APPENDIX 3
Hereford Multi-Modal Transport Model
Model Development and Validation Report

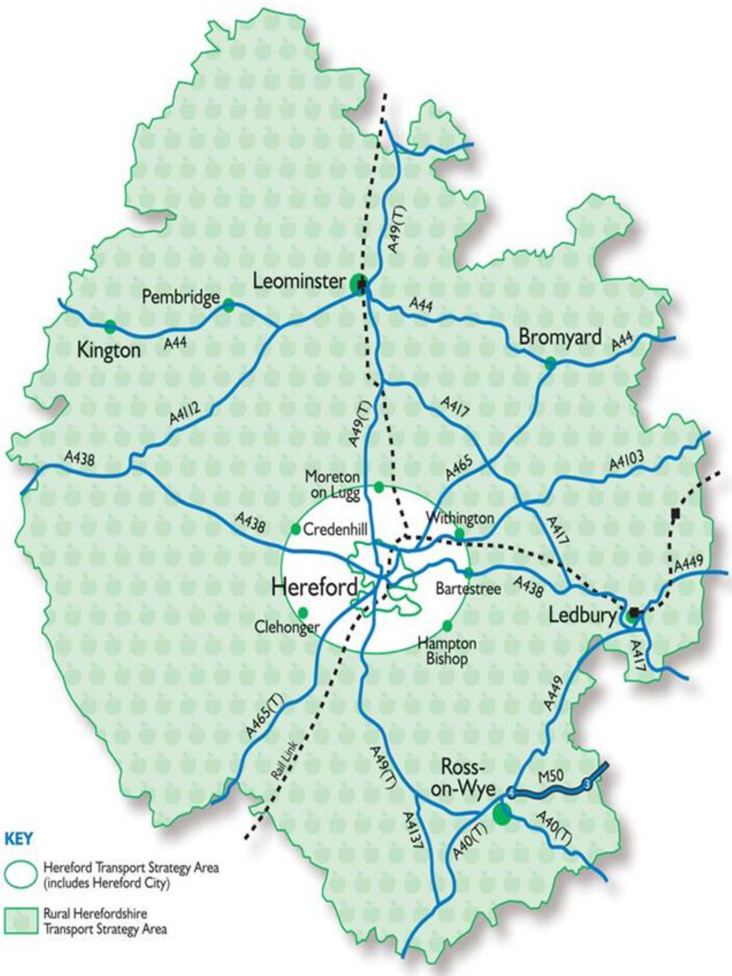
Hereford Multi-Modal Transport Model

Model Development and Validation Report

Document Reference: CO00551578-DR-03

Revision: 03

Issued: March 2014



Service is our passion. People, our strength

Document Control Sheet

Project Name:	Hereford Multi-Modal Transport Model
Project Number:	CO00551578
Document / Report Title:	Model Development and Validation Report
Document / Report Number:	CO00551578-DR-03

Issue Status/Amendment	Prepared	Reviewed	Approved
Draft Rev. 01	Name: John Rochester Signature: Date: 01.04.13	Name: Wayne Garside Signature: Date: 12.04.13	Name: Timothy Lynn Signature: Date: 16.04.13

Draft Rev. 02	Name: Wayne Garside Signature: Date: 09.05.13	Name: Timothy Lynn Signature: Date: 09.05.13	Name: Neil Anderson Signature: Date: 09.05.13
Draft Rev. 03	Name: Wayne Garside Signature: Date: 13.08.13	Name: Huw Williams Signature: Date: 19.09.13	Name: Timothy Lynn Signature: Date: 20.03.14
	Name: Signature: Date:	Name: Signature: Date:	Name: Signature: Date:

Contents

1. Introduction 1
1.1. Background 1
1.2. Model Overview 1
1.3. Purpose of this Report 1
1.4. Report Structure 2

2. Model Overview 3
2.1. Introduction 3
2.2. Model Scale and Form 3
2.3. Model Software 3
2.4. Model Time Periods 5
2.5. Modes 5
2.6. Journey Purposes 6
2.7. Geographical Extent and Zone System 6

3. Travel Data 11
3.1. Introduction 11
3.2. Traffic Flow Volumes 11
3.3. Journey Time Data 12
3.4. Public Transport Travel Data 12
3.5. Walk and Cycle Flow Volumes 12
3.6. Car Park Travel Data 13
3.7. Vehicle Registration Plate Data 13
3.8. Hereford Travel Surveys 13

4. Assignment Model Networks 15
4.1. Introduction 15
4.2. Highway Network 15
4.3. Public Transport Network 17
4.4. Cycle Network 18
4.5. Walk Network 19

5. Base Year Trip Matrix Development 20
5.1. Introduction 20
5.2. Highway Trip Matrix Development 20
5.3. Highway Trip Matrix Segmentation 21

5.4. Highway Trip Matrix Building from Multiple Data Sources 22
5.5. Highway Trip Matrix Merging 25
5.6. Highway Trip Matrix Smoothing/Estimation 27
5.7. Highway Prior/Final Trip Matrix Comparison 28
5.8. Final Highway Trip Matrices 30
5.9. Public Transport Trip Matrix Development 35
5.10. Final Public Transport Trip Matrices 36
5.11. Walk and Cycle Trip Matrix Development 38
5.12. Final Cycle and Walk Trip Matrices 39
5.13. Overall Base Year 2012 Person Trip Matrix Comparison 42

6. Model Assignment Calibration and Validation 44
6.1. Introduction 44
6.2. Multi-Modal Assignment Procedure 44
6.3. Highway Assignment Procedure 44
6.4. Highway Generalised Cost Function 44
6.5. Highway Assignment Convergence, Proximity and Stability 45
6.6. Highway Assignment Calibration 48
6.7. Highway Assignment Validation 48
6.8. Public Transport Model Assignment Procedure 65
6.9. Public Transport Assignment Validation 65
6.10. Walk and Cycle Assignment Procedure 68
6.11. Walk and Cycle Flow Validation 68

7. Conclusions and Recommendations 71
7.1. Summary of Key Findings 71
7.2. Recommendations 73

List of Figures

Figure 1: Hereford Detailed Study Area Zoning 7
Figure 2: Hereford Wider Area Zoning 8
Figure 3: Herefordshire County Full Area Model Network 9
Figure 4: Hereford City and Peripheral Model Network 9
Figure 5: Hereford City Model Network 10
Figure 6: Hereford City Centre Model Network 10
Figure 7: Trip Matrix Building Summary 21
Figure 8: Highway AM Matrix Trip Length Distribution Pre/Post Estimation 29
Figure 9: Highway IP Matrix Trip Length Distribution Pre/Post Estimation 29
Figure 10: Highway PM Matrix Trip Length Distribution Pre/Post Estimation 30
Figure 11: Hereford Sector Boundaries 52
Figure 12: Highway Journey Time Survey Route Map 63

List of Tables

Table 1: 2012 Hereford Model Trip Matrix: Internal and External Zones (154) 6
Table 2: AM Peak 2012 Highway PCU Trips Before and After Matrix Estimation 31
Table 3: Inter Peak 2012 Highway PCU Trips Before and After Matrix Estimation 32
Table 4: PM Peak 2012 Highway PCU Trips Before and After Matrix Estimation 33
Table 5: Final Trip Purpose Splits in 2012 Highway Model and NTEM V6.2 at 2011 34
Table 6: Public Transport Trips Before and After Matrix Estimation 37
Table 7: Cycling Trips Before and After Matrix Estimation 39
Table 8: Walking Trips Before and After Matrix Estimation 41
Table 9: Hereford Base Model 2012 Total All-Mode Trip Matrix Comparison with NTEM V6.2 Trip Ends (Persons Excluding Goods) 42
Table 10: AM Peak 2012 Highway Model Convergence and Stability 46
Table 11: Inter Peak 2012 Highway Model Convergence and Stability 47
Table 12: PM Peak 2012 Highway Model Convergence and Stability 47
Table 13: Final Post-Estimation Highway Trip Patterns by Time Period 2012 50
Table 14: External Highway Trips passing through Hereford by Time Period at 2012 51
Table 15: Hereford Base Model Trip Matrix AM Peak 2012: Selected Zones and Largest Sector Movements 53

Table 16: Hereford Base Model Trip Matrix Inter Peak 2012: Selected Zones and Largest Sector Movements 54

Table 17: Hereford Base Model Trip Matrix PM Peak 2012: Selected Zones and Largest Sector Movements 55

Table 18: Highway Classified Link and Junction Flow 'Secondary' Validation 58

Table 19: AM Peak 2012 Highway Model Cordon and Screen-line Flow 'Primary' Validation 59

Table 20: Inter Peak 2012 Highway Model Cordon and Screen-line Flow 'Primary' Validation 60

Table 21: PM Peak 2012 Highway Model Cordon and Screen-line Flow 'Primary' Validation 61

Table 22: Highway Classified Link and Junction Flow 'Secondary' Validation on A49 62

Table 23: Highway Journey Time Validation 64

Table 24: Highway Journey Time Validation 65

Table 25: Public Transport Flow Validation 67

Table 26: Bus Journey Time Validation 68

Table 27: Walk Flow Validation 69

Table 28: Cycle Flow Validation 70

Appendix A

Model Trip Matrix Building Spread Sheets

Appendix B

Highway Trip Length Distribution Plots

Appendix C

Highway Route Choice Plots

Appendix D

Highway Matrix Trip End Plots

Appendix E

Highway Assigned Flow Validation Spread-Sheets

1. Introduction

1.1. Background

1.1.1. This report describes the methods and components used to assemble a base year 2012 multi-modal transport model for Hereford on behalf of Herefordshire Council. It also verifies the accuracy of the base model with respect to accepted accuracy criteria and summarises the model's strengths, weaknesses and fitness-for-purpose.

1.1.2. Amey was commissioned by Herefordshire Council (HC), in November 2011, to develop a new Herefordshire Multi-Modal Transport Model (HMMTM). It is anticipated that the model will be used to test future impacts of land-use options and transport interventions, including: Local Plan core strategy development allocations (formerly LDF); a proposed Rotherwas Enterprise Zone; a staged relief road; sustainable (active) travel schemes; public transport improvements; and new traffic regulation and management.

1.1.3. The first stage in the project was to collect and analyse new data relating to travel patterns and network conditions at 2012. Outcomes from this were documented in the Transport Survey Report (March 2014). The second stage was to use these data to assemble and validate a base year 2012 transport model. The results are documented in this Model Development and Validation Report.

1.2. Model Overview

1.2.1. The multi-modal model structure comprises SATURN highway, CUBE public transport (PT) bus and rail and CUBE walk and cycle components. It covers the City in detail and outer Herefordshire at a coarser level. The 2012 upgrade is founded upon the 2008 multi-modal model, which was developed for Herefordshire Council and the Highways Agency, to assess LDF growth point scenarios and impacts of a Hereford relief road.

1.2.2. A new base model validation for each travel mode has been undertaken at 2012, using several new sources of trip origin-destination (O-D) records, flow movement counts, vehicle registration matches, journey time measurements and land-use trip rate estimates by zone and by type of activity. The full model will be projected to future years, using a CUBE variable demand and mode choice forecasting method.

1.3. Purpose of this Report

1.3.1. This report details the development, calibration and validation of the model at 2012 base year, to verify that it is a suitable platform for forecasting future travel conditions and robustly appraising different travel demand and transport intervention packages.

1.3.2. Model accuracy has been examined in terms of the validation criteria set out by the Department for Transport (DfT), in: Design Manual for Roads and Bridges (DMRB) Volume 12, Section 2, Part 1, 'Traffic Appraisal in Urban Areas' (Chapters 4.3, 4.4 and Appendix B); DfT former WebTAG guidance in units 3.19 and 3.11.2; and current Transport Analysis Guidance (TAG) Unit M3.1 (Highway Assignment Modelling); and Unit M3.2 (Public Transport Assignment Modelling).

1.3.3. Preceding documents have outlined the development and potential use of the model and are listed below:

- Hereford Transportation Model Scope for Model Development (October 2011);
- Hereford Transportation Model Development Proposal PQP (November 2011);
- Hereford Transportation Model Data Collection Survey Proposal (March 2012); and
- Hereford Transportation Model Transport Survey Report (March 2014).

1.4. Report Structure

1.4.1. In the remainder of this report, section 2 provides an overview of the model and section 3 summarises the data used for model development, matrix building and validation. Section 4 outlines the development of the highway, public transport, walk and cycle networks, whilst section 5 provides details of the development of the multi-modal base year demand matrices. Next, section 6 summarises the calibration and validation of the assignment model. Finally, section 7 provides some conclusions regarding the 2012 model validation.

2. Model Overview

2.1. Introduction

2.1.1. This chapter outlines the key parameters that define the scope and technical capabilities of the Hereford base year assignment model. It also contains a detailed description of the zoning system for the model.

2.2. Model Scale and Form

2.2.1. The developed model will be used to test future impacts of land-use options and transport interventions. It includes a multi-modal travel demand component, which assigns trips to highway, public transport, cycle and walk networks. There is interaction between the demand and network elements, to ensure that the impacts of transport interventions on travel demand and network performance can be fully represented.

2.2.2. The demand model interacts with the individual assignment models, so that equilibrium can be achieved between transport-supply (i.e. the costs and capacity of transport options) and travel-demand (i.e. the numbers of trips and their origin-destination patterns). Details about the model structure and processes and the method of operation are covered in the Scope for Model Development Report and are consistent with current DfT guidelines.

2.3. Model Software

2.3.1. Three software packages were used to implement the developed model on two platforms as detailed below:

- Highway assignment - SATURN 11.1.10;
- Public transport, walk and cycle assignment - CUBE Voyager 6.0.2; and
- Demand model - bespoke model, assembled using CUBE Voyager scripts.

2.3.2. The demand model was implemented in CUBE software, which was programmed using CUBE Voyager scripting language. It was tailored to match the specific requirements of the HMMTM study and includes full multi-modal mechanisms affecting travel decisions, including:

- Public transport crowding effects;
- Impacts of highway speeds on the public transport network;
- Mode choice;
- Destination choice;
- Time of day choice;
- Route choice; and
- Trip frequency selection.

2.3.3. This report is focused on the base year model development, only, entailing the matrix and network building, and assignment calibration and validation only. It does not describe the assembly of the future year demand model nor the forecast scenarios.

SATURN

2.3.4. SATURN is a comprehensive and reliable highway assignment modelling tool. It entails a capacity-restrained loading of zone-to-zone trip demands on to a geometrically defined road link and junction network. Network assignment of traffic is based upon route choice, to minimise costs of time and distance by private and goods vehicle.

2.3.5. It provides the accurate highway cost skims that are critical to the operation of the demand model.

2.3.6. SATURN includes two important mechanisms within its ‘simulation’ network, namely ‘flow metering’ and ‘blocking back’. These mechanisms restrain link flows and queuing capacities on a congested road network. Modelling them is important, owing to the prevalence of highway congestion in the Hereford urban area.

2.3.7. Using SATURN software provided continuity with the previous 2008 Hereford SATURN model, which gave a reliable starting point from which to develop the enhanced 2012 network. All SATURN model parameters were reviewed and amended as appropriate to comply with current guidance.

CUBE VOYAGER

2.3.8. CUBE Voyager is a public transport modelling package. It carries out a multiple mode, capacity-restrained, loading of combined PT travel demand (e.g. bus a rail passengers) on to an interconnected network of bus and rail lines and operated services. Choice of PT mode is determined within the assignment.

2.3.9. As in SATURN, the CUBE PT network assignment of passengers is based upon route choice, to minimise costs of time and distance by bus and train.

2.3.10. CUBE was also used to assemble separate walk and cycle models, each entailing a least-cost assignment of trip demand on to a representative ‘active travel’ network.

2.3.11. As with SATURN, using CUBE software provided continuity with the previous 2008 Hereford CUBE model, from which the PT, walk and cycle 2012 networks were derived. All CUBE model parameters were reviewed and amended as appropriate to comply with current guidance.

