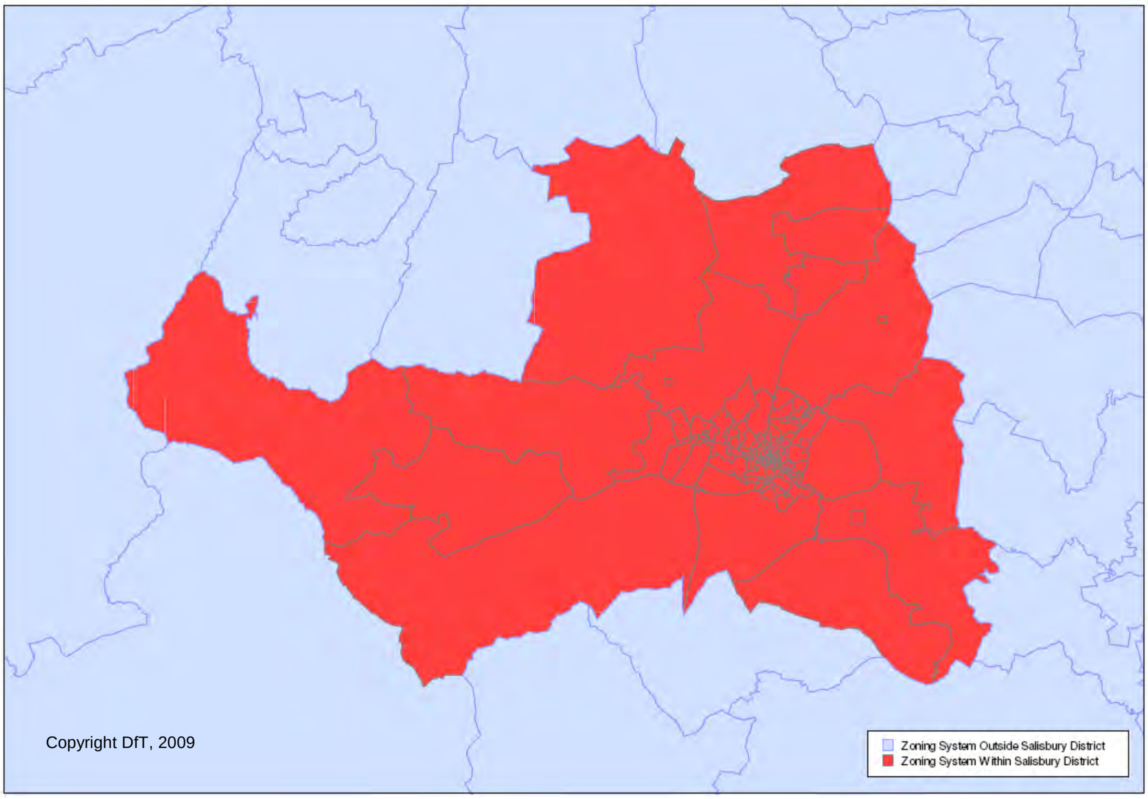


Figure 2.4 – Zoning System Within Salisbury City Centre

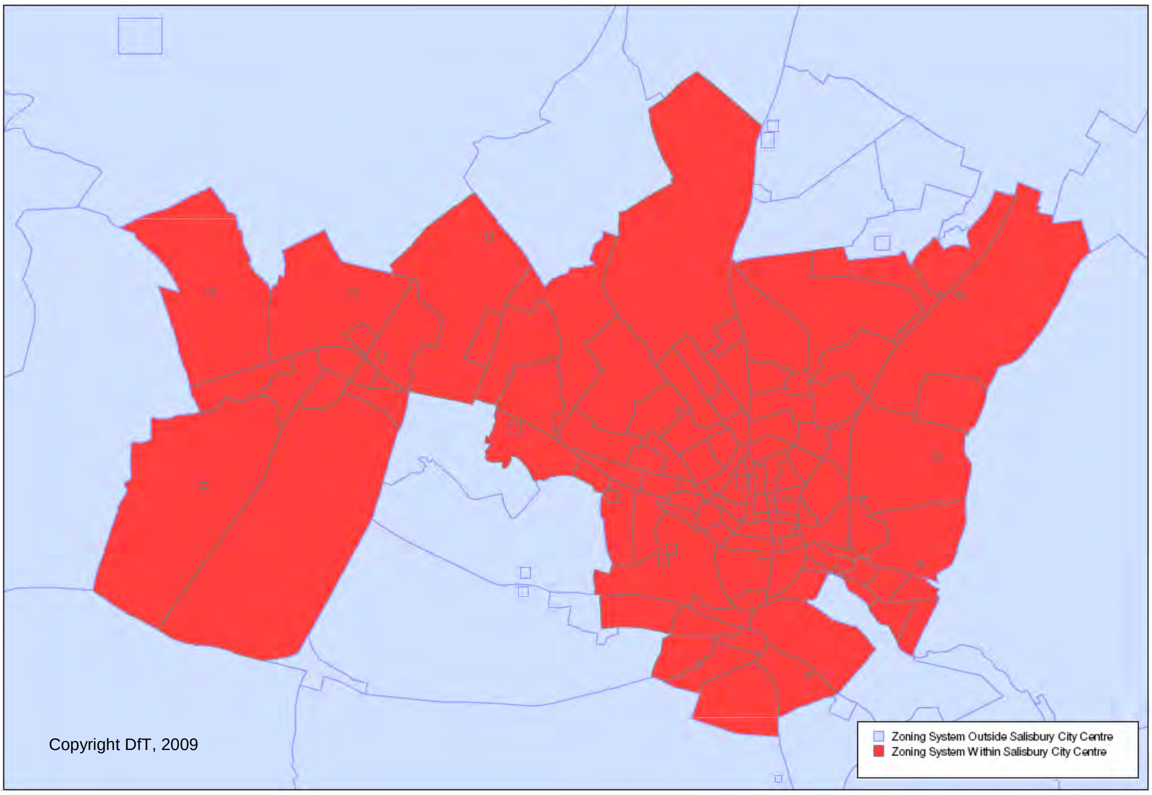
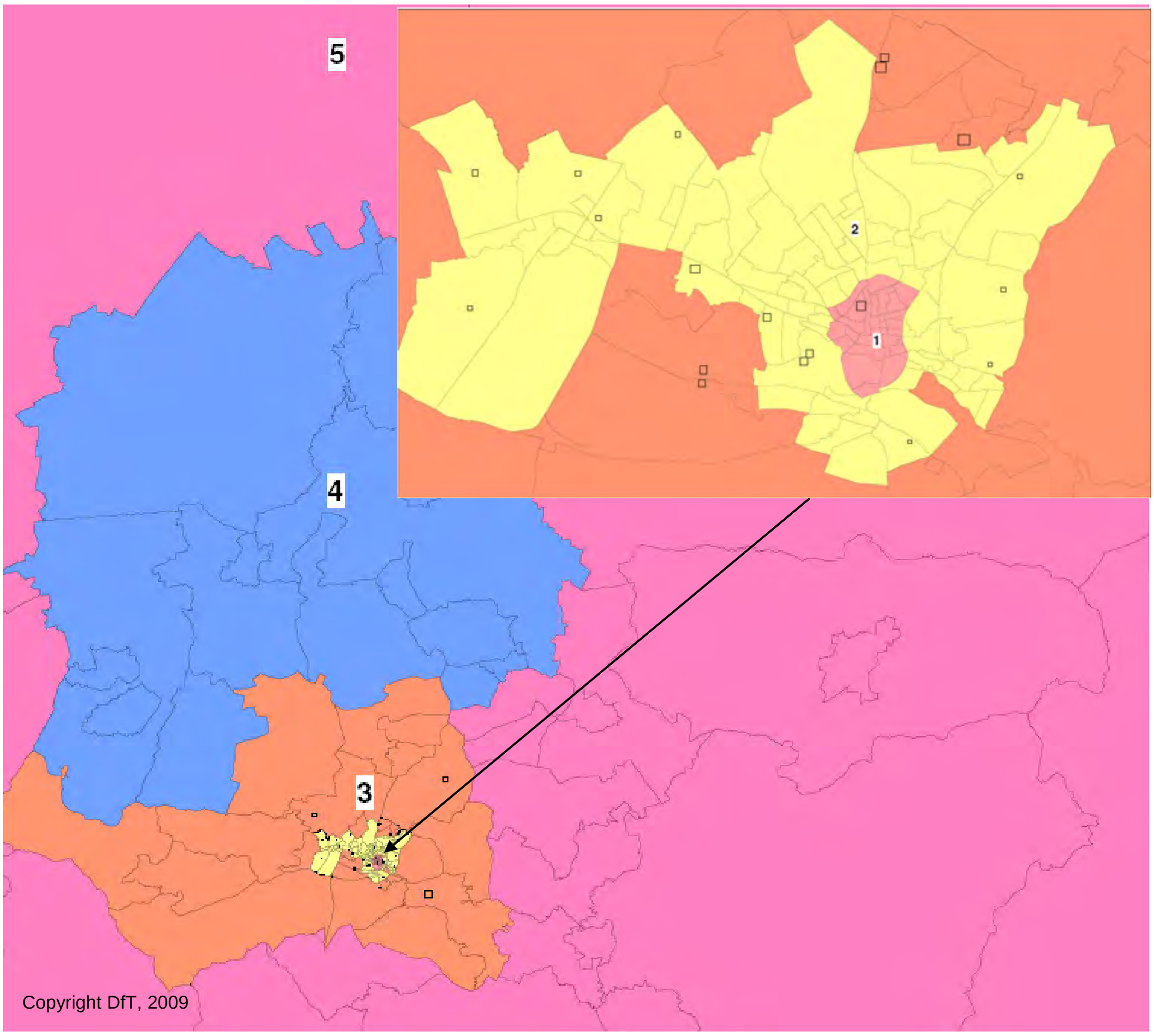


Figure 2.5 – Sector System



Temporal Scope

2.6 The scope of the Salisbury Transport Model framework is a 24 hour period of an average weekday. This is a requirement for production/attraction (PA) modelling rather than origin/destination (OD) modelling. Within the full model framework four time periods are specifically modelled, namely;

- Morning peak period from 07:00 to 10:00;
- Inter-peak period from 10:00 to 16:00; and
- Evening peak period from 16:00 to 19:00.

2.7 It is necessary to have an off-peak period to form a 24hr day but there is no need for an off-peak assignment model. The base off-peak demands and costs, are inferred from the base inter-peak demands and costs.

Vehicles and Trip Purposes

Within the Demand Model

2.8 TAG Unit 3.12.2 (para. 2.1.1. et al) provides guidance on the segmentation required for the modelling of road pricing. Although there is no immediate or indeed likely requirement to model road pricing in Salisbury, the SDM maintains this capacity; doing so is not detrimental to modelling non-road pricing schemes. Salisbury travel demands were segmented by car availability and journey purpose as described below. The structure of the demand model considers segmentation of demand by person type, income (effectively ignored in the SDM) and journey purpose:

- By person type
  - car available (CA); and
  - non-car available (NCA)
- By household income (ignored in this model)
  - Income Low (IL): less than £17,500;
  - Income Medium (IM): £17,500 to £35,000, and
  - 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).