Demand Model

2.3.12. The demand model was implemented in CUBE and was programmed using CUBE Voyager script. It was tailored to match the specific requirements of the HMMTM study and allow for the following:

- Full multi-modal interaction (including highway capacity restraint, public transport crowding and impacts of highway speeds on the public transport network);

- Trip generation, attraction and frequency, at specific zones; travel mode choice; trip distribution amongst destinations; and time of day for travel.

2.3.13. All demand components of the base model were segmented by journey purpose.

2.3.14. The full variable demand and mode choice mechanisms were represented for all modes using CUBE. In the previous model, DIADEM was used to predict VDM responses for highway trips, only, whilst CUBE was used to predict modal split of non-highway trips, but non-highway trips were excluded from any VDM mechanisms. In the new model, all modes are now subject to variable demand effects.

2.4. Model Time Periods

2.4.1. Three 2012 models have been developed, corresponding with the following time periods:

- AM peak hour (08:00-09:00);
- Inter peak hour (11:00-12:00); and
- PM peak hour (17:00-18:00).

2.4.2. The modelled AM and PM peak hours have been selected as being the busiest during each of the respective 3-hour peak morning and evening time periods and were determined by analysing count data. The analysis is discussed in the Transport Survey Report. The model time periods are the same as those used in the 2008 model.

2.4.3. The modelled Inter peak is the hour for which traffic flows most closely reflect an average during the inter peak period (10:00 to 16:00). The main purpose of the Inter peak hour model is to provide representative data for economic assessment, which can be factored to represent the whole Inter peak period.

2.4.4. Each of the AM, IP and PM models are representative of an average weekday for the associated time period.

2.5. Modes

2.5.1. The complete model has four main modes of travel, namely:

- Highway;
- Public transport (comprising bus and rail);
- Cycle; and
- Walk.

2.5.2. In the highway model, the following vehicle types are assigned:

- Private cars;
- Light goods vehicles (LGV);
- Other goods vehicles (OGV); and

- Public service vehicles (PSV) – represented as fixed-route bus flows.

2.5.3. In the public transport model, the following passenger types are assigned:

- Bus users;
- Rail users; and
- Passengers walking to and from boarding and alighting points.

2.5.4. It should be noted that public transport demand is allocated to sub modes, bus and rail, during the assignment process.

2.6. Journey Purposes

2.6.1. Travel demands have been segmented into the following five trip purposes:

- Home based work;
- Home based education;
- Home based other;
- Combined home and non-home based employers' business; and
- None-home based other.

2.6.2. The segmentation of trip purposes is a simplification of the eight home-based and eight non-home-based trip purposes referred to in TAG and the National Trip End Model (NTEM) forecasting database. The chosen groupings have been selected to distinguish higher and lower value-of-time categories and also responsiveness to variable demand mechanisms, such as choice of trip destination and travel mode.

2.7. Geographical Extent and Zone System

2.7.1. The geographical extent of the model remains unchanged from the 2008 model, in which the study area was divided into a detailed core and a less detailed periphery. The detailed model covers all of Hereford City whilst the peripheral model extends between the city and the boundary of Herefordshire County.

2.7.2. The modelled trip-end zoning structure is as summarised in Table 1.

Table 1: 2012 Hereford Model Trip Matrix: Internal and External Zones (154)

Internal Zones	External Zones	
Hereford City (128 zones)	**Hereford County Hinterland (12 zones)**	**Herefordshire Boundary (14 zones)**
1-80 91-96 98-99 105-120 122-123 133-154	81-90 97 121	100-104 124-132

2.7.3. The number of origin and destination (O-D) zones has been increased from 123, in the 2008 model, to 154, in the 2012 model, in order to provide greater precision in the routing of journeys and to differentiate key trip generators and attractors (such as public off-street car parks in the city).

2.7.4. The number of zones has increased from 106 to 128, within the city segment of the model and from 5 to 14 at the external points. Within the city hinterland the 12 zones remain unchanged.

2.7.5. The 2012 modelled zone plan for the Hereford City zones is shown in Figure 1.

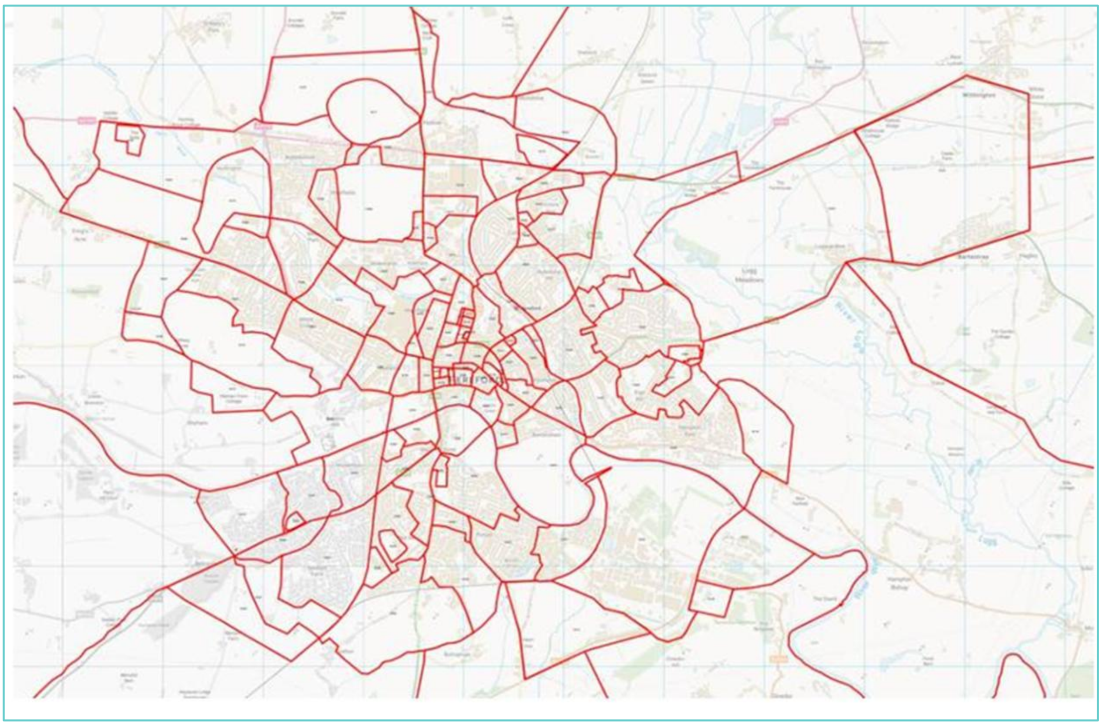


Figure 1: Hereford Detailed Study Area Zoning

2.7.6. The zoning system within the detailed study area is split in order to represent major trip attractors and generators. For example secondary schools and large supermarkets are given their own zones.

2.7.7. The 2012 modelled zone plan for the 12 Hereford City hinterland zones and the 14 external to Herefordshire zones are shown in Figure 2.

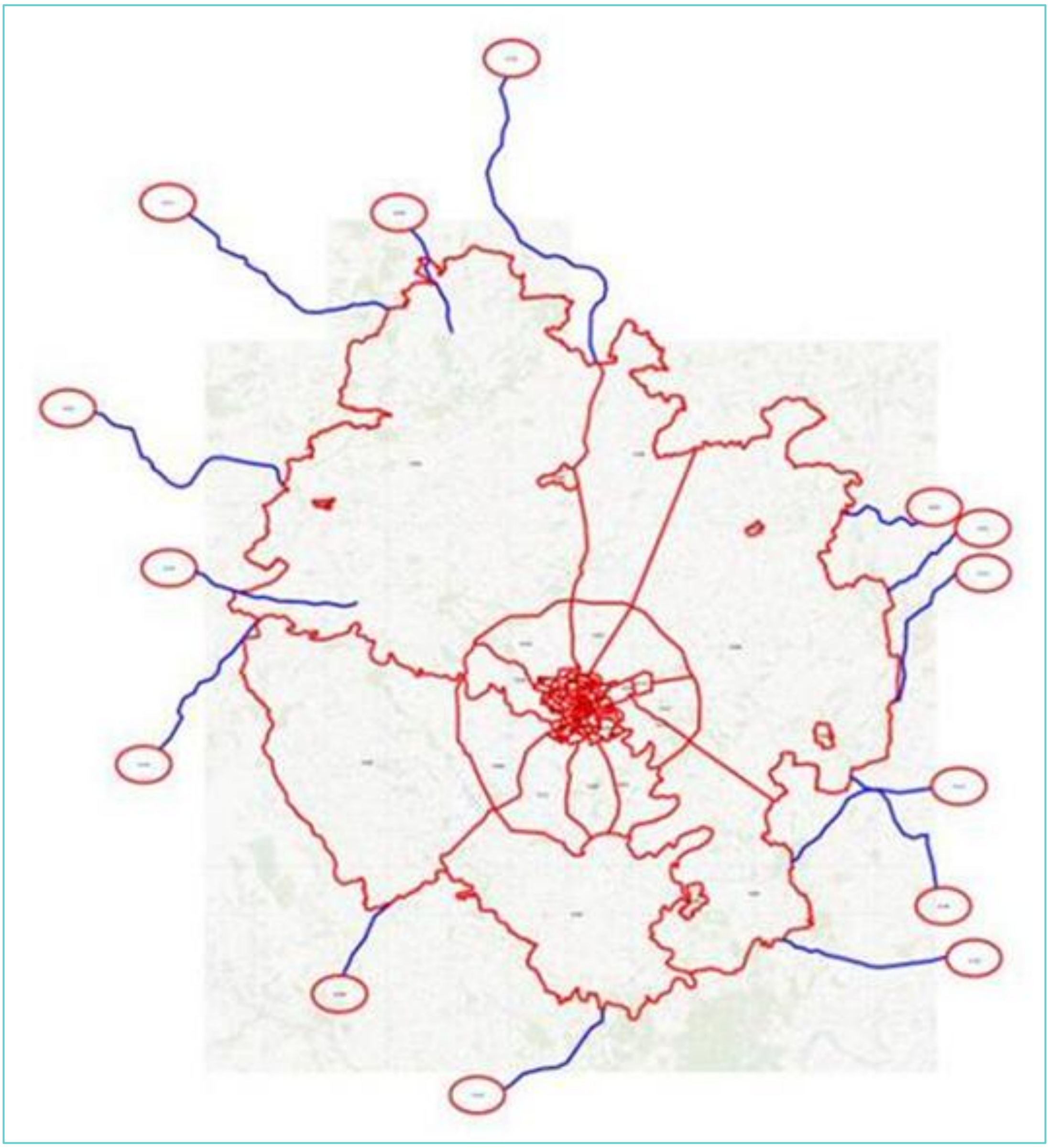


Figure 2: Hereford Wider Area Zoning

2.7.8. Figure 2 shows that Herefordshire rural areas are covered by relatively large model zones. However, the key settlements of Ledbury, Leominster, Ross-on-Wye, Kington and Bromyard are each allocated to an individual zone.

2.7.9. External zones have ben coded to represent, broadly, the main highway routes that access Herefordshire across the county boundary.

2.7.10. The extent of the modelled network, as represented for all travel modes, is shown in Figures 3, 4, 5 and 6, at increasing levels of detail from the full Herefordshire County area down to Hereford City centre.

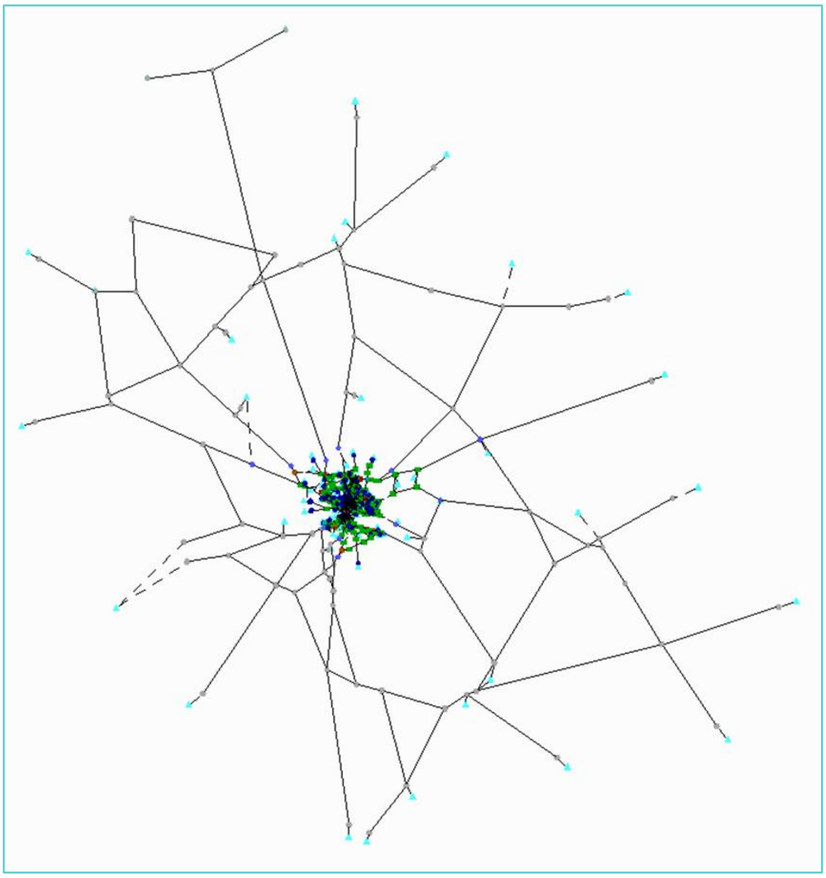


Figure 3: Herefordshire County Full Area Model Network

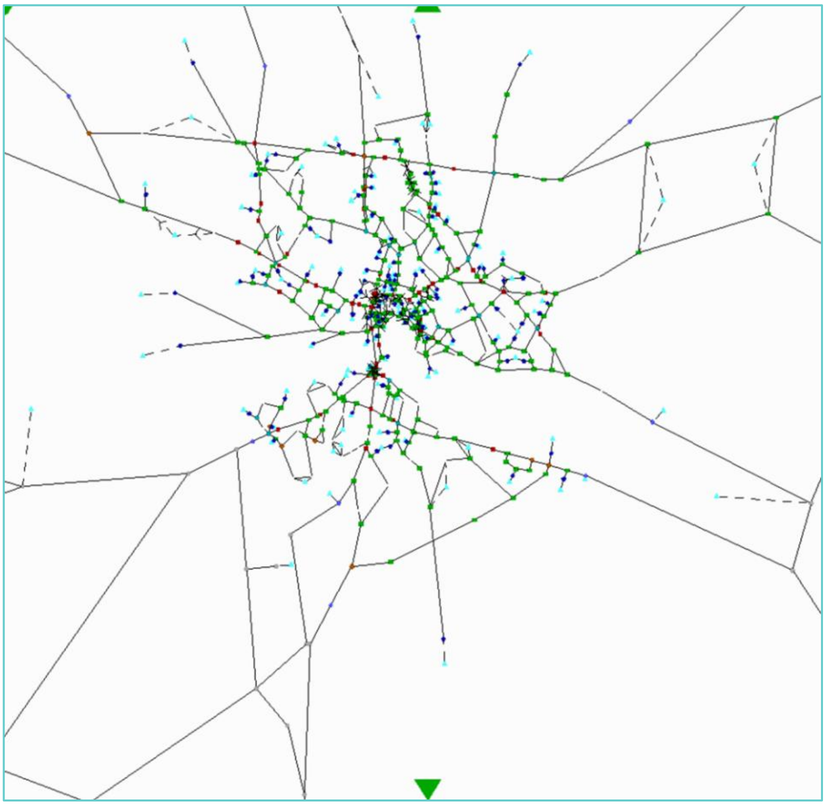


Figure 4: Hereford City and Peripheral Model Network

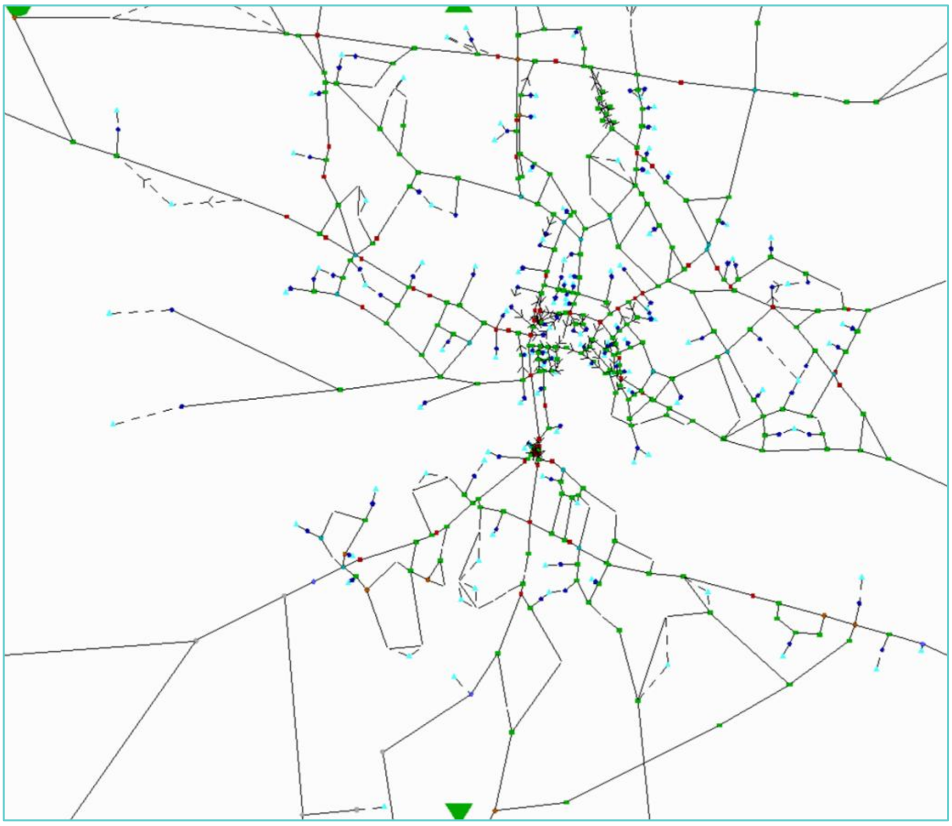


Figure 5: Hereford City Model Network

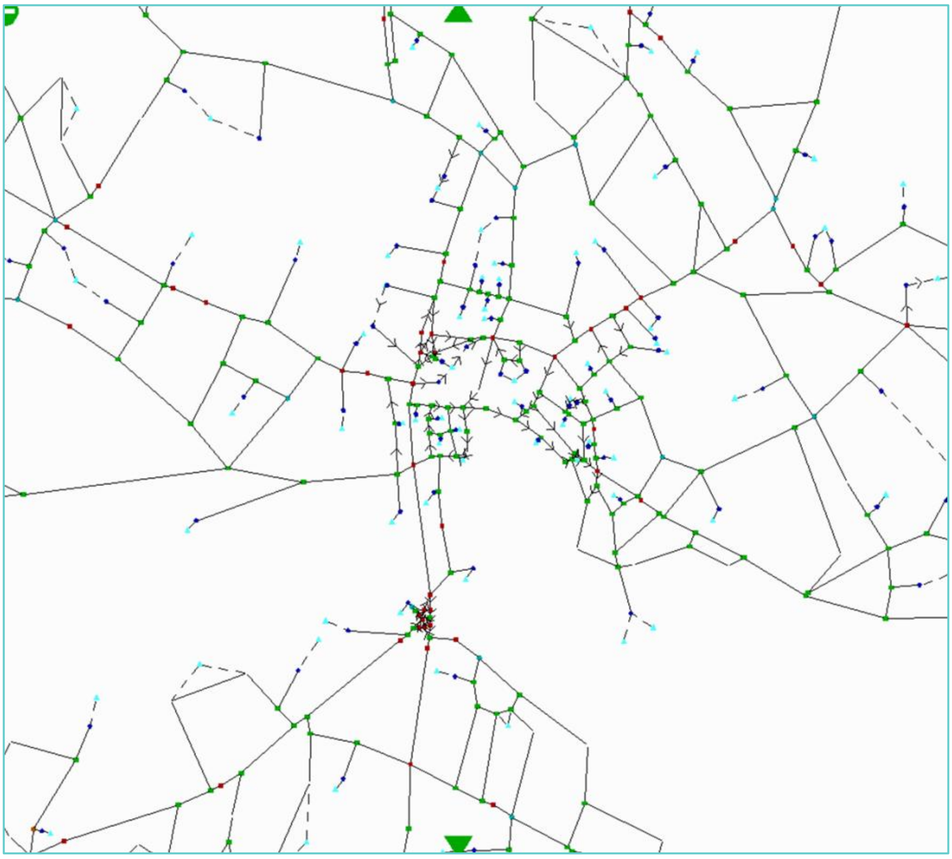


Figure 6: Hereford City Centre Model Network

3. Travel Data

3.1. Introduction

3.1.1. A large amount of travel data and interview responses reflecting trip movements in Herefordshire have been used to develop the 2012 model. A detailed description of the sources, dates, survey time periods and data collection and analysis methods is contained in the Transport Survey Report (March 2014). This chapter provides an outline of the data used to construct the base year model.

3.1.2. Data were collected for each of the AM, IP and PM base year model time periods and for the respective highway vehicle types and PT, walk and cycle modes. Wherever possible, O-D trip movements were segmented by trip purpose.

3.1.3. All data were carefully cleaned and checked to ensure consistency and good representation of a typical weekday, before being used in the base 2012 model.

3.2. Traffic Flow Volumes

3.2.1. Traffic flow volumes were required, to gauge current traffic conditions, calibrate and validate the traffic model, identify network operational characteristics and assess remedial schemes. Traffic count data from spring 2012, within the study area, were compiled from various sources, as follows:

- Long period, seasonal, Automatic Traffic Counts (ATC) (at 13 sites), provided by Herefordshire Council and the Highways Agency;
- Short-term ATC (at 4 sites), collected by Amey, during the survey period;
- Manual Classified Junction Counts (MCJC), of turning movements (at 43 sites), undertaken by Amey;
- Manual Classified Link Counts (MCLC) of link passing flows (at 43 sites), undertaken by Amey;
- Multi-Modal link video counts on main radial routes (at 7 sites), undertaken by Herefordshire Council; and
- Automatic Number Plate Recognition (ANPR) surveys (at 17 inner cordon, outer cordon and river screen-line sites), undertaken by Amey.

3.2.2. The traffic counts were also used as input to highway matrix estimation to enhance poorly observed segments of the O-D trip matrix.

3.3. Journey Time Data

3.3.1. Accurate travel time measurements, on key roads, were needed throughout the core study area in Hereford during the AM, PM and inter-peak periods. Journey time surveys were undertaken, in spring 2012, in both directions along six, cross-city routes, selected to include key junctions in the city. The surveyed data entailed free-flow link time, junction delays and overall route travel time. The highway journey times were checked for accuracy, albeit that when averaged they showed greater variability from the true mean route times, than was desirable. Additional journey times were collected, but these did not entirely rectify the variability. The journey time data were used to calibrate and validate the base model.

3.4. Public Transport Travel Data

3.4.1. Bus and rail passenger flow data were collected during the spring 2012 surveys. Bus passenger boarding, alighting and occupancy counts were undertaken to record volumes of passengers at key stops, on main radial routes for bus services around the city (at 5 inbound sites and at 6 outbound sites) and also at the three main interchange points, the City and County bus stations and Maylord Orchards. The same method was used to obtain the rail passenger boarding, alighting and occupancy data at Hereford station. The bus and rail count data was used for base year matrix estimation, model calibration and validation.

3.4.2. Bus travel time surveys were undertaken by Herefordshire County Council, in both directions, on 10 major bus routes throughout Hereford. The bus travel time measurements comprised both the free-flow travel time between each bus stop and the overall travel time, including delays at bus stops and junctions.

3.4.3. Accuracy of the timed runs was checked. Then the average travel times were calculated for each route and used to calibrate and validate the traffic model.

3.4.4. Ticket sales data from 2012 were obtained from the main bus and rail operators to provide a measure of the total number of people using each public transport service and to give essential part-trip (i.e. fare-stage to fare-stage, or station to station), O-D information for enhancing matrix estimation processes.

3.5. Walk and Cycle Flow Volumes

3.5.1. Walk and cycle flow volumes were recorded at 43 survey sites, by link direction, in spring 2012, as part of the MCC link surveys and at seven multi-modal cordon locations on main radial routes. In addition, pedestrian and cyclist movements were recorded at 11 key cordon locations where active travel routes intersect with major highways or form gateways in the city. As in the highway and PT models, the walk and cycle flows were used for matrix estimation, model calibration and validation.

3.6. Car Park Travel Data

3.6.1. Trip origin and destination movements were recorded at 14 of the main council-controlled, public off-street car parks, in the city centre, through a user questionnaire survey (interview and postal). This was supplemented by an entry and exit count undertaken at each car park to monitor usage levels and expand the response sample from the postcard questionnaire survey. The data collection was conducted during the AM, IP and PM time periods.

3.6.2. Trip O-D movements were recorded for the inbound vehicle journey to each car park and also the outbound vehicle journey from each car park. Movements were segmented by time of trip and journey purpose and then incorporated into the base year trip matrices.

3.7. Vehicle Registration Plate Data

3.7.1. A vehicle registration plate survey was undertaken to establish highway trip origin-destination movements within the study area. The survey consisted of 12-hour vehicle flow counts and accompanying AM, IP and PM sample records of vehicle registrations, passing in both directions through 17 monitoring sites, configured as an inner and outer cordon and river screen-line, covering strategic routes within the study area.

3.7.2. From the 17 sites, registrations were matched, by vehicle type, across nine outer cordon and eight inner cordon sites, including Wye river crossings at A49 Greyfriars and St Martins Street.

3.7.3. Matched movements were deduced between the following study area sectors:

- North of Wye external (outside the outer cordon, north);
- South of Wye external (outside the outer cordon, south);
- North of Wye internal (between the inner and outer cordon, north);
- South of Wye internal (between the inner and outer cordon, south); and
- City centre (inside the inner cordon, north of river).

3.7.4. The matched sector to sector records were then distributed amongst appropriate model O-D zones, according to trip orientation and then incorporated into the highway base year trip matrices.

3.8. Hereford Travel Surveys

3.8.1. Travel surveys in the form of household and workplace travel diaries were undertaken to establish the trip origins and destinations of vehicles travelling to, from and within the core study area (i.e. Hereford 'City Locality'), on a typical weekday.

3.8.2. Trip information from the travel surveys was used to produce a matrix of O-D movements, by time period, travel mode and trip purpose. These surveys were the primary source of accurate, base year O-D information, which was vital for predicting how route selection and mode choice for journeys may change in response to any future land use or transport improvements in the Hereford study area.

3.8.3. The household travel survey entailed a typical weekday travel diary that was distributed throughout Hereford city locality, to a random sample of respondents, stratified according to Census characteristics. The survey recorded trip O-D patterns of one occupant, above 16 years of age, in each household. Across a total target population of 48,690 (aged 15+) and 25,380 households in the surveyed area, a valid sample of 3,685 was achieved, equivalent to a sample rate of about 8% of people and 15% of households.

3.8.4. The workplace travel survey also entailed a typical weekday travel diary, which was distributed to employees of major organisations, operating in central Hereford. The survey was used to identify trip O-D patterns of all employees, including those whose residence was outside Hereford and who were, therefore, not captured by the household travel survey. Across a total targeted employee population of 6,650 at major workplaces in the surveyed area, a valid sample of 1,570 was achieved, equivalent to a sample rate of about 24%. In terms of the overall totality of Hereford employees, 29,650, representing all organisations in Hereford, a valid sample rate of about 5% was achieved.

4. Assignment Model Networks

4.1. Introduction

4.1.1. This chapter describes the development of the highway, public transport, walk and cycle networks and configuration of PT service 'lines' (i.e. scheduled bus and rail operations).

4.1.2. Wherever possible, the network configurations were retained from the previous 2008 Hereford model, as this was robustly assembled. However, careful checks have been made and amendments included where necessary, to ensure that the 2012 networks are up to date and coded appropriately for the required testing of land use and transport interventions.

4.2. Highway Network

4.2.1. The extent of the modelled highway network is discussed in section 2.7. A more detailed description of the highway coding is given below.

4.2.2. The SATURN model represents the highway network in and around Herefordshire in road link and junction (node) format. Considerable local detail was incorporated in the core area of the model (i.e. Hereford City), which was coded in 'simulation' format. Here, traffic assignment is controlled mainly by junction capacity constraints, delay, available lanes, permitted movements and 'blocking back' effects. 'Blocking back' occurs where queuing vehicles in a congested lane interrupt turning movements in other lanes that would otherwise operate within capacity. The outer surrounding area of Herefordshire was coded in simpler 'buffer' format, in which junction details are omitted and traffic assignment is controlled by link speed and capacity constraints and not junction congestion and 'blocking back'.

4.2.3. It was not necessary or advantageous to model all roads within Herefordshire, merely the main arterial and distributor roads. Local access roads were generally aggregated as a single O-D zone 'centroid' connector (i.e. zone entry and exit point), although local access roads that serve as bus routes are included individually in the model.

4.2.4. SATURN is a node-based model and is able to simulate junction characteristics in considerable detail. The accurate representation of junctions is a key feature of the core Hereford network. Details of the inventory process and coding procedures are described below.

<u>Junction Nodes</u>

4.2.5. Junction type was confirmed using aerial photography during the network inventory stage. Lane allocations were also interpreted from aerial photography and site visits to identify and allow for any obscured highway markings.

4.2.6. Junction capacities are modelled in terms of saturation flow. These were specified consistently throughout the simulation network, such that similar geometric layouts show comparable saturation flows. Modelled saturation flows are also consistent with conventional formulas that relate geometry and capacity (i.e. Greater Manchester Transportation Unit technical notes 155 and 306).

4.2.7. Turn bans were applied to the model in accordance with any existing Traffic Regulation Orders.

4.2.8. Nodes have been correctly located using GIS to determine the location of each junction.

Road Links

4.2.9. The model network was imported into a GIS package so that all nodes were correctly geocoded (associating each node with an Ordnance Survey grid reference). All links within the detailed and wider study area were also curved to the alignment of roads in the GIS package to estimate link distances to the nearest metre and subsequently fed back into SATURN. This approach ensured that link distances were realistic and consistent in both directions. Link lengths have been calculated using GIS.

4.2.10. Link capacities have been defined in terms of speed flow curves. Each directional speed flow curve is described by a free-flow link speed, speed at capacity, maximum link capacity across all lanes and an exponent (capacity restraint power). The exponent indicates the rate at which link travel time and delay increases when the link flow increases between free-flow and maximum capacity. Speed flow parameters were defined by road type, in accordance with DfT link characteristics specified in COBA10.

4.2.11. Use of speed flow curves was largely confined to non-urban links within outer (buffer) areas of the network. They were not generally used on urban links within the simulation network, because this would have entailed double-counting of simulated junction delay.

4.2.12. However, there are several parts of the simulation network for which speed flow curves have been defined, because it was not possible to model link delay through junction performance alone. This is typically the case on long semi-urban and rural links and also on urban links where bus stops, parking and side road interaction reduce link capacity without affecting junction capacity.

4.2.13. Speed limits have been assigned and checked against Traffic Regulation Orders.

Traffic Signal Timings

4.2.14. Current traffic signal data were obtained for junction and pedestrian crossing installations controlled by Herefordshire Council and the Highways Agency (A49). Data were input to the model for typical, average weekday conditions during the respective AM, IP and PM time periods. The input signal information comprised the following:

- Cycle time;
- Offset;
- Stage definition and sequence;
- Green splits;
- Stage inter-greens; and
- Average frequency of calls for demand-dependent traffic and pedestrian movements.