2.9 Note the distinction made between home-based and non-home based purposes – this is required for adoption of PA-based modelling.

2.10 As noted above, the SDM segmentation was undertaken in a more aggregated form than that adopted for the demand models to significantly reduce the model runtimes. Salisbury aggregates the five demand purposes into two supply-side purposes namely:

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

Supply Models

Highway Model

2.11 The Salisbury Highway Model (SHM) model is a key element of the model framework as it is an integral part of the demand model as it undertakes the highway assignment that in turn provides highway costs to the demand model, which determines the highway and public transport demand.

2.12 Three separate weekday models will model the following time periods:

- the morning peak hour (08:00-09:00),
- an average inter-peak hour (between 10:00-1600), and
- the evening peak hour (17:00-1800)

2.13 The SHM model has been developed by incorporating new transport demand data from a number of road side interviews and a car park survey with existing school and work travel data. The highway network has been thoroughly updated from the previous Salisbury Highway model.

2.14 The new SHM has a base year of 2008 and its development and validation are described in *5076688 PD2.2 Salisbury Highway LMVR (Atkins 2009).*

Public Transport Model

2.15 The Salisbury Highway Model (SPTM) model is another key element of the model framework as it is an integral part of the demand model as it undertakes the public transport (bus and rail) assignment that in turn provides costs to the demand model.

2.16 Three separate weekday models will model the following time periods:

- the morning peak hour (08:00-09:00),
- an average inter-peak hour (between 10:00-1600), and
- the evening peak hour (17:00-1800)

2.17 The SPTM model was developed using the SHM as its starting point. The development work has entailed the estimation of bus demand matrices using up-to-date Wayfarer ticket data where available and the estimation of rail demand matrices using up-to-date ticket and survey data. The bus and rail services for autumn / winter 2008 were used.

2.18 The SPTM has a base year of 2008 and its development and calibration are described in *5076688 PD2.3 Salisbury Public Transport LMVR (Atkins 2009).*

3. Model Form

Introduction

3.1 The aim of this chapter is to describe the form of the Salisbury Demand Model (SDM) in some detail. This chapter specifies the:

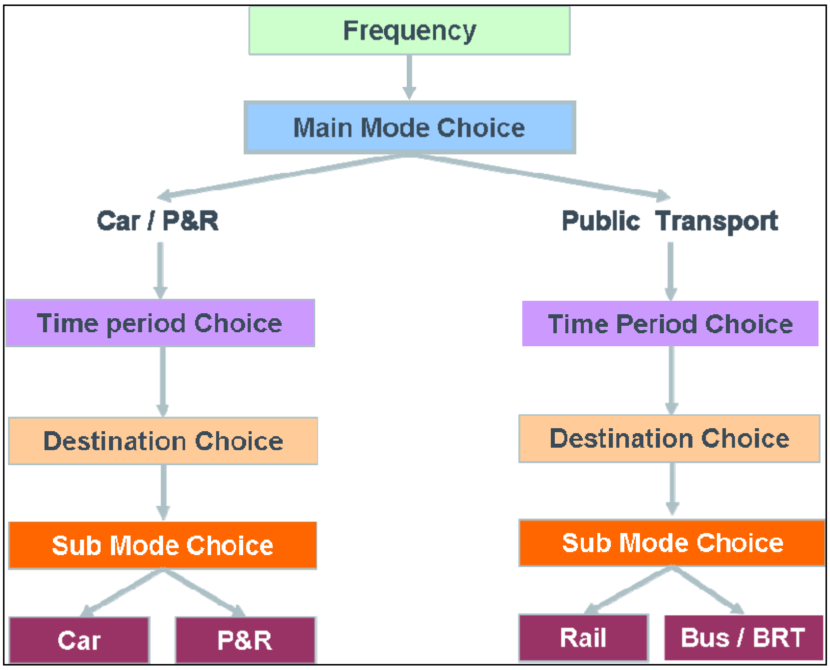
- model structure;
- model formulation;
- value of time variation with distance;
- modelling park and ride;
- pa-based time period choice;
- modelling the off-peak period; and
- demand and supply model outputs.

Model Structure

Demand Model Structure

3.2 A hierarchical logit choice structure as shown in Figure 3.1 is adopted for the SDM. Compliant to WebTAG, an incremental demand modelling approach was adopted which responds to changes from the base generalised costs, measured in generalised minutes.

Figure 3.1 – Demand Model Choice Structure



3.3 The sub-mode choice between bus, BRT and LRT (if any) is undertaken by the public transport assignment, i.e. they are within the same segmentation within the demand model. The park and ride (P&R) sub mode is a highway sub-mode and reflects the reality of most users switch from 'car –all-the-way' to park and ride. Any P&R extraction from 'bus-all-the-way' is modelled implicitly at the main mode choice stage and hence P&R is not a sub-mode of public transport.

3.4 An overview of the model stages, functional forms (e.g. OD/PA and Car-Available / Non-Car Available) and time periods is listed below in Table 3.1 for each of the six stages for Salisbury demand modelling. Note that 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.

3.5 The frequency modelling (stages 1) is undertaken for HBO and NHBO trips only as suggested by WebTAG. The main mode choice (stage 2) between car and public transport 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 public transport assignments (stage 6) are undertaken.

Table 3.1 - Salisbury 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)

Model Formulation

Generalised Cost Formulation

Private Car

3.6 WebTAG 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.

3.7 The Salisbury follows the WebTAG formulae for the definition of generalised costs for cars: Gcar , measured in units of time-minutes:

$$Gcar = Vwk*A + T + D*VOC/(occ*VOT) + PC/(occ*VOT)$$

where:

Vwk 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 (i.e. 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).

3.8 WebTAG 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 Salisbury is undertaken by following the WebTAG guidance.

Public Transport

3.9 WebTAG 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; and
- interchange penalty.

3.10 The WebTAG formula for public transport generalist cost GPT, measured in units of time (minutes) is given as:

$$GPT = Vwk*A + Vwt*W + T + F/VOT + I$$

where:

Vwk (=2) is the weight applied to time spent walking;

A is the total walking time to and from the service;

Vwt (=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; and

I (=10 minutes) is the interchange penalty if the journey involves transferring from one service to another.

3.11 The above weights 2 and 2.5 are obtained through the base calibration / validation work for the walk and waiting times, respectively.

Incremental Logit-Based Modelling

3.12 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 other model development work undertaken by Atkins.

3.13 The SDM is implemented in terms of utilities and composite utilities consistent to the WebTAG hierarchical logit (HL) formulation. The formulas given below are specified in terms of the WebTAG HL tree structure, i.e. using lambda parameters for the lower level sub mode choice and destination choice but using theta parameters for the upper level time period choice, main mode choice and the top frequency modelling.

3.14 It is also noted that the same sensitivity parameters are used for person types within the various household income segments (although not applicable to the SDM). This applies to all parameter values given below for destination choices and mode/time period choices.

Frequency Modelling

3.15 Salisbury 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.

3.16 The formulae 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

$\Delta U_{ipc} = \ln(\sum_m T_{ipcm}^{0} e^{\theta_m \Delta C_{ipcm}} / T_{ipc}^{0}$: logsum of lower level main mode choice.

3.17 WebTAG recommends that frequency modelling is undertaken for HBO and NHBO purposes only. The frequency modelling structure parameter is 0.05 for both purposes HBO and NHBO and for both person types CA and NCA, derived from iterative testing.

Main Mode Choice

3.18 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.

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

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

where:

i = production end; p: purpose; c: person type; m: main mode (car or public transport);

T^{0}_{ipcm} : reference zonal production tripends over i.p.c.m;

θ_m : main mode choice sensitivity parameter

T_{ipc} : input zonal production tripends over i.p.c from the above frequency stage;

$\Delta U_{ipcm} = \ln(\sum_t T^{0}_{ipcmt} e^{\theta_t \Delta U_{ipcmt}} / T^{0}_{ipcm}$: logsum of lower level time period choice.

3.20 The main mode choice sensitivity parameter values are provided below in Table 3.2. They are exactly the median WebTAG thetas shown in WebTAG 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.

Table 3.2 - Main Mode / Time Period Choice Parameters

Purpose	WebTAG Theta (Median)	Salisbury 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

3.21 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

3.22 WebTAG (Unit 3.10.2, para. 1.7.13) suggests 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.

3.23 The formula for the time period choice between the four periods (i.e. AM, IP, PM and OP period) is as follows:

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

Where:

t: time period;

T^0_{ipcmt} : 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;

$\Delta U_{ipcmt} = \ln(\sum_j T^0_{ijpcmt} e^{\lambda_{dist} \Delta U_{ijpcmt}} / T^0_{ipcmt}$: logsum of lower level, singly constrained destination choice for HBO, NHBO, NHBEB, and HBEB purposes; and

$\Delta U_{ipcmt} = \ln(\sum_j B_{jp} T^0_{ijpcmt} e^{\lambda_{dist} \Delta U_{ijpcmt}} / T^0_{ipcmt}$: logsum of lower level, doubly constrained destination choice for HBW purpose only.

Destination Choice

3.24 WebTAG (Unit 3.10.2, para, 1.7.11) recommends 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 (i.e. origin-and-destination) constrained distribution. To meet this requirement, a rectangular furnessing procedure was developed to undertake the HBW distribution modelling.

3.25 The formula for the singly constrained destination choice was:

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

where:

j = attraction end;

T^0_{ijpcmt} : 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

$\Delta U_{ijpcmt} = \ln(\sum_s T^0_{ijpcmts} e^{\lambda_{sub} \Delta C_{ijpcmts}} / T^0_{ijpcmt})$: logsum of lower level sub- mode choice.

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

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

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

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

3.28 The rectangular furnessing 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.

3.29 The formula for the doubly constrained distribution was

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

where:

j = attraction end;

T^0_{ijpcmt} : 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;

$\Delta U_{ijpcmt} = \ln(\sum_s T^0_{ijpcmts} e^{\lambda_{sub} \Delta U_{ijpcmts}} / T^0_{ijpcmt})$: logsum of sub mode choice

3.30 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) of this doubly constrained stage.

3.31 The initial values for the inner loops were:

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

3.32 Within the inner loops, before the logsum is evaluated, the attraction balance factors were normalised such that where N = number of zones with non-zero attractions.

3.33 The destination choice sensitivity parameter values are presented below in Table 3.3 and are derived from the realism tests described in Chapter 4. The demand model uses the maximum WebTAG illustrative lambdas specified in Unit 3.10.3 for highway distribution modelling except work (EB) trips, to which median lambdas are used. Again, the same lambdas are used for both CA and NCA public transport users inside the demand model by taking median WebTAG values.