4.2.15. The modelled traffic signal timings represent only a snapshot of the SCOOT vehicle responsive control system, because it is not possible for SATURN to model the constant variation of signal timings (green splits, cycle times and offsets) that occurs on the ground.

Bus Networks

4.2.16. Bus services have been coded as fixed vehicle flows within the SATURN network, as well as being modelled specifically for passenger movements in the CUBE PT model. Inclusion of buses in SATURN ensures that a true representation is made of occupied road space and hence travel times and available capacity for other vehicles.

4.2.17. All buses operating within Herefordshire have been included in the highway network including school services.

4.3. Public Transport Network

4.3.1. The public transport model was constructed using CUBE Voyager. It consists of a network file, containing details of the infrastructure on which the public transport services run (i.e. roads and railways) and a line definitions file consisting of the specifications of the operated services in terms of their routes, stops, fare structures, timetables, and walk and wait penalties.

Network Infrastructure

4.3.2. Network infrastructure and zoning from the validated 2012 highway network were copied into CUBE to form the majority of the public transport network. This approach ensured consistency between the highway and PT networks, such that link speeds and junction delays could be passed from the highway to the public transport network, thereby achieving realistic speeds for buses.

4.3.3. PT bus and rail services have been superimposed on to the copied PT network.

Public Transport Routes

4.3.4. Bus and rail services were coded in accordance with published timetables and route maps. Service frequencies (headways) were extracted from the timetables. For services with irregular headways an average frequency per hour was assumed. For example, if a bus service operated at 10, 20 and 50 minutes past the hour, headway of 20 minutes was assumed.

Non-Transit Journeys

4.3.5. The start and end portions of PT journeys are not represented as on-board trips. These non-transit journeys were, however, included in the model as walk movements. These are called 'non-transit legs' and comprise the following:

- Travel between stops or stations and O-D zones at the beginning and end of trips; and
- Transfers between transit lines and PT modes.

4.3.6. The non-transit (walk) legs are considered to be part of a PT journey and cannot be separately transferred to other modes in the mode choice model.

Transit Speeds

4.3.7. Modelled bus journey times are based on the assigned road speeds in the highway model. However, adjustment factors have been applied to account for the slowness of buses, in comparison with the general traffic, caused by lower vehicle speed, dwell time at bus stops and time lost when buses arrive and depart each stop.

4.3.8. Speeds for rail services were derived from scheduled train timetables.

Public Transport Fares

4.3.9. The bus services in Herefordshire have been modelled with a single distance-based fare structure, across all routes. This was considered to be a suitable approximation of the complex stage-based fare structure that is operated in Herefordshire and which differs between routes.

4.3.10. Rail services have also been modelled with a distance-based fare structure derived from local station to station fares and distances between stations.

Crowding model

4.3.11. A form of capacity constraint, known as 'crowding', was represented in the PT bus and rail models. It reflects the capacity limitations of transit services and simulates the passenger discomfort on crowded vehicles and extra waiting time needed when vehicles are full to capacity. The discomfort and wait penalties were modelled as a higher travel cost for travellers.

4.3.12. The crowding model produces a penalty factor based on passenger utilisation of each PT service, representing the ratio of standing passengers to available standing capacity. The model also represents some passengers as standing before seating capacity is fully occupied. This allows a discomfort factor to be calculated, before all seats are taken.

4.4. Cycle Network

4.4.1. The cycle model network was constructed using CUBE Voyager in a similar way to the public transport network, based upon the validated 2012 highway model.

Network Infrastructure

4.4.2. Network infrastructure from the developed highway network was imported into CUBE to form the core cycle network. Additional, dedicated, cycle links were then added, as follows:

- Cycle route running north/south along the disused railway line between Penhaligon Way (Courtyard Theatre) and Redhill, known as the Great Western Way; this route incorporates a crossing of the River Wye to the west of the A49 Greyfriars;

- Cycle routes running east/west across Bishop`s Meadow and King George`s Field, south of the River Wye, including Victoria Bridge across the River Wye to the east of St Martins Street; and
- Cycle routes running east/west along Yazor Brook, between Plough Lane and Three Elms Road at Moor Park, with a further link between Plough Lane and Grandstand Road.

4.4.3. In addition, some one-way highway links were coded as two-way movements in the cycle model, to reflect the opportunity for cyclists to dismount and push their bicycles against the flow of traffic.

4.4.4. To be consistent with the previous model, all cycle links, at base year 2012, were coded with a fixed speed of 15kph. No junction modelling has been included in the cycle model. However, notional link capacity limits have been represented.

4.5. Walk Network

4.5.1. The modelled walk network was based on the newly created 2012 cycle network, but incorporated the following changes;

- One-way highway and cycle links were converted to two-way walk links;
- Walk links were added, constituting the pedestrian-only links in the core of Hereford city centre; and
- Pedestrian subways crossing beneath the Inner Ring Road and other key pedestrian links were included.

4.5.2. All walk links were coded with a fixed speed of 4kph, consistent with the previous model. No junction modelling has been included in the walk model. However, notional link capacity limits have been represented.

5. Base Year Trip Matrix Development

5.1. Introduction

5.1.1. The purpose of this chapter is to describe the process of constructing base year 2012 trip demand inputs for the HMMTM. The trip demands have been segmented by travel mode, journey purpose and time period.

5.1.2. Trip movements have been assembled from survey data, for the respective SATURN and CUBE models, as vehicle trips (in passenger car units – PCU) in the highway model, as passenger trips in the PT (bus and rail) model and as pedestrian and cyclist trips in the active mode (walk and cycle) models.

5.1.3. Trips are represented as a table of O-D zone-to-zone movements (i.e. a trip matrix) for each demand segment, which has been enhanced, using conventional matrix estimation techniques, to expand any poorly observed O-D cells.

5.1.4. Final 2012 matrix trips have been derived from the aggregated data sources itemised in chapter 3, after adjustments to remove double-counting of trips that were captured by more than one survey.

5.1.5. Matrices have been augmented using zone trip-end constraints, which reflect observed scales and types of land-use activity in each zone. They have also been calibrated against observed flow volume counts, on routes on the respective modal networks where particular zone-to-zone movements would be expected to travel.

5.2. Highway Trip Matrix Development

5.2.1. The highway matrices were built using, principally, the following sources of trip O-D data:

- Registration plate data matches for vehicles crossing an inner and outer cordon and river screen-line in Hereford City;
- Household travel survey (HTS) data from across Hereford City;
- Workplace travel survey (WTS) data from employees of key organisations within Hereford City; and
- Trip O-D survey data from Herefordshire Council public off-street car parks within Hereford City.

5.2.2. Data from the above sources were first processed: registration plates were matched to give trips between sectored areas; HTS, WTS and car park trip records were translated from O-D postcodes to model zones; trips were segmented by journey purpose and time period; and survey samples were expanded to observed control totals.

5.2.3. Next, analysed data from the respective sources were combined and duplicate trips removed.

5.2.4. Finally, the resulting matrices were assigned to the highway network and adjusted using the SATURN matrix estimation program. The purpose of matrix estimation was twofold: first to smooth out the O-D distribution of trips, thereby removing the 'lumpy' pattern derived from the restricted sample of observed data; and second, to enhance any poorly observed elements of the trip matrices. These matrix estimation stages are summarised in Figure 7.

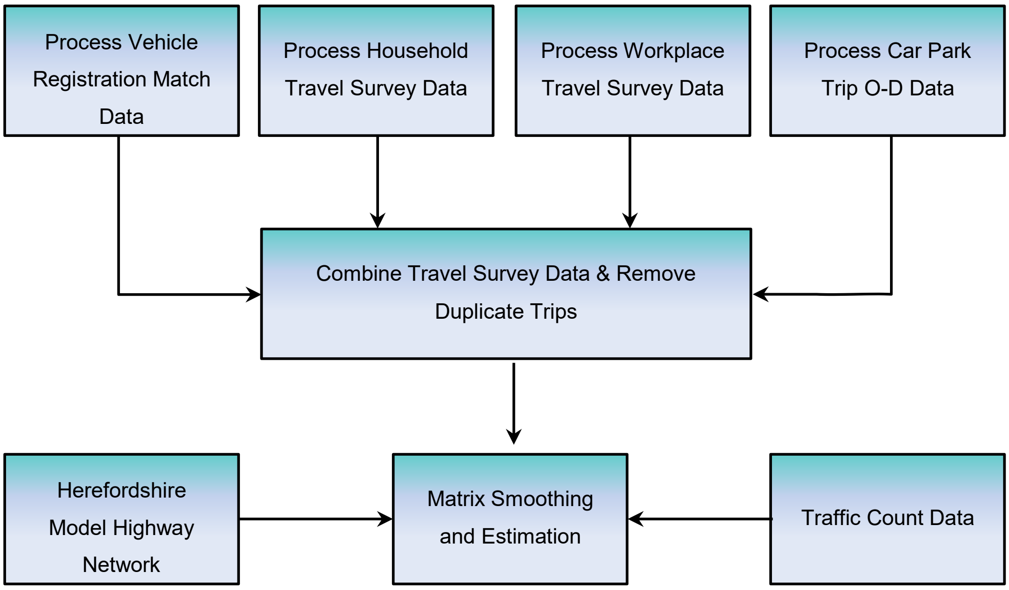


Figure 7: Trip Matrix Building Summary

5.3. Highway Trip Matrix Segmentation

5.3.1. The segmentation of highway trip matrices was undertaken by time of day, journey purpose and vehicle type. Below are the detailed segments of the highway matrices:

- Three modelled weekday time periods:
  - AM peak hour (08:00-09:00);
  - Inter peak hour (11:00-12:00); and
  - PM peak hour (17:00-18:00);
- Five trip purposes:
  - Home based work,
  - Home based education;
  - Home based other;
  - Combined home and non-home based employer's business; and
  - Non-home based other;
- Four highway vehicle classes:
  - Car;
  - LGV;
  - HGV; and

- PSV (fixed-flow buses).

5.3.2. Vehicle trips have been converted to Passenger Car Units (PCU`s). This procedure has been carried out for all data to be used in the highway modelling process and for the presentation of the model validation. Below are the vehicle to PCU conversion factors recommended from the Institution of Highways and Transportation (Transport in the Urban Environment, 1997, IHT), for each vehicle type within each user class:

- Car 1.0;
- LGV 1.0;
- OGV1 1.5;
- OGV2 2.3;
- Bus 2.0;
- Motorcycle 0.4; and
- Pedal cycle 0.2.

5.4. Highway Trip Matrix Building from Multiple Data Sources

5.4.1. This section focuses on the preparation and building of the individual dataset matrices that were ultimately combined to form the base year 2012 highway trip matrices.

Registration Plate Matrices

5.4.2. In order to process the vehicle registration data, the matrix zone system was aggregated into a number of appropriate sectors, whereby each sector was an identifiable group of trip origins or destinations, relative to the 17 registration survey sites. It was not possible to identify individual model zone to zone movements from the registration data.

5.4.3. For each possible O-D sector movement, a list was made of the registration match sites that would be passed through. This was done using maps and local knowledge to identify the possible routes between the O and D sectors, and the survey stations passed through along each route. The process of matching the registrations was aided by segmenting the registrations at each site by flow direction and vehicle type (i.e. car, LGV and HGV).

5.4.4. The survey data was subsequently coded into an ASCII text file, checked for errors and imported into the MICROMATCH program. An analysis of the data was then carried out by matching registrations through various sequences of survey sites, depending upon the sector O-D movements in question, for all possible O-D sector pairs. Logic constraints were set in the matching procedure to define the minimum and maximum feasible length of time taken to travel between each pair of survey sites. However, this was problematic as vehicle registrations were only recorded by 15-minute time slot.

5.4.5. As part of the matrix building process, unmatched registrations (i.e. registrations that were only observed at a single site) were also used to infill shorter distance O-D sector movements, which pass between adjacent sectors, but not through multiple sites.

5.4.6. The samples of matched and unmatched registrations, at the O-D sector level, were expanded to the accompanying classified link flow counts undertaken at each survey site, by vehicle type and time period.

5.4.7. After completing the registration matching and expansion, the new sectored registration O-D trips were spread amongst those detailed model zones constituting each sector, using initial proportions from the previous 2008 model.

5.4.8. A 'Furness' process was then used to factor the resulting full O-D matrix cells to meet target trip O and D trip-end totals for each model zone, by vehicle type. The application of an average factor to the whole matrix was not appropriate, as it would not achieve either the O or D targets. In essence, the Furness process applied a balancing factor to each row and column, iteratively, so that both the origin and destination targets were achieved. Trip end targets were set using a combination of land use trip rate profiles for internal model zones, together with 2012 link flow counts and previous 2008 trip end proportions for external zones.

5.4.9. Finally, the resulting car registration matrices were processed into the five required journey purposes using National Trip End Model (NTEM) purpose proportions, for the car driver vehicle category, as follows:

AM peak hour (08.00-09.00)

- 54.5% Home based work,
- 8.3% Home based education;
- 20.2% Home based other;
- 8.5% Combined home and non-home based employer's business; and
- 8.5% Non-home based other.

Inter peak hour (11.00-12.00)

- 15.1% Home based work,
- 6.4% Home based education;
- 52.2% Home based other;
- 9.8% Combined home and non-home based employer's business; and
- 16.5% Non-home based other.

PM peak hour (17.00-18.00)

- 39.9% Home based work,
- 2.9% Home based education;
- 40.6% Home based other;
- 7.2% Combined home and non-home based employer's business; and
- 9.4% Non-home based other.

Household Travel Survey Trip Matrices

5.4.10. In the household travel survey, the home address, ultimate destination, start time, travel mode and journey purpose, for each specified trip, were recorded. Household travel survey data responses were allocated to model zones by geo-coding the origin and the destination postcodes.

5.4.11. It was not possible to take account of an intermediate, planned stop-off destination during a recorded HTS journey, because there were insufficient responses against this item in the data set. If a recorded highway trip ended at an identified car park, the trip was coded to this zone in the model, rather than to the final destination zone, because there was found to be no accurate way of linking car park use with final destination in the model.

5.4.12. Logic checks were carried out to ensure that the HTS O-D patterns were sensible in relation to journey purpose and time of travel. The checked responses were subsequently expanded to population estimates for Census Lower Super Output Areas (LSOA), split amongst constituent model zones. Consistent expansion factors were applied across all time periods. Household O-D matrices were then produced for each model period and trip purpose.

Workplace Travel Survey Trip Matrices

5.4.13. In the workplace travel survey, the origin of each inbound trip to the place of work, the destination of each outbound trip from the workplace, and the travel mode, start time and trip purpose, for the respective inbound and outbound journeys, were recorded. Employee responses were allocated to model zones by geo-coding the origin and destination postcodes.

5.4.14. If a recorded highway trip ended at an identified car park, the trip was coded to this zone in the model, rather than to the final work destination zone, because there was found to be no accurate way of linking car park use with final destination in the model.

5.4.15. Again, logic checks were undertaken to ensure that the O-D patterns were sensible in relation to journey purpose and time of travel. Responses received from each workplace were cleaned to remove spurious records, analysed by time of travel and expanded to the total number of employees in that organisation and appropriate trip O-D zone. The responses could not be expanded to the level of total Hereford employees, because the collected responses in certain zones were not necessarily representative of other workplaces and other zones. Furthermore, there was no available information regarding the proportion of total employees that were full-time, permanent positions at regular workplaces, so reliable expansion factors could not be derived.

5.4.16. Finally, workplace O-D matrices were produced for each model period and trip purpose.

Car Park Travel Survey Trip Matrices

5.4.17. The car park survey recorded the origin of the inbound vehicle trip to the car park, the destination of the outbound vehicle trip from the car park, the time of travel, vehicle type (i.e. Car or LGV) and trip purpose.