Table 3.3 - Destination Choice Sensitivity Parameters

Purpose	WebTAG		Salisbury Demand Model	
	Highway (Median/Max.)	Public transport (Median)	Highway	Public transport (CA / NCA)
HBO	-0.090/-0.160	-0.036	-0.160	-0.036
NHBO	-0.077/-0.105	-0.033	-0.105	-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	-0.113	-0.033

Sub-Mode Choice

3.34 After destination choice, the sub-mode choices were undertaken for highway and public transport users independently. Park and Ride (P&R) users appeared in the single nest of sub mode choices (as previously shown in Figure 2.2), to facilitate the sub-mode switching in forecast years between highway and P&R only. WebTAG does not provide explicit values to be used for the sub-mode choice. demand modelling.

3.35 The formula for the sub mode choice was:

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

where

s: sub-mode such as rail, bus, BRT, P&R;

$T^0_{ijpcmts}$: 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 (-0.16, and -0.10 for highway and public transport, respectively);

$T_{ijpcmts}$: output PA matrix over p.c.m.t.s;

$\Delta U_{ijpcmts} = \lambda_{sub}(C_{ijpcmtsb} - C^0_{ijpcmtsb})$: the change of generalised costs at the lowest level of the hierarchy.

3.36 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 disutility - longer distance trips exhibited larger cost differences.

3.37 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:

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

Value of Time Variation with Distance

3.38 Given the nature of logit formulation, unrealistically large elasticities would normally derived for long distance trips. Value of Time (VOT) variation with distance for non-work trips has been introduced to enable the model to replicate recommended WebTAG elasticities.

3.39 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 Salisbury demand model.

3.40 Following discussions with the DfT and its advisor on other projects, 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 Salisbury 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 ηs: parameters.

3.41 Evaluation of the above formula 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.

3.42 The distance elasticity parameter (ηs) 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 as 7.58 miles (12.2 kilometres). The reason to use D_0 (=4km) is to deal with intra-zonal or short distance trips as the Salisbury demand model contains a large number of intra-zonal trips with estimated distances generally very short (<4km, approximately).

3.43 Table 2.6 below presents a summary of the VOTs used for the Salisbury demand model, where the VOT variation by distance is represented by the matrix average, minimum and maximum.

Table 3.4 – Variation of VOT by Distance

Purpose	Income Low	Income median	Income High	HBW	HBO/NHBO
Central Value	10.21	10.21	10.21	7.49	6.18
Matrix Average	12.31	12.31	12.31	10.15	7.45
Matrix Minimum	7.19	7.19	7.19	4.68	4.35
Matrix maximum	39.74	39.74	39.74	46.32	24.05

3.44 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 to the Department advisor, the central VOT values were resumed for the CA HBW demands.

Modelling Park And Ride

Overall Approach

3.45 Modelling park and ride (a highway sub-mode) raises a number of issues as it requires linking highway and public transport elements of the model.

3.46 There are four key stages in the park and ride 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 public transport legs of park and ride trips to the networks.

Deriving Park and Ride Generalised Costs

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

3.48 Park and ride sites are defined in the model as individual zones. In forecasting 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 public transport networks

3.49 The highway network model (SATURN) is used to determine travel times and costs from production zones to each park and ride zone. The public transport network model (EMME/2) is used to determine travel times and costs from the park and ride zones to each attraction zone.

3.50 A park and ride generalised cost for a given production to attraction zone movement is determined by taking the minimum combination of highway plus public transport costs – also taking into account a parking charge, public transport fare and site specific constant.

3.51 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.

3.52 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 park and ride site are assumed to have a choice of every park and ride site in determining the minimum generalised cost combination of highway and public transport. However, some restriction on the movements for which park and ride is a valid movement are applied to avoid illogical movements (e.g. 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

3.53 The park and ride generalised costs derived as described above with the lowest generalised cost highway plus park and ride combination being used in the demand model. The demand model conforms to WebTAG standards.

3.54 As shown in Figure 2.2 the demand model has a hierarchical structure. Park and ride appears at the bottom of the car nest of the main mode choice and is not treated as a public transport sub-mode.

3.55 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

3.56 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.

3.57 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):

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

where:

r = Park & Ride site under consideration;

k = all Park & Ride sites

θ_1 = 0.02, θ_2 = 0.02, and θ_3 = 0.01;

D_{pkq} : P&R trips from p to q using site r;

D^{c}_{pq} : input aggregated P&R matrix from the above highway and public transport sub mode choice;

C^{car}_{pr} : average generalised car costs from origin p to site r;

C^{PT}_{rq} : average generalised public transport costs from site r to final destination q

w_r : the total cost of parking at site r (including site penalties etc and currently 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).

3.58 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^{car}_{pr}) and public transport leg (C^{PT}_{rq}), 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, i.e. site choices are done at aggregate level.

3.59 The park and ride site choice mechanism was implemented by using the Emme2 matrix convolution methodology. The generalised cost for park and ride users was defined as the sum of the generalised costs of the car leg, public transport leg, parking charges and penalties at the park and ride sites. The average costs used in modelling were the average generalised costs across all segmentation, i.e. site choices are done at aggregate level.

3.60 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 there 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 and need to be added if new sites are to be considered.

3.61 The subsequent output from the site choice module consists of separate car-leg highway matrices and public transport-leg bus matrices. These car-leg and bus-leg demands were person PA trips which were then added into the relevant car and public transport 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 2008 RSI data for each of the appropriate demand on model segments (i.e. income, purpose and period)

PA-Based Time Period Choice

3.62 The introduction of PA-based modelling with the explicit consideration of time period choice is complex, particularly when (as shown in Figure 2.2), 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.

3.63 Within the demand model, the key issue was to determine the appropriate travel demand and associated costs of return-legs of home based trips 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.

3.64 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.

3.65 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

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

3.67 The four time periods (t) in a 24-hour day in Salisbury 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;

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

- s = t for t {am, ip, pm, op}.

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

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

The Off-Peak Period

3.70 The off-peak (OP) time period (i.e. 19:00 – 07:00) is modelled within the SDM (rather than by assignment) to enable the 24-hour model to be developed

3.71 WebTAG does not provide any guidance on how the off-peak 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 potential non-accumulation of scheme benefits within this period. The assumptions were:

- off-peak car users travelled at free-flow conditions in the base year;
- the change of off-peak costs was equal to the change in inter-peak costs in the same forecasting year; and
- the use of nominal off-peak base demands were assumed, consisting of 5% of the corresponding inter-peak base demands.

3.72 These assumptions ensured that the switch to the off-peak period from any of the morning peak, inter-peak and evening peak is always limited and restrictive.

Demand and Supply Model Inputs and Outputs

3.73 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 public transport assignments

3.74 The output from the public transport 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
- public transport matrices: demand by mode, skimmed in-vehicle time, wait time, penalties, and number of interchanges.

3.75 Both highway and public transport 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.

4. Data Sources and Analysis

Introduction

4.1 The aim of this chapter is to describe the data sources used in the development of the Salisbury Demand Model (SDM). This chapter specifies the:

- modelling factors; and
- base year matrices.

Demand Modelling Factors

4.2 One of the principal data sources for the demand model was the 2008 road side interview (RSI) survey data undertaken specifically for the STM, supplemented by other data sources such as TEMPRO and the National Travel Survey where necessary.

4.3 The following factors were derived from the 2008 RSI survey data:

- journey purpose splitting factors; and
- car occupancy factors by purpose and time period.

4.4 Table 4.1 provides factors by purpose and time period for the base year 2008.

Table 4.1 – Demand Segmentation Factors by Purpose

Purpose	Morning Peak	Inter-Peak	Evening Peak
Other (HBO)	0.235	0.436	0.254
Other (NHBO)	0.049	0.089	0.054
Work (NHBEB)	0.039	0.081	0.043
Work (HBEB)	0.056	0.034	0.059
Commuting (HBW)	0.620	0.365	0.590
Total	1.00	1.00	1.00

4.5 Table 4.2 gives highway car occupancy factors for the base year 2008 by purpose, income and time period. Note that no distinction was made between home-based and non home-based trips.

Table 4.2 – Highway Car Occupancy Factors

Time Period	Commuting	Work	Other
Morning Peak	1.15	1.22	1.67
Inter-Peak	1.14	1.18	1.74
Evening Peak	1.13	1.16	1.79

4.6 Table 4.3 summarises the 2008 from-home / to-home factors derived from the 2008 RSI surveys. These base year values are assumed to be constant across all the forecast years.

Table 4.3 – From-home / To-home Factors

Demand Segment	Morning Peak	Inter-Peak	Evening Peak
Commuting (HBW)	0.91 / 0.09	0.46 / 0.54	0.03 / 0.97
Other (HBO)	0.72 / 0.28	0.58 / 0.42	0.30 / 0.70
Work (HBEB)	0.94 / 0.06	0.35 / 0.65	0.15 / 0.85

4.7 Local household survey data was not available and the car availability person type factors were derived for the public transport segmentation using the 2008 public transport Surveys. Table 4.4 presents the Car-available (CA) and non-Car available (NCA) splitting factors for rail and bus users in the 2008 base year (i.e. assuming that bus users have the same equal split as rail users).

Table 4.4 – CA / NCA Splits for Rail & Bus Users

Demand Segment	Morning Peak	Inter-Peak	Evening Peak
Car available	0.655	0.569	0.606
Non-car available	0.345	0.431	0.394

4.8 The factors to convert demand from the peak hour to peak period (or inverse for the reverse), derived from the 2008 RSI surveys, are presented below in Table 4.5 by time period and segmentation.

Table 4.5 – Peak Hour to Peak Period Factors

Demand Segment	Morning Peak	Inter-Peak	Evening Peak
Car			
Commuting (HBW)	1.55	6.00	1.46
Other (HBO+NHBO)	2.84	6.00	3.07
Work (HBEB+NHBEB)	2.17	6.00	2.08
Bus			
All purposes	2.70	6.00	2.15
Rail			
All purposes	2.71	6.00	2.15

4.9 Table 4.6 and Table 4.7 present the base year 2008 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 4.6 – 2008 Value of Time by Person-Type

Demand Segment	Purpose	Value of Time (pence / minute)
Car Available	Commuting (HBW)	11.54
	Other (HBO+NHBO)	10.21
	Work (HBEB+NHBEB)	52.11
Non-Car Available	Commuting (HBW)	7.49
	Other (HBO+NHBO)	6.18
	Work (HBEB+NHBEB)	22.71

Table 4.7 - Demand Segmentation Factors by Purpose / Income

Purpose	Morning Peak		Inter-Peak		Evening Peak	
	Pence / Min.	Pence / Km	Pence / Min.	Pence / Km	Pence / Min.	Pence / Km
Non Work	15.02	7.22	17.47	7.22	16.17	7.22
Work	59.69	14.06	58.31	14.06	57.49	14.06

4.10 The values between Table 4.2, Table 4.6 and Table 4.7 are compatible between the person VOTs and vehicle PPMs. In calculating the PPMs of Table 3.7, WebTAG driver and passenger values were used accordingly with time-period specific occupancies given in Table 4.2; whilst in calculating the person VOTs of Table 3.6 WebTAG average car user values were used.