5.4.18. Car park survey responses were allocated to model zones by geocoding the origin and destination postcode of the sampled trips. For certain trips, the destination of the vehicle journey leaving the car park was not recorded. Here, the likely destination and trip purpose were interpreted as the reverse of the inbound vehicle journey to the car park. The outbound trip time was interpreted from the survey form (e.g. the journey purpose), or from the profile of flows counted at the car park entry and exit.

5.4.19. Logic checks were performed to ensure that the O-D patterns were sensible relative to journey purpose and time of travel. The checked responses were subsequently expanded to match counted car park entry and exit flows. Car park O-D matrices were then produced for each model period and trip purpose.

Detailed Handling of O-D Trip Data

5.4.20. A detailed overview of how the various components of segmented trip O-D demands were manipulated for use in the base year model is given in Appendix A. This contains extensive manipulation spread sheets, which were developed from the data appendices in transport survey report. These manipulation spread sheets outline the adjustments made to the each of the datasets, comprising:

- Car park survey (‘Hereford Car Park Data - with coding HW 081112.xls’);
- HTS (‘HTSJOU~1 Analysis.XLS’, ‘HouseholdMatrices.xls’ and ‘HTS Journey Purpose Analysis HW.xls’); and
- WTS (‘Hereford WTS Combined Raw Data HW 18-10-12.xlsx’).

5.4.21. In addition, there is a spread sheet summarising the land-use trip-end constraints that were identified for each model zone, based upon scrutiny of mapping, photography, published data and local knowledge:

- (‘Model Trip Ends (Planning Data) TJL Rev 150113hw.xlsx’).

5.4.22. NTEM trip end data calculations are also given for 2011:

- (‘Tempro NTEM 6.2 Hereford 2011_12 V7.xlsx’).

5.5. Highway Trip Matrix Merging

5.5.1. Owing to the broad coverage of the individual O-D surveys, it was possible that some movements would be fully observed in more than one of the survey trip matrices. A trip from Ledbury to Rotherwas, for example, could be observed in the inbound direction, towards Hereford, in both the vehicle registration matrix and in the workplace survey matrix. However, owing to the relatively poor response rate in the respective trip O-D surveys, it was unlikely that one person’s trip at a particular time was captured by more than one survey.

5.5.2. The various O-D data sets were therefore 'merged', prioritising the order in which data sources were used, so as to reduce any risk of double counting and to give the best estimate of the actual number of trips making each O-D movement. Rather than simply averaging the double counted cell values, across each of the duplicated surveys, the adopted 'merging' procedure reflected the respective accuracies of the different data sources for particular travel movements. Trip O-D movements were retained from the most reliable surveys and then in-filled or omitted from the less robust surveys.

5.5.3. As a further control on the double counting of O-D movements, the numbers of trip departures and arrivals at each model zone, by mode, time period and purpose, were constrained in line with trip volumes that were predicted from the scales and types of land-use within that zone. The land-use details were used in conjunction with a trip rate database (e.g. TRICS) to predict the upper and lower limits on trip numbers.

5.5.4. At its broadest level, the matrix merging strategy entailed the following prioritisation of data sources:

<u>AM peak hour (08.00-09.00)</u>

- External to external – registration plate matrix only;
- External to internal – workplace, registration plate, then car park, matrices;
- Internal to external – household, registration plate, then workplace, matrices; and
- Internal to internal – household, workplace, car park, then registration plate, matrices.

<u>Inter peak hour (11.00-12.00)</u>

- External to external – registration plate matrix only;
- External to internal – registration plate, car park, then workplace, matrices;
- Internal to external – household, registration plate, then car park, matrices; and
- Internal to internal – household, car park, registration plate, then workplace, matrices.

<u>PM peak hour (17.00-18.00)</u>

- External to external – registration plate matrix only;
- External to internal – household, registration plate, then car park, matrices;
- Internal to external – workplace, car park, then registration plate, matrices; and
- Internal to internal – workplace, household, car park, then registration plate matrices.

5.6. Highway Trip Matrix Smoothing/Estimation

5.6.1. Matrix estimation has been applied, in SATURN, to the base AM, IP and PM models, in a carefully controlled process. It was used to smooth the distribution of trips from the observed data and to enhance poorly observed elements of the trip matrices. There were two steps in matrix estimation, namely: run SATPIJA to calculate the likelihood (i.e. proportion) of specific O-D movements using particular road links and junction turns; then run SATME2 to factor the input matrix O-D movements to match a selection of link and junction flow counts and O/D trip end totals.

5.6.2. The estimation process has been controlled, using the following techniques:

- Estimate separately by vehicle class (i.e. car, LGV, HGV), to calculate existing O-D movements using particular network links and turns and factor to observed counts, retaining existing journey purpose splits from the input pre-estimation matrix;
- Estimate using maximum internal iterations and estimation loops, to ensure convergence between modelled flows and observed counts;
- Apply low matrix adjustment factor (i.e. maximum of 4.0), to discourage the estimation process from creating too many short-distance trips;
- Include zone trip end origin and destination constraints, by vehicle class, as derived from land-use trip rate estimates, to assist the model in producing a reliable trip distribution; and
- Estimate in three stages, whereby, the first was to assemble a prior matrix; the second was to estimate under control of both flow counts and trip end constraints together; and the third was to estimate again under control of flow counts alone.

5.6.3. The traffic count data for the matrix estimation runs was obtained for base year 2012 from five sources, namely:

- Manual classified junction counts;
- Manual classified link counts;
- Long period Automatic Traffic Counts (ATC) from Herefordshire Council's database;
- Long period ATC counts from the Highways Agency's TRADS database; and
- Entry and exit counts for Herefordshire Council's public off-street car parks within Hereford City.

5.6.4. All counts were checked to exclude counts affected by known 'unusual' events such as accidents, road works, adverse weather conditions, holidays etc.

5.6.5. Where manual classified counts were used, these were segmented by car, LGV and HGV for each of the modelled hours. Where ATC counts were used, all-vehicle combined flows were extracted. These were then converted into separate car, LGV and HGV flows using vehicle composition factors calculated from manual counts at comparable locations.

5.6.6. Matrix estimation procedures require accurate and consistent traffic counts if they are to work successfully. As matrix estimation strategies were developed, inconsistent counts were identified and either re-analysed or eliminated from this process. Reasons for counts being eliminated included:

- Day-to-day variations in traffic flows;
- Enumerator errors; and
- Other errors, such as count transcription errors, where counts are specified with incorrect locations, or incorrect directions of movement.

5.7. Highway Prior/Final Trip Matrix Comparison

5.7.1. In order to assess the change in trip distribution brought about by the matrix smoothing and estimation exercise, the following comparisons were made between the prior (pre-estimation) and final (post estimation) highway trip matrices:

- Change in trip patterns at matrix sector level; and
- Change in trip length distribution.

5.7.2. These comparisons provide some reassurance as to the minimal distortion caused by the matrix adjustment processes. Trip length distribution calculations for the AM, IP and PM highway models are shown in Appendix B. The plots in Figures 8, 9 and 10, for the AM, IP and PM respectively, indicate total PCU trip volumes by distance band for: the prior matrix (stage 1); the estimated matrix, constrained to both counts and land-use trip ends (stage 2); and the estimated matrix, constrained to counts alone (stage 3).

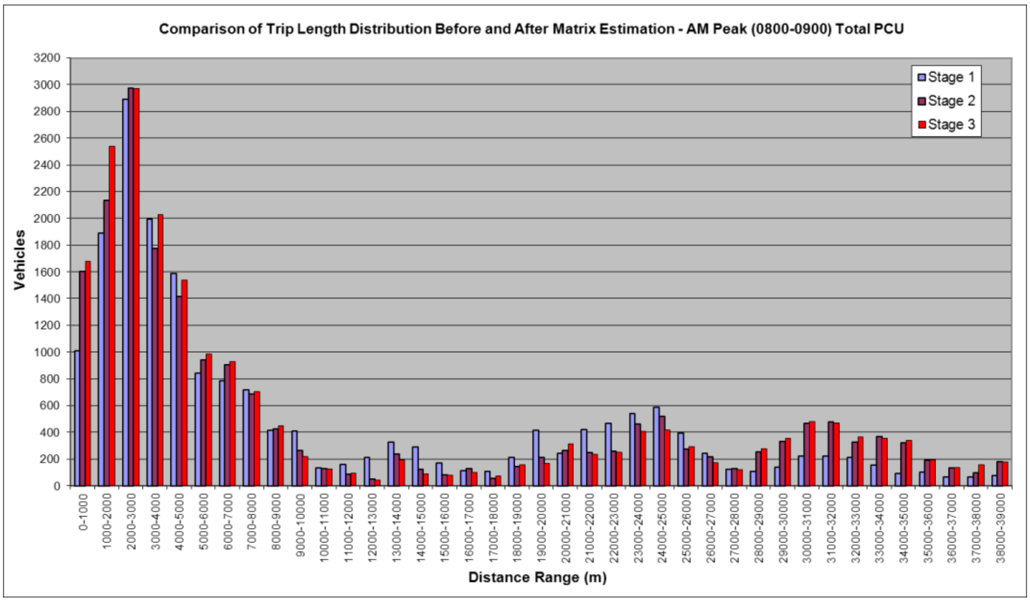


Figure 8: Highway AM Matrix Trip Length Distribution Pre/Post Estimation

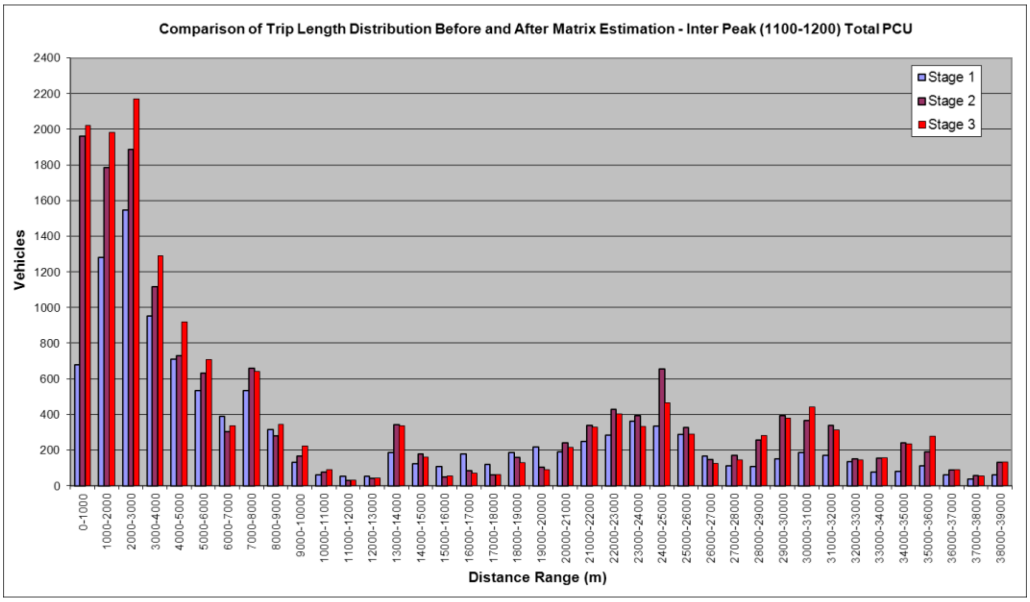


Figure 9: Highway IP Matrix Trip Length Distribution Pre/Post Estimation

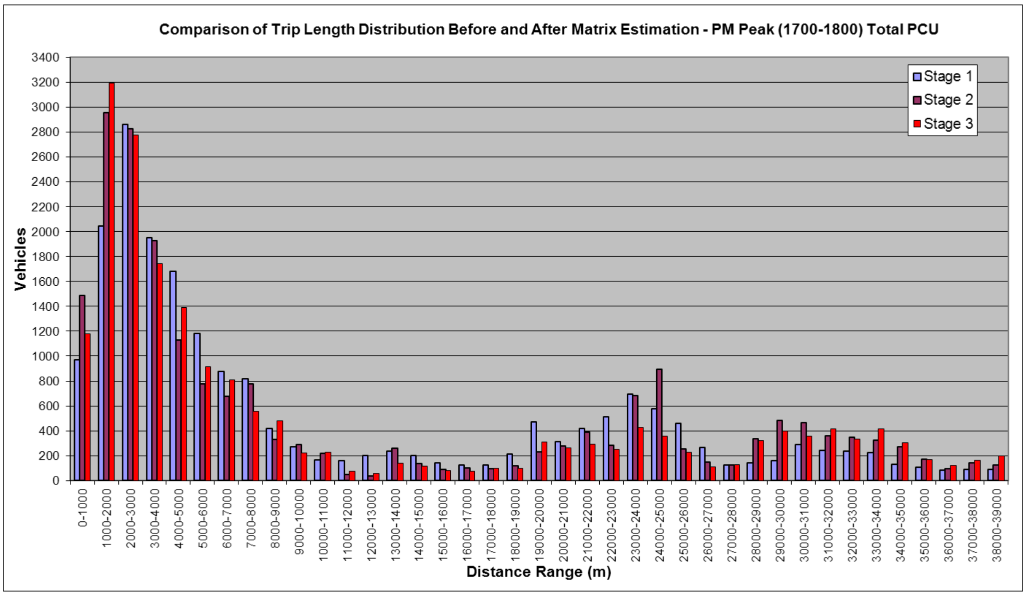


Figure 10: Highway PM Matrix Trip Length Distribution Pre/Post Estimation

5.7.3. The majority of sector to sector O-D movements were not changed significantly and any changes were typically trip increases (i.e. infilling of poorly observed movements).

5.7.4. Trip length distributions were also reasonably similar between prior and final matrices, with the majority of changes being increases in volume of trips, spread across all trip-length categories.

5.8. Final Highway Trip Matrices

5.8.1. For the AM peak, Inter peak and PM peak, a model comparison has been made between total PCU trips in each vehicle class, and trip purpose category, before and after matrix estimation. The AM peak results are shown in Table 2 below.

Table 2: AM Peak 2012 Highway PCU Trips Before and After Matrix Estimation

Trip Purpose	Trip Volumes				
	Car		LGV	HGV	Total
	PCU	%	PCU	PCU	PCU
Pre Estimation					
HB Work	8127	45%	0	0	8127
HB Education	930	5%	0	0	930
HB Other	5006	28%	0	0	5006
HB and NHB Employers Business	1654	9%	1245	586	3485
NHB Other	2243	12%	0	0	2243
All Trips	17961	100%	1245	586	19792
Post Estimation					
HB Work	8188	44%	0	0	8188
HB Education	1256	7%	0	0	1256
HB Other	4745	26%	0	0	4745
HB and NHB Employers Business	1982	11%	2836	1467	6285
NHB Other	2289	12%	0	0	2289
All Trips	18460	100%	2836	1467	22763

5.8.2. Table 2 shows that there has not been a large change in the AM peak 2012 highway trip matrix during the estimation process. Total PCU trips, across all vehicle classes, have increased by 15%, as poorly observed O-D movements are enhanced. The overall demand in the AM peak model is 22,763 PCU. There has been no significant change in journey purpose splits.

5.8.3. It is likely that matrix estimation rebalanced a shortfall of AM observed, shorter distance highway trips, within local areas of Hereford, especially where:

- Trips did not cross outside of the inner cordon or the outer cordon respectively, in the vehicle registration surveys;
- Education trips were made by people under the age of 15, who were not captured in the household travel survey.

5.8.4. The volume of AM movements increased in every purpose category, except home-based other, where trips were replaced by home-based education.

5.8.5. The inter peak model comparisons before and after matrix estimation are shown in Table 3 below.

Table 3: Inter Peak 2012 Highway PCU Trips Before and After Matrix Estimation					
Trip Purpose	Trip Volumes				
	Car		LGV	HGV	Total
	PCU	%	PCU	PCU	PCU
Pre Estimation					
HB Work	1076	10%	0	0	1076
HB Education	428	4%	0	0	428
HB Other	5620	54%	0	0	5620
HB and NHB Employers Business	988	10%	991	739	2718
NHB Other	2252	22%	0	0	2252
All Trips	10364	100%	991	739	12094
Post Estimation					
HB Work	1633	12%	0	0	1633
HB Education	1006	7%	0	0	1006
HB Other	6055	43%	0	0	6055
HB and NHB Employers Business	1813	13%	2383	1700	5896
NHB Other	3531	25%	0	0	3531
All Trips	14038	100%	2383	1700	18121

5.8.6. Table 3 shows that there has been a significant change in the Inter peak 2012 highway trip matrix during the estimation process. Total PCU trips, across all vehicle classes, have increased by 50%, as poorly observed O-D movements were enhanced. There was a greater shortage of observed O-D data in the Inter peak than in the AM or PM peaks, especially with respect to employer's business and non-home-based other trips. The overall demand in the Inter peak model is 18,121 PCU.

5.8.7. The volume of IP movements increased in every purpose category, after estimation. There has been no significant change in IP journey purpose splits, except for a reduction in home-based other. However, this disguises the absolute increase in home-based other trips in the IP matrix.

5.8.8. The PM peak trip volumes between pre estimation and post estimation are shown in Table 4 below.

Table 4: PM Peak 2012 Highway PCU Trips Before and After Matrix Estimation

Trip Purpose	Trip Volumes				
	Car		LGV	HGV	Total
	PCU	%	PCU	PCU	PCU
Pre Estimation					
HB Work	8918	45%	0	0	8918
HB Education	313	2%	0	0	313
HB Other	6397	32%	0	0	6397
HB and NHB Employers Business	1717	9%	936	272	2925
NHB Other	2462	12%	0	0	2462
All Trips	19806	100%	936	272	21014
Post Estimation					
HB Work	8648	46%	0	0	8648
HB Education	539	3%	0	0	539
HB Other	5499	29%	0	0	5499
HB and NHB Employers Business	1588	8%	2263	713	4563
NHB Other	2643	14%	0	0	2643
All Trips	18917	100%	2263	713	21892

5.8.9. Table 4 shows that there has not been a large change in the PM peak 2012 highway trip matrix during the estimation process. Total PCU trips, across all vehicle classes, have increased by 4%, as poorly observed O-D movements are enhanced. This is in addition to an initial transposition of some AM peak observed movements into the PM peak, to redress a shortfall in PM survey responses in the household and car park surveys. The overall demand in the PM peak model is 21,892 PCU.

5.8.10. The volume of PM movements reduced in the work, employer's business and home-based other categories after estimation, to compensate for the higher proportion of these trips in the morning. However, the number of PM trips increased with respect to education and non-home-based other. There has been no significant change in journey purpose splits.

5.8.11. In the final 2012 highway matrices, for each time period after estimation, the modelled purpose splits for cars are considered to be reliable, as they match reasonably closely with the proportions contained in the National Trip End Model (NTEM V6.2) for Hereford at 2011. The comparative purpose splits are shown in Table 5, for AM peak, Inter peak and PM peak, respectively.

Table 5: Final Trip Purpose Splits in 2012 Highway Model and NTEM V6.2 at 2011						
	AM Peak (Post Estimation)		Inter Peak (Post Estimation)		PM Peak (Post Estimation)	
Journey Purpose Category	2012 Modelled Purpose Split	2011 NTEM Purpose Split	2012 Modelled Purpose Split	2011 NTEM Purpose Split	2012 Modelled Purpose Split	2011 NTEM Purpose Split
HB Work	44%	54%	12%	15%	46%	40%
HB Education	7%	8%	7%	6%	3%	3%
HB Other	26%	20%	43%	52%	29%	41%
HB and NHB Employers Business	11%	9%	13%	10%	8%	7%
NHB Other	12%	9%	25%	17%	14%	9%
All Trips	100%	100%	100%	100%	100%	100%

5.8.12. From Table 5, it can be concluded that the final base year matrix trip proportions by journey purpose were a reasonable representation of NTEM data. Modelled journey purpose proportions were within 10% of NTEM in all categories and time periods, except for a 10% shortfall of home-based work trips in the AM peak model and a 12% shortfall in home-based other trips in the PM peak model. Overall, the differences are thought to be acceptable and of little consequence to the reliability of the model.

5.8.13. As a check on the highway model outcomes, the final highway PCU trip totals have been converted to person trips and then compared with NTEM (V6.2) trip ends for the Herefordshire County zone at 2012. NTEM trip ends have been converted to 1-hour peak periods by applying observed 1-hour to 3-hour peak flow ratios and 1-hour to 6-hour inter peak flow ratios, to NTEM, derived from the Hereford multi-modal cordon count data recorded in 2012. A further adjustment has been made consistently in each time period to estimate the proportion of NTEM Herefordshire County trips that are represented by the model, given the mismatch between model and NTEM boundaries, patterns of intra-zonal trips and unobserved trip movements in the model area. Overall, the modelled highway trips are judged to represent about three quarters (75%) of NTEM journeys in Herefordshire County.

5.8.14. The resulting person trip comparison is shown below:

- AMP – Modelled person trips 23,806; i.e. +1% more than NTEM trips 23,580;
- IP – Modelled person trips 19,309; i.e. +7% more than NTEM trips 18,031; and
- PMP – Modelled person trips 24,669; i.e. -6% less than NTEM trips 26,216.

5.8.15. It can be seen that person trip totals in the highway model are calculated as being very similar to NTEM trip totals for Herefordshire County.

5.8.16. The final highway post estimation trip matrices were assigned in the base 2012 model networks. The assignment outcomes demonstrated that the modelled matrix movements gave a sufficiently accurate representation of 2012 observed flows. Full details of the comparison of modelled traffic patterns with observed patterns are given in Chapter 6.

5.9. Public Transport Trip Matrix Development

5.9.1. The demand matrices for public transport services within Herefordshire were based on ticket sales data from the PT service operators, household travel surveys across Hereford City and workplace travel surveys at key organisations. The recorded trip purposes for the PT O-D movements have been matched to the same five user classes as the private car trips described earlier in this section, namely:

- Home based work,
- Home based education;
- Home based other;
- Combined home and non-home based employer's business; and
- Non-home based other.

5.9.2. The various components of PT trip data were first cleaned and analysed. Part-trip data from ticket sales were coded to boarding/alighting fare stages. Full O-D movements were transcribed from postcodes to equivalent model zones, by time period and trip purpose. Then, the O-D sample movements were expanded to match Census LSOA population estimates for the appropriate model zones.

5.9.3. Next, the PT trip data sources were combined and adjustments made for possibly duplicated O-D movements. Finally, the resulting matrices were assigned to the Herefordshire network and O-D movements were manipulated using matrix estimation to smooth the sample trip distribution and enhance any poorly observed movements.

5.9.4. Matrix estimation was carried out using the CUBE program Analyst, with the public transport paths (i.e. routes chosen by passengers) taken from the initial assignment. The following data were required for matrix estimation:

- A prior trip demand matrix – in this case the demand matrices developed from household and workplace survey data;
- Passenger flow count data for individual PT links;
- Electronic ticket machine part-trip data; and
- Confidence levels specified for each input to the matrix estimation process.

5.9.5. There were, inevitably, inconsistencies between sources of PT trip data, owing to variability of demand on different surveyed days and errors in the survey data. Matrix estimation, as implemented in CUBE, applies statistical procedures to establish a demand matrix that most accurately matches the input data. Confidence levels (or weightings) are assigned to the input data to indicate their relative accuracy and reliability. Confidence levels can be assigned to any combination of:

- Individual matrix O-D cells;
- Individual link counts; and
- Part trip data.

5.9.6. The confidence levels used in the PT matrix estimation for Hereford were determined by scrutiny of the data sources, local knowledge of PT passenger movements and professional judgement. These weightings were then adjusted in an iterative process to achieve the best fit of O-D movements to passenger count data, without unduly distorting the demand matrix.

5.9.7. No further details of the PT matrix building process have been included in the appendix, because the bus and train ticketing data were obtained from the operators under confidentiality agreement.

5.10. Final Public Transport Trip Matrices

5.10.1. For the AM peak, Inter peak and PM peak PT 2012 base models, a comparison has been made between total PT trips in each trip purpose category, before and after matrix estimation. The results, for bus and rail trips combined, are shown in Table 6 below.

5.10.2. Table 6 shows that there has been a modest increase in public transport trips during the matrix estimation process. The total PT trip volumes changed by +7% in the AM peak, to 2,252 passenger trips, by -2% in the Inter peak, to 1,883 trips and by +2% in the PM peak, to 1,998 trips. There was no change in the relative proportions of trips by each journey purpose, in any model period.

Table 6: Public Transport Trips Before and After Matrix Estimation						
Trip Purpose	Passenger Trip Volumes (Bus and Rail Combined)					
	AM Peak		Inter Peak		PM Peak	
	Pass. Trips	%	Pass. Trips	%	Pass. Trips	%
Pre Estimation						
HB Work	823	39%	274	14%	765	39%
HB Education	269	13%	0	0%	269	14%
HB Other	324	15%	780	41%	323	16%
HB and NHB Employers Business	336	16%	270	14%	257	13%
NHB Other	350	17%	595	31%	350	18%
All Trips	2102	100%	1919	100%	1964	100%
Post Estimation						
HB Work	878	39%	264	14%	779	39%
HB Education	293	13%	0	0%	280	14%
HB Other	338	15%	772	41%	320	16%
HB and NHB Employers Business	360	16%	264	14%	260	13%
NHB Other	383	17%	584	31%	360	18%
All Trips	2252	100%	1883	100%	1998	100%

5.10.3. As a check on the PT model outcomes, the final PT trip totals have been compared with NTEM (V6.2) trip ends for the Herefordshire County zone at 2012. NTEM trip ends have been converted to 1-hour peak periods by applying bus passenger 1-hour to 3-hour peak flow ratios and 1-hour to 6-hour inter peak flow ratios, to NTEM, derived from the First Group ticket sales data recorded in 2012.

5.10.4. However, the comparison of modelled trip totals with NTEM is not wholly reliable, because the public transport models cover more trips than are just contained within NTEM Hereford City district, but fewer trips than in the NTEM county-wide area. A further adjustment has been made consistently in each time period to estimate the proportion of NTEM Herefordshire County trips that are represented by the model, given the mismatch between model and NTEM boundaries, patterns of intra-zonal trips and unobserved trip movements in the model area. The modelled PT trips are judged to represent about two thirds (68%) of NTEM journeys in Herefordshire County.

5.10.5. The resulting comparison is shown below:

- AMP – Modelled person trips 2,252; i.e. +4% more than NTEM trips 2,169;
- IP – Modelled person trips 1,883; i.e. -12% less than NTEM trips 2,136; and
- PMP – Modelled person trips 1,998; i.e. +10% more than NTEM trips 1,817.

5.10.6. It can be seen that PT trip totals in the model are calculated as being slightly overestimated, relative to NTEM, in the AM and PM peaks, but slightly underestimated in the Inter peak. The model shortfall in the IP probably reflects that the model is an average hour between 10am and 4pm, whereas the NTEM hour factor represents the peak in trips between 11am and 12md.

5.10.7. The final PT matrices were assigned to the model. The outcomes demonstrated that the matrices were capable of producing modelled passenger flows that resembled observed flows reasonably closely. Full details of the comparison of modelled PT flows against observed are shown in Chapter 6.

5.11. Walk and Cycle Trip Matrix Development

5.11.1. The demand matrices for walk and cycle trips within Herefordshire were based entirely on trip O-D data collected during household travel surveys across Hereford City and workplace travel surveys at key employers. The recorded trip purposes for the walk and cycle O-D movements have been matched to the same five user classes as the private car and PT trips, described earlier in this section, namely:

- Home based work,
- Home based education;
- Home based other;
- Combined home and non-home based employer’s business; and
- Non-home based other.

5.11.2. The elements of walk and cycle trip data were cleaned and analysed: O-D movements were transcribed from postcodes to equivalent model zones, by time period and trip purpose; and the O-D sample movements were expanded to match population estimates.

5.11.3. Then, the walk and cycle trip data sources were combined and adjusted to allow for the possibility of duplicated O-D movements. Finally, the resulting matrices were assigned to the Herefordshire network and O-D movements were rebalanced using matrix estimation to smooth the sample trip distribution and enhance any poorly observed movements.

5.11.4. The data merging and matrix estimation procedures that were applied in the walk and cycle models were very similar to those used in the highway model, as outlined in sections 5.5 and 5.6.

5.11.5. Merging of O-D datasets was undertaken by giving priority weighting to the more reliable source, so as to mitigate the risk of duplicate trips. Matrix estimation was performed in SATURN using comparable control criteria to the highway model. The resulting, enhanced walk and cycle matrices and networks were then translated into CUBE model format.

5.11.6. Flow count data used in walk and cycle matrix estimation were derived from the following observed 2012 datasets:

- Manual classified link counts across Hereford city; and
- Multi-modal link counts.

5.11.7. Movements at the city centre access points, crossing the inner ring road, which were recorded during walk and cycle counts at cordon intersections, were omitted from matrix estimation, as these sites were used in model validation.

5.12. Final Cycle and Walk Trip Matrices

5.12.1. For the 2012 AM peak, Inter peak and PM peak cycling and walking base year models, a comparison has been made between total trips, by journey purpose, before and after matrix estimation. The results are shown in Tables 7 and 8, for the cyclist and pedestrian models, respectively.

Table 7: Cycling Trips Before and After Matrix Estimation

Trip Purpose	Trip Volumes					
	AM Peak		Inter Peak		PM Peak	
	Trips	%	Trips	%	Trips	%
Pre Estimation						
HB Work	1547	60%	257	21%	1500	60%
HB Education	220	9%	186	16%	186	7%
HB Other	339	13%	275	22%	339	14%
HB and NHB Employers Business	308	12%	261	21%	308	12%
NHB Other	167	6%	252	20%	167	7%
All Trips	2581	100%	1231	100%	2500	100%
Post Estimation						
HB Work	213	38%	48	22%	225	42%
HB Education	90	16%	38	18%	65	12%
HB Other	106	18%	46	22%	98	19%
HB and NHB Employers Business	84	15%	41	19%	79	15%
NHB Other	75	13%	41	19%	65	12%
All Trips	567	100%	214	100%	533	100%

5.12.2. Table 7 shows that there has been a large reduction in cycling trips during the matrix estimation process. The total cycle trip volumes decreased by 78% in the AM peak, to 567 trips, by 80% in the Inter peak, to 214 trips and by 79% in the PM peak, to 533 trips. The trip reductions were concentrated on home-based work trips in the AM peak and PM peak and across all purposes in the inter peak period.

5.12.3. The reductions in cycle trips during matrix estimation reflect an unexpected bias in the initial household and workplace travel surveys towards responses from cyclists, especially for work trips. As a check on the model outcomes, the final cycle trip totals have been compared with NTEM (6.2) trip ends for the Hereford district at 2012. NTEM trip ends have been converted to 1-hour peak periods by applying observed 1-hour to 3-hour peak flow ratios and 1-hour to 6-hour inter peak flow ratios, to NTEM, as derived from the Hereford multi-modal cordon counts on radial routes, undertaken in 2012.

5.12.4. A minor adjustment has been made consistently in each time period to estimate the proportion of NTEM Herefordshire County trips that are represented by the model, given the mismatch between model and NTEM boundaries, patterns of intra-zonal trips and unobserved trip movements in the model area. The modelled cyclist trips are judged to represent most (90%) of NTEM journeys in Hereford district.

5.12.5. The resulting comparison is shown below:

- AMP – Modelled person trips 567; i.e. -6% less than NTEM trips 601;
- IP – Modelled person trips 214; i.e. +6% more than NTEM trips 202; and
- PMP – Modelled person trips 533; i.e. +6% more than NTEM trips 504.