Base Year Matrices

Table 4.8 summarises the overall matrix totals per peak (trips per hour) by the highway assignment segment for cars following the application of the segmentation and fixed return proportion factors. Note that these totals do not include park and ride trips.

Table 4.8 – Validated Highway Base Year Demand by Segment (Cars only)

Purpose	Morning Peak	Inter-Peak	Evening Peak
Non Work Total	12267	8957	12368
Work Total	1353	1134	1402
Total Car	13620	10092	13770

4.11 Table 4.9 provides the 2008 base year bus trip totals per peak period by person type and purpose.

Table 4.9 – 2008 Base Bus Matrix Totals (Person)

	Purpose	Morning Peak Period (3hr)	Inter-Peak Period (6hr)	Evening Peak Period (3hr)
Car Available	Commuting Sub-Total	1,378	975	936
	Other Sub-Total	486	2,180	485
	Work Sub-Total	71	150	25
	Total Car Available (CA)	1,935	3,305	1,446
Non Car Available	Commuting	739	667	528
	Other	261	1,691	369
	Work	38	115	15
	Total Non Car Available (NCA)	1,038	2,473	912
	Total (CA + NCA)	2,973	5,778	2,358

4.12 Table 4.10 illustrates the 2008 base year rail person trip totals in terms of demand segmentation.

Table 4.10 – 2008 Base Rail Matrix Totals (Person)

	Purpose	Morning Peak Period (3hr)	Inter-Peak Period (6hr)	Evening Peak Period (3hr)
Car available	Commuting Sub-Total	727	409	511
	Other Sub-Total	256	770	502
	Work Sub-Total	37	54	33
	Total Car Available (CA)	1,020	1,234	1,047
Non car available	Commuting	390	269	278
	Other	137	592	261
	Work	20	41	16
	Total Non Car Available (NCA)	547	902	554
	Total (CA + NCA)	1,568	2,136	1,601

5. Demand Model Validation

Introduction

5.1 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
- *Public transport fare* - recommended elasticity between -0.1 to -0.4 up to 0.9.

5.2 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 Salisbury, 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.

Convergence Between Supply-Demand

5.3 The five-stage Salisbury demand model employs an iterative method to achieve convergence between the assignment models (i.e. SATURN highway and EMME/2 public transport) and the EMME2-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.

5.4 Two convergence algorithms were implemented within Salisbury 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.

5.5 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). Table 5.1 gives an example of the %GAP values for the Salisbury fuel cost realism tests.

Table 5.1 - Example of Convergence for the Salisbury Realism Tests

Demand/Supply Iteration	%GAP
5	1.336
6	0.780
7	0.444
8	0.258
9	0.154
10	0.087

Realism Tests

5.6 During the Salisbury model 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 parameters were the most appropriate for the Salisbury area (with respect to the demand hierarchy form presented in Figure 2.3).

5.7 The demand response parameters presented in Chapter two were the result of finer tuning of the minimum illustrative parameters – these were achieved by an iterative process of tuning the parameters values to achieve the target values described above.

5.8 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;
- *public transport fare elasticity*: *T* represents public transport trips and *C* represents fares.

5.9 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

5.10 The car fuel cost elasticities in terms of car vehicle kilometres with respect to (w.r.t) fuel costs, are shown below in Table 5.2, presented by segmentation of highway assignment user classes, i.e. 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.

5.11 The network-based fuel cost elasticities in Table 5.2 are given for each of the three peak hours. As requested by the DFT, the annual average fuel cost elasticities are reported in the last column by applying the Salisbury annualisation factors as follows (i.e. 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 3.5 for AM, IP, and PM periods respectively. (Note 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).

5.12 Table 5.2 also distinguishes between the various network areas (i.e. simulation, buffer link and buffer centroid connectors). The elasticity values presented are obtained by direct calculation on SATURN network statistics reported in output SATURN LPT files.

Table 5.2 - Car Fuel Cost Elasticity (WebTAG: -0.1 to -0.4)

PCU-Kms w.r.t Fuel Cost	Morning Peak	Inter-Peak	Evening Peak	Annual
Car – Total Non Work				
Simulation Area	-0.10	-0.11	-0.07	-0.10
Buffer Area (B)	-0.27	-0.32	-0.43	-0.33
Buffer Area (BCC)	-0.15	-0.22	-0.07	-0.16
Total	*-0.20*	*-0.25*	*-0.27*	*-0.24*
UC4 Car – Work				
Simulation Area	0.02	-0.02	0.10	0.03
Buffer Area (B)	-0.10	-0.09	0.01	-0.06
Buffer Area (BCC)	-0.03	-0.06	0.17	0.01
Total	*-0.07*	*-0.07*	*0.06*	*-0.03*
Total Cars				
Simulation Area	-0.08	-0.10	-0.05	-0.08
Buffer Area (B)	-0.23	-0.27	-0.32	-0.27
Buffer Area (BCC)	-0.13	-0.18	-0.02	-0.12
Total	*-0.18*	*-0.22*	*-0.20*	*-0.20*

Matrix Level

The matrix-based vehicle-km fuel cost elasticities are presented below in Table 5.3 with the elasticities reported by time period, by 'super' sector (i.e. Internal or External), and by purpose (i.e. HBW / HBO / NHBO / Work).