5.12.6. It can be seen that cyclist trip totals in the model are slightly below those in NTEM, in the AM peak, but slightly overestimated in the Inter peak and PM peak periods. The model shortfall in the AMP is probably a consequence of enthusiastic cyclist responses to the household travel and workplace travel surveys in the AM period, which needed to be moderated and the resulting large downward adjustment that was needed to the AM matrix during estimation. The slight overestimate of cycle trips in the PM and IP probably reflects the need to infill a certain amount of missing trip data to these models, owing to shortcomings in the survey sample rates.

5.12.7. It is reasonable that the total cycle trips in the area-wide model are similar to NTEM for Hereford city, because the model does not represent cycling journeys in peripheral rural areas in the wider Herefordshire County. The comparison checks indicate that the 2012 base cycle matrices are reliable.

Table 8: Walking Trips Before and After Matrix Estimation

Trip Purpose	Trip Volumes					
	AM Peak		Inter Peak		PM Peak	
	Trips	%	Trips	%	Trips	%
Pre Estimation						
HB Work	1791	43%	152	11%	1741	46%
HB Education	323	8%	111	8%	111	3%
HB Other	1135	28%	617	44%	1119	29%
HB and NHB Employers Business	348	9%	111	8%	349	9%
NHB Other	480	12%	408	29%	481	13%
All Trips	4078	100%	1399	100%	3801	100%
Post Estimation						
HB Work	1663	39%	363	13%	1291	37%
HB Education	428	10%	307	11%	250	7%
HB Other	1059	25%	855	31%	930	27%
HB and NHB Employers Business	496	12%	307	11%	492	15%
NHB Other	621	14%	937	34%	487	14%
All Trips	4268	100%	2769	100%	3450	100%

5.12.8. Table 8 shows that there has been some change in walk trips during the matrix estimation process. In the AM peak, the number of journeys increased by 5%, to 4,268 walk trips. In the Inter Peak, the volume rose by 98%, to 2,769 trips. In the PM peak, the trip volume fell by 9%, to 3,450.

5.12.9. As a check on the walking model outcomes, the final person trip totals have been compared with NTEM (6.2) trip ends for the Hereford district zone at 2012. NTEM trip ends have been converted to 1-hour peak periods by applying observed 1-hour to 3-hour peak flow ratios and 1-hour to 6-hour inter peak flow ratios, to NTEM, as derived from the Hereford multi-modal cordon counts on radial routes, undertaken in 2012.

5.12.10. However, the comparison of trip totals is difficult to rely upon because the walk models contain only trips that were entirely on foot and not short distance dual-mode journeys. They also do not include many walk journeys that are predominantly off-road, or trips outside Hereford City. Hence, the models are judged to represent about 85% of total NTEM walk journeys in Hereford district. Also, the Cordon Count period to 1-hour pedestrian factors do not include the many pedestrian journeys that travel on minor routes, avoiding the cordon sites and so the factors may not be wholly accurate.

5.12.11. The resulting comparison is shown below:

- AMP – Modelled person trips 4,268; i.e. -18% less than NTEM trips 5,215;
- IP – Modelled person trips 2,769; i.e. -23% less than NTEM trips 3,599; and
- PMP – Modelled person trips 3,450; i.e. +42% more than NTEM trips 2,438.

5.12.12. It can be seen that pedestrian trip totals in the model are less than those in NTEM, in the AM peak and Inter peak, but greater in the PM peak period. The differences probably reflect constraints on the matrix estimation process, which have moderated the required increase in AM and IP walk trips and decrease in PM walk trips. There was probably a shortfall of AM school walk trips in the model, because pupils were not eligible for the survey and an underestimate of short distance walk trips in the AM and IP periods, because these would not appear as intra-zonal trips in the transport model. The excess of PM pedestrian trips in the model may reflect multiple mode journeys, in which people stated walk as their purpose, when they were in fact returning to pick up other modes for their an onward journey.

5.12.13. It is reasonable to compare the total walk trips in the model with NTEM for Hereford city, because the model does not represent pedestrian journeys in peripheral rural areas in the wider Herefordshire County. The comparison checks indicate that the 2012 base walk matrices are reasonably reliable, given the scope for discrepancies between the two datasets.

5.12.14. The final post estimation cycle and walk matrices were assigned to the CUBE model. The results verified that the matrices were capable of producing modelled cyclist and pedestrian 'active mode' movements that resembled observed flow patterns. Full details of the comparison of modelled flows against observed are shown in Chapter 6.

5.13. Overall Base Year 2012 Person Trip Matrix Comparison

5.13.1. A final analysis has been undertaken, to compare the assembled base year 2012 total person trip matrices, for all combined modes, with the totals in NTEM for Herefordshire County. The results are summarised in Table 9.

Table 9: Hereford Base Model 2012 Total All Mode Trip Matrix Comparison with NTEM V6.2 Trip Ends (Persons Excluding Goods)

		NTEM Person Trips (from sections 5.8 5.11)			Modelled Person Trips (from sections 5.8 5.11)	
Travel Mode	Time Period	Total Period O D Trips	Estimated 1 Hour Model Period Proportion	1 Hour Period Composite O D Trips	1 Hour Matrix Trips (Post Estimation)	% Difference between Modelled Trips and NTEM
All Modes	AM (8am–10am)	103,333	31%	31,566	30,893	-2%
	IP (10am–4pm)	195,030	12%	23,967	24,175	+1%
	PM (4pm–7pm)	116,006	27%	30,975	30,650	-1%

5.13.2. Table 11 above shows that the overall trip totals in the Hereford base models are very similar to those derived from NTEM, for combined travel modes. Across all time periods, the modelled combined trip total is within +/- 2% of that estimated from NTEM. Also, all time periods show modelled trip ends within 1,000 person trips of NTEM, for all modes together. Overall, this verifies that the base model matrix trip totals are robust and reliable.

6. Model Assignment Calibration and Validation

6.1. Introduction

6.1.1. This chapter summarises the steps undertaken to calibrate and validate the component parts of the Hereford multi-modal model. It discusses convergence levels, user classes, generalised cost formulation, calibration and validation procedures, comparison with counts, comparison with journey time records and characteristics of the final matrices.

6.2. Multi-Modal Assignment Procedure

6.2.1. Assignment of base year travel demands on to the respective multi-modal networks was undertaken according to the principles of 'user equilibrium' and 'capacity constraint'. This was found to give the most realistic pattern of traffic and passengers across alternative routes and PT services within the study area.

6.2.2. Achieving 'User equilibrium' in the model means a situation in which there is a stable pattern of route choice and minimised travel costs across all modes and O-D trips on the network, relative to the available transport capacity (i.e. network supply). This equilibrium is reflected in the final volume and pattern of assigned trip movements (i.e. travel demand) in the model and allows for travel speed decreasing and journey delay increasing, as flows become nearer to capacity on each transport link.

6.2.3. The model passes through numerous iterations, whereby it adjusts the traffic and transit flows and routes chosen on the network, with 'volume-averaging' between iterations, until no traveller can reduce their journey costs further by changing route. The end result is a converged model. Travel costs are directly related to journey distance, travel time and congestion on capacity-constrained parts of the network. This process aligns with DfT (WebTAG and DMRB) guidance.

6.3. Highway Assignment Procedure

6.3.1. In the SATURN highway model a 'user equilibrium' traffic assignment was carried out using a 'Wardrop' algorithm method. Volume averaging of flows between iterations was undertaken, in order to achieve convergence.

6.4. Highway Generalised Cost Function

6.4.1. SATURN assigns traffic between origin and destination zones according to a minimum cost criterion, whereby cost is directly related to travel time and distance values, known as the generalised cost function. Coefficients are applied to the time and distance values in seeking to minimise this function. In SATURN the coefficients are Pence per Minute (PPM) and Pence per Kilometre (PPK), applied to time and distance respectively.

6.4.2. Values of time and distance (PPM and PPK) were specified for five individual user classes and three separate time periods (AM, IP and PM) in the SATURN model. The values of time and distance are in accordance with WebTAG former Unit 3.5.6 and current 'TAG Data Book Autumn 2013'. The different values reflect variations in average vehicle occupancy, journey purposes of occupants and values of time, during a typical day.

6.4.3. Modelled values of time and distance are summarised below:

AM peak hour (08.00-09.00)

- Car (HB work) 12.55 VoT; 11.68 VoC;
- Car (HB education) 16.09 VoT; 11.68 VoC;
- Car (HB other) 16.09 VoT; 11.68 VoC;
- Car (HB and NHB employers business) 65.80 VoT; 15.03 VoC;
- Car (NHB other) 16.09 VoT; 11.68 VoC;
- LGV (employers business) 24.86 VoT; 17.63 VoC; and
- HGV (employers business) 21.94 VoT; 51.66 VoC.

Inter peak hour (11.00-12.00)

- Car (HB work) 12.46 VoT; 11.68 VoC;
- Car (HB education) 16.80 VoT; 11.68 VoC;
- Car (HB other) 16.80 VoT; 11.68 VoC;
- Car (HB and NHB employers business) 64.33 VoT; 15.03 VoC;
- Car (NHB other) 16.80 VoT; 11.68 VoC;
- LGV (employers business) 24.86 VoT; 17.63 VoC; and
- HGV (employers business) 21.94 VoT; 51.66 VoC.

PM peak hour (17.00-18.00)

- Car (HB work) 12.22 VoT; 11.68 VoC;
- Car (HB education) 16.97 VoT; 11.68 VoC;
- Car (HB other) 16.97 VoT; 11.68 VoC;
- Car (HB and NHB employers business) 63.38 VoT; 15.03 VoC;
- Car (NHB other) 16.97 VoT; 11.68 VoC;
- LGV (employers business) 24.86 VoT; 17.63 VoC; and
- HGV (employers business) 21.94 VoT; 51.66 VoC.

6.5. Highway Assignment Convergence, Proximity and Stability

6.5.1. The SATURN model was assembled with the appropriate matrix and network data file for each time period. This required an iterative assignment process, terminating when a satisfactory state of equilibrium and level of reliability has been achieved, as defined by the following:

- Level of assignment convergence and proximity, to a point of travel demand / travel cost equilibrium; and
- Level of assignment stability, between successive model iterations.

6.5.2. Model convergence, proximity and stability are judged against the following WebTAG criteria:

- Proximity – %GAP (difference between total assigned/simulated costs and minimum route costs, as a proportion of total costs) – Target <0.1%, over four successive iterations;
- Stability – %FLOWS (proportion of assigned flows within 1% of values from previous iteration) – Target >98%, over four successive iterations;

6.5.3. There is an alternative measure of assigned flow stability, namely Random Average Absolute Difference (RAAD) of link flows. The WebTAG target is <0.1% over four successive iterations. This is similar to %FLOWS, but the RAAD target does not need to be achieved if %FLOWS is satisfied.

6.5.4. In SATURN, the ISTOP value dictates the percentage (PI) of link flows in the current iteration that must be within 1% of those from the previous iteration before convergence is considered adequate. Former WebTAG 3.19 and current TAG Unit M3.1, Appendix C, states that at least four consecutive iterations must be in excess of 98%.

6.5.5. Secondly, the MASL parameter sets the Maximum Assignment Simulation Loops to be allowed before the program is terminated. This value was set to its maximum value in each time period to allow the models increased opportunity to satisfy the ISTOP parameter.

6.5.6. Once the assignment-simulation process has terminated the P statistic and percentage GAP statistic can be used to assess the general accuracy of the model. The GAP value gives the percentage difference in assigned route costs compared with minimum cost routes, where a value of less than 1% is a good indicator of a well converged model.

6.5.7. A summary of the AM peak highway model equilibrium measurements is provided in Table 10.

Table 10: AM Peak 2012 Highway Model Convergence and Stability

SATURN Assignment / Simulation Loop No. (Final four iterations)	%GAP (Difference between total assigned/simulated costs and minimum route costs, as a proportion of total costs)		%FLOWS (Proportion of assigned flows within 1% of values from previous iteration)		RAAD Relative Average Absolute Difference in Link Flows between Successive Iterations	
	Target value	Value Achieved	Target value	Value Achieved	Target value	Value Achieved
94	<0.1%	0.020%	>98%	97.8%	<0.1%	0.10%
95	<0.1%	0.0099%	>98%	98.3%	<0.1%	0.08%
96	<0.1%	0.0089%	>98%	98.5%	<0.1%	0.06%
97	<0.1%	0.026%	>98%	98.4%	<0.1%	0.06%

6.5.8. It is clear from Table 10, that the AM peak model achieved a satisfactory level of convergence and stability with respect to threshold criteria. This indicates that the AM peak model outcome is reliable and would not change if it was subject to further iterations.

6.5.9. Table 11 gives a summary of the Inter peak highway model equilibrium measurements.

Table 11: Inter Peak 2012 Highway Model Convergence and Stability

SATURN Assignment / Simulation Loop No. (Final four iterations)	%GAP (Difference between total assigned/simulated costs and minimum route costs, as a proportion of total costs)		%FLOWS (Proportion of assigned flows within 1% of values from previous iteration)		RAAD Relative Average Absolute Difference in Link Flows between Successive Iterations	
	Target value	Value Achieved	Target value	Value Achieved	Target value	Value Achieved
70	<0.1%	0.017%	>98%	98.7%	<0.1%	0.18%
71	<0.1%	0.023%	>98%	98.8%	<0.1%	0.14%
72	<0.1%	0.018%	>98%	98.7%	<0.1%	0.17%
73	<0.1%	0.015%	>98%	98.6%	<0.1%	0.18%

6.5.10. From Table 11 it can be seen that the final Inter peak highway model was sufficiently stable in terms of traffic flow variation and reached acceptable proximity in terms of cost differences. The slight shortfall in RAAD was not a concern, as the inter peak flow stability criteria had already been achieved.

6.5.11. Highway model equilibrium measurements from the PM peak are given in Table 12. The initial PM peak model fell short of the convergence stability target of >98% of assigned flows within 1% of values from the previous iteration. However a slightly relaxed target of >98% of flows within 2% of values from the previous iteration (difference of <2 vehicles in 100) was achieved. Acceptable assigned cost proximity was also successfully reached in the PM model.

Table 12: PM Peak 2012 Highway Model Convergence and Stability

SATURN Assignment / Simulation Loop No. (Final four iterations)	%GAP (Difference between total assigned/simulated costs and minimum route costs, as a proportion of total costs)		%FLOWS (Proportion of assigned flows within 1% of values from previous iteration)		RAAD Relative Average Absolute Difference in Link Flows between Successive Iterations	
	Target value	Value Achieved	Target value	Value Achieved	Target value	Value Achieved
39	<0.1%	0.0052%	>98%	98.6%	<0.1%	0.07%
40	<0.1%	0.0045%	>98%	98.9%	<0.1%	0.06%
41	<0.1%	0.074%	>98%	98.8%	<0.1%	0.06%
42	<0.1%	0.0055%	>98%	97.7%	<0.1%	0.14%

6.6. Highway Assignment Calibration

6.6.1. Calibration is the process of adjusting the model performance to improve its consistency with observed data, by way of the following techniques:

- Adjusting the model assignment parameters;
- Adjusting the coding of links and junctions in the network; and
- Adjusting the elements of the matrix that were synthesised.

6.6.2. The calibration process was guided by comparing modelled trip movements with classified link flows and junction turning movements, at precise locations, and by comparing modelled journey times with recorded surveys.

6.6.3. Adjustments to network specifications and assignment parameters were made in order to improve the consistency between modelled outcomes and observed link flows and journey times. Care was taken to ensure that any changes were justifiable, within acceptable guidelines and resulted in a better representation of conditions on the ground. Unrealistic changes to improve the model accuracy were avoided.

6.6.4. After changes were made to the network and model parameters, the full cycle of matrix estimation (commencing with the original, pre-estimation trip matrix) was repeated. This ensured that previous matrix changes, made as a consequence of errors in the network which have since been rectified, were now reversed. Each stage of matrix estimation was aligned with a specific user class.