WebTAG species values between -0.1 and -0.4. The model meets the WebTAG requirement for combined non-work and work totals and for all purposes combined.

Table 5.3 – Matrix-Based Car Fuel Cost Elasticity

Time Period	Sector	HBW	HBO	NHBO	Non-Work (Total)	Work	All
Morning Peak	I to I&E	-0.33	-0.43	-0.43	-0.37	-0.16	-0.33
Inter-Peak	I to I&E	-0.19	-0.40	-0.39	-0.17	-0.17	-0.32
Evening Peak	I to I&E	-0.09	-0.36	-0.30	-0.21	0.09	-0.17
Annual	I to I&E	-0.20	-0.40	-0.38	-0.33	-0.12	-0.30

Car Journey time Elasticities

5.13 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 5.4.

5.14 Table 5.4 shows that journey time elasticities were all less than or equal to -2.00 as recommended by WebTAG. The overall journey time elasticities for the three time periods are -0.92, -1.11, and -1.04, respectively.

Table 5.4 - Car Journey Time Elasticity

PCU-KMs w.r.t Journey Time	Morning Peak	Inter-Peak	Evening Peak
Car – Total Non Work			
Simulation Area	-0.49	-0.58	-0.38
Buffer Area (B)	-1.38	-1.64	-2.18
Buffer Area (BCC)	-0.77	-1.11	-0.34
Total	-1.05	-1.29	-1.39
UC4 Car – Work			
Simulation Area	0.13	-0.11	0.53
Buffer Area (B)	-0.49	-0.45	0.07
Buffer Area (BCC)	-0.18	-0.32	0.85
Total	-0.34	-0.38	0.29
Total Cars			
Simulation Area	-0.41	-0.52	-0.25
Buffer Area (B)	-1.19	-1.37	-1.65
Buffer Area (BCC)	-0.66	-0.94	-0.09
Total	-0.92	-1.11	-1.04

Public Transport Fare Elasticities

5.15 The Public Transport (public transport) fare elasticities derived from the public transport realism test should reflect WebTAG elasticities between -0.1 and -0.4 up to -0.9. Matrix-based public transport fare elasticities were calculated by internal / external sector. Table 5.5 below presents fare elasticities for car available public transport travellers with “I to I&E” movements, whilst Table 5.6 shows fare elasticities for non car available public transport travellers not only with “I to I&E” movements but also with “Total” movements (including external to internal movements as well as “I to I&E” trips).

5.16 Table 5.5 shows that some of the elasticities of public transport demand (number of trips) w.r.t public transport fare increase were greater than -0.9. The overall elasticity for CA users is -0.71, within the range of values recommended by WebTAG (< -0.9).

Table 5.5 - Matrix-based CA public transport Fare Elasticities (WebTAG: up to 0.9)

Time Period	Sector	HBW	HBO	NHBO	Non-Work (Total)	Work	All
Morning Peak	I to I&E	-1.25	-0.37	-0.49	-1.02	-0.06	-0.98
Inter-Peak	I to I&E	-1.05	-0.32	-0.41	-0.56	-0.07	-0.54
Evening Peak	I to I&E	-1.08	-0.32	-0.34	-0.79	-0.05	-0.77
Annual	I to I&E	-1.13	-0.33	-0.42	-0.73	-0.07	-0.71

5.17 Non-car available (NCA) public transport demands are captive to public transport. Looking at the daily level the "Total" fare elasticities by purpose are all with small negative numbers. Compared to fare elasticity values in Table 5.5, the elasticities in Table 5.6 reflect very limited choice available for captive public transport users.

5.18 Looking at the NCA "I to I&E" movement in Table 5.6, there appear some positive fare elasticities for HBW: positive in the AM, IP, and PM 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 public transport 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 deceased. Therefore, the all-day net impact is balanced when all movements are considered (including "I to I&E" and "E to I"), as shown in Table 5.5, the "Total" fare elasticity of NCA HBW is zero.

Table 5.6 - Matrix-based NCA public transport Fare Elasticities (WebTAG: up to 0.9)

Time Period	Sector	HBW	HBO	NHBO	Non-Work (Total)	Work	All
Morning Peak	I to I&E	0.07	-0.06	-0.06	0.04	0.00	0.04
	Total	0.05	-0.07	-0.09	0.02	-0.01	0.02
Inter-Peak	I to I&E	0.39	-0.07	-0.07	0.07	0.00	0.06
	Total	-0.04	-0.06	-0.06	-0.05	0.00	-0.05
Evening Peak	I to I&E	0.69	-0.08	0.02	0.38	0.01	0.37
	Total	0.02	-0.05	0.00	-0.01	0.00	-0.01
Annual	I to I&E	0.37	-0.07	-0.06	0.13	0.00	0.12
	Total	0.01	-0.06	-0.06	-0.03	0.00	-0.03

6. Summary

6.1 The car vehicle-kilometre elasticities shown in the above tables demonstrate the Salisbury demand model replicates network-wide, published elasticities of the impact of fuel cost on vehicle kilometres. The annual average fuel cost elasticity -0.30 in Table 5.3 is in line with the national average of -0.3. The analysis demonstrates that the Salisbury modelling system is a robust tool for the forecasting of highway demand.

6.2 The majority of the public transport fare elasticities presented in Table 5.5 and Table 5.6 are within the range of WebTAG target values by using the median WebTAG lambdas and thetas specified in TAG unit 3.10.3, even though there are some large fare elasticities such as CA HBW. The analysis demonstrates that the Salisbury demand model is still a robust tool for the assessment of public transport demand forecasting.