6.7. Highway Assignment Validation

6.7.1. Model validation is an exercise of comparing the calibrated outcomes with independent data sources, which, wherever possible, were not used in the initial model construction or calibration. Validation of the Hereford highway assignment model has entailed the following five elements:

- Network validation;
- Trip matrix validation;
- Flow validation; comprising –
  - link and junction turning movement ‘secondary’ validation for total flows recorded at manually classified count sites;
  - Individual link and combined link flow ‘primary’ validation for movements recorded at cordon / screen-line count sites; and
- Journey time validation.

6.7.2. It should be noted that, for the Hereford model, the assigned flow 'primary' validation has been undertaken legitimately, using independent cordon and screen-line counts that were not used for model building or calibration. However, additional 'secondary' validation has been carried out using the classified link and junction counts that were used for model construction, because it was judged important to show accuracy at key intersections and arteries on the road network.

6.7.3. Outcomes from both the 'primary' and 'secondary' flow validations are discussed later in this section.

Model Network Validation

6.7.4. In the developing the model, the highway assignment network was systematically checked and validated in respect of such aspects as: zone accesses, route connectivity, permitted movements, link speeds and capacities, number of lanes at stop-lines, junction types, priorities and signal timings, and saturation flows. This ensured the characteristics of each link and junction fell within the ranges appropriate to their respective classification.

6.7.5. Routing analysis was also undertaken between selected zones based on the converged assignment results in all time periods. It was found that the routes chosen accord with common sense and local knowledge. Representative extracts from the highway route choice analysis, for ten key journeys in each time period, are presented in Appendix C of this report, in order to demonstrate that the developed highway model was capable of realistically reflecting traveller's route choices.

Model Trip Matrix Validation

6.7.6. Trip matrix validation was undertaken, as a sense-check on the O-D travel patterns in the final highway matrices, which had been enhanced using matrix estimation. Appendix D contains O-D zone diagrams, which indicate, as proportionately sized circles, the relative volumes of trip ends arriving and departing at key zones, during each of the AM, IP and PM model periods, respectively. The trip end patterns are only shown for zones in the core of the model area in Hereford City, not the wider area model zones.

6.7.7. It can be seen from these diagrams that the patterns and magnitudes of trip origin and destination volumes is sensible in each of the highway models, when judged against known scales and types of land-use activity in key zones.

6.7.8. The dominant movements, in the final highway models, are between residential areas and zones with jobs/education/commercial uses. The travel patterns and volumes of traffic contained in the matrices are consistent with local knowledge.

6.7.9. A breakdown of highway trip movements within, to, from and outside Hereford City, in the final base year highway matrices, is provided in Table 13.

Table 13: Final Post Estimation Highway Trip Patterns by Time Period 2012

	AM Peak		Inter Peak		PM Peak	
Trip Movement Category	No. PCU Trips	%	No. PCU Trips	%	No. PCU Trips	%
Internal to Internal	10064	44%	7629	42%	9975	46%
External to Internal	5026	22%	3125	17%	3950	18%
Internal to External	4318	19%	3142	17%	4986	23%
External to External	3356	15%	4225	23%	2981	14%
Total Trips	22764	100%	18121	100%	21893	100%

6.7.10. The trip orientation in Table 13 appears sensible, with the largest proportion of recorded journeys travelling within Hereford in each time period. The proportion of trips either starting or ending outside Hereford, but which are not through movements, is greater for inbound movements in the AM peak, higher for outbound movements in the PM peak and equally balanced between inbound and outbound movements in the Inter peak.

6.7.11. The proportion of journeys starting and ending outside Hereford, only some of which pass through the City, is broadly constant in the AM and PM peak periods, equivalent to about one in six trips in the matrix. This proportion is highest in the Inter peak, when it amounts to about one in four trips.

6.7.12. Further analysis of the base year trip matrices has been carried out to produce a robust estimate of those external to external highway movements that are most likely to pass through Hereford City. The precise number is difficult to quantify, without extensive select link analysis.

6.7.13. Table 14 shows a breakdown of O-D movements, travelling between grouped zones to the south and west of Hereford (i.e. sectors 2001 and 2002) and grouped zones to the north and east of the city (i.e. sectors 2003 and 2004), most of which are likely to pass through Hereford. It is assumed that most trips between south and west of Hereford and between east and north of the City would not tend to travel through the urban area.

Table 14: External Highway Trips passing through Hereford by Time Period at 2012						
External Sector Trip Movement	AM Peak		Inter Peak		PM Peak	
	No. Trips	% of Total Matrix Trips	No. Trips	% of Total Matrix Trips	No. Trips	% of Total Matrix Trips
From South to North	113	0.5%	159	0.9%	191	0.9%
From North to South	126	0.6%	112	0.6%	128	0.6%
From West to North	163	0.7%	189	1.0%	219	1.0%
From North to West	231	1.0%	190	1.0%	114	0.5%
From South to East	191	0.8%	251	1.4%	205	0.9%
From East to South	274	1.2%	317	1.7%	123	0.6%
From West to East	108	0.5%	101	0.6%	113	0.5%
From East to West	143	0.6%	93	0.5%	89	0.4%
From South & West to North & East	574	2.5%	700	3.9%	729	3.3%
From North & East to South & West	773	3.4%	712	3.9%	454	2.1%
Two-Way Through Trips	1347	5.9%	1412	7.8%	1183	5.4%
Total Matrix Trips	22764		18121		21893	

6.7.14. The results in Table 14 show that a similar proportion of modelled trips constitute through traffic movements in Hereford during the AM and PM peak periods, amounting to 6% and 5%, respectively. The proportion in the Inter peak is slightly higher, at 8%.

Model Trip Matrix Sector Analysis

6.7.15. This analysis makes an important distinction between model zones (154 O/D zones) and aggregated sectors (14 O/D sectors). Key parts of the final base model trip matrices have been analysed to confirm that trip patterns at a sector level appear to be sensible. A small selection of model zones was chosen for analysis on the basis of their significance as key trip generators or attractors for different land-use activities. The relative distribution of trips from these zone trip generators to surrounding destination sectors and conversely, the relative distribution of trips to these zone trip attractors from surrounding origin sectors were assessed after matrix estimation, for all model periods.

6.7.16. The definition of the 14 sectored model zones were as follows:

- 1001 – City northwest and racecourse;
- 1002 – City north and Holmer industrial estate;
- 1003 – City northeast and Aylestone Hill;
- 1004 – City east and Tupsley;

- 1005 – Rotherwas industrial estate;
- 1006 – City south, Ross Road and Red Hill;
- 1007 – City south west, Hunderton and Newton Farm;
- 1008 – City west and Whitecross;
- 1009 – City centre north;
- 1010 – City centre core;
- 2001 – External south and southeast, (A49, Ross On Wye and M50);
- 2002 – External southwest, (A465 and Abergavenny);
- 2003 – External north and northwest, (A49 Leominster and A438); and
- 2004 – External east and northeast, (A4103 Worcester and A438 Ledbury).

6.7.17. The sectored zone locations are shown in Figure 11.

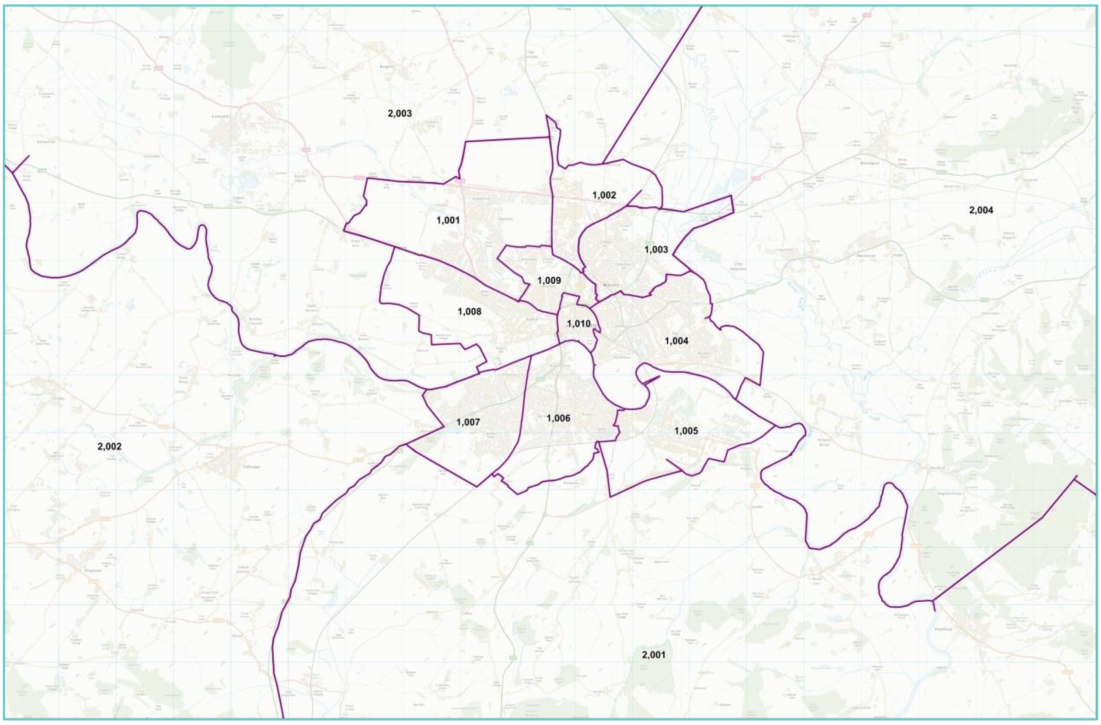


Figure 11: Hereford Sector Boundaries

6.7.18. Table 15, 16 and 17 give a simplified summary of findings for the respective AM peak, Inter peak and PM peak models, focussing on just the largest, sectored trip movement from, or to, each selected key zone. It is not easy to condense the large number of trip O-D movements into a simplified summary, because there are 23,716 possible zone movements in each strategic model and 196 sectored movements. Hence, there is inevitably some coarseness and over-simplicity in the analysis. At each of the selected zones there are, in the model, several significant sector movements. However, only the movement with the highest volume is shown in Tables 15-17.

Table 15: Hereford Base Model Trip Matrix AM Peak 2012: Selected Zones and Largest Sector Movements				
Zone Details (Selected from 154 Zone Matrix)				**Sector Details (from 14 Sector Matrix)**
Selected Zone No.	**Internal / External Zone Location**	**Selected Zone Location**	**Zone's Main Land Use**	**Busiest Sector Trips (PCU) to/from Selected Zone by O D Travel Direction**
3	Internal	Tesco Bewell Street	Retail / Employment	Arrival from City east and Tupsley (130)
9	Internal	St Owen Street	Employment	Arrival from City west and Whitecross (210)
30	Internal	Rotherwas	Employment	Arrival from City south, Ross Road and Red Hill (104)
31	Internal	Morrison Station Approach	Retail / Employment	Arrival from External east and northeast (125)
34	Internal	Tesco Abbotsmead Road	Retail / Employment	Arrival from City south west, Hunderton and Newton Farm (71)
36	Internal	Westfields Estate	Residential	Departure to External east and northeast (143)
37	Internal	Centurion Way and Legion Way	Employment	Arrival from External north and northwest (13)
41	Internal	6th Form College Folly Lane	Education / Employment	Arrival from City northeast and Aylestone Hill (120)
47	Internal	Eign Hill Estate	Residential	Departure to City east and Tupsley (91)
71	Internal	Aylestone Hill Estate	Residential	Departure to City east and Tupsley (81)
72	Internal	Newton Farm Estate	Residential	Departure to City south, Ross Road and Red Hill (88)
75	Internal	County Hospital Stonebow Road	Employment	Arrival from External east and northeast (110)
77	Internal	Putson Estate	Residential	Departure to Rotherwas industrial estate (85)
81	External	Peterchurch	Residential / Employment	Departure to Rotherwas industrial estate (23)
83	External	Leominster	Residential / Employment	Departure to External east and northeast (21)
84	External	Weobley	Residential / Employment	Departure to External east and northeast (62)
85	External	Bromyard	Residential / Employment	Departure to City east and Tupsley (25)
86	External	Ledbury	Residential / Employment	Departure to External north and northwest (35)
87	External	Ross On Wye	Residential / Employment	Departure to External north and northwest (37)
94	External	Credenhill	Residential / Employment	Departure to City northwest and racecourse (112)
97	Internal	Herefordshire Council Plough Lane	Employment	Arrival from External north and northwest (69)
99	External	Abergavenny	Residential / Employment	Departure to External east and northeast (66)
120	External	Monmouth	Residential / Employment	Departure to City south, Ross Road and Red Hill (22)
133	Internal	Sainsbury Grimmer Road	Retail / Employment	Arrival from City northwest and racecourse (78)
134	Internal	Holmer Road	Employment	Arrival from External east and northeast (26)
151	Internal	Whitecross Estate	Residential	Departure to City northwest and racecourse (96)

6.7.19. The results in Table 15 above, suggest that the largest sector movements at key model zones in the AM peak are sensible, judged on local knowledge and land-use and travel characteristics. The largest five selected-zone trip movements in the AM peak were:

- From city west and Whitecross to St Owen Street;
- From Westfields to external east and northeast;
- From city east and Tupsley to Tesco / Bewell Street;

- From external east and northeast to Morrison / Station Approach; and
- From city northeast and Aylestone Hill to college / Folly Lane.

Table 16: Hereford Base Model Trip Matrix Inter Peak 2012: Selected Zones and Largest Sector Movements

Zone Details (Selected from 154 Zone Matrix)				Sector Details (from 14 Sector Matrix)
Selected Zone No.	Internal / External Zone Location	Selected Zone No.	Main Land Use	Inter Peak
3	Internal	Tesco Bewell Street	Retail / Employment	Arrival from City south, Ross Road and Red Hill (125)
9	Internal	St Owen Street	Employment	Arrival from City northeast and Aylestone Hill (96)
30	Internal	Rotherwas	Employment	Departure to External east and northeast (48)
31	Internal	Morrison Station Approach	Retail / Employment	Arrival from External east and northeast (96)
34	Internal	Tesco Abbotsmead Road	Retail / Employment	Arrival from City south, Ross Road and Red Hill (128)
36	Internal	Westfields Estate	Residential	Departure to City west and Whitecross (82)
37	Internal	Centurion Way and Legion Way	Employment	Departure to City northwest and racecourse (3)
41	Internal	6th Form College Folly Lane	Education / Employment	Arrival from City northeast and Aylestone Hill (24)
47	Internal	Eign Hill Estate	Residential	Departure to City northeast and Aylestone Hill (36)
71	Internal	Aylestone Hill Estate	Residential	Departure to City centre core (42)
72	Internal	Newton Farm Estate	Residential	Departure to City south, Ross Road and Red Hill (99)
75	Internal	County Hospital Stonebow Road	Employment	Arrival from External east and northeast (35)
77	Internal	Putson Estate	Residential	Departure to City south west, Hunderton and Newton Farm (50)
81	External	Peterchurch	Residential / Employment	Arrival from External north and northwest (23)
83	External	Leominster	Residential / Employment	Arrival from External south and southeast (73)
84	External	Weobley	Residential / Employment	Departure to City west and Whitecross (47)
85	External	Bromyard	Residential / Employment	Arrival from External north and northwest (48)
86	External	Ledbury	Residential / Employment	Arrival from External east and northeast (335)
87	External	Ross On Wye	Residential / Employment	Arrival from External east and northeast (88)
94	External	Credenhill	Residential / Employment	Departure to City centre core (58)
97	Internal	Herefordshire Council Plough Lane	Employment	Arrival from External east and northeast (44)
99	External	Abergavenny	Residential / Employment	Arrival from External north and northwest (89)
120	External	Monmouth	Residential / Employment	Arrival from City south, Ross Road and Red Hill (18)
133	Internal	Sainsbury Grimmer Road	Retail / Employment	Arrival from External north and northwest (161)
134	Internal	Holmer Road	Employment	Arrival from External north and northwest (5)
151	Internal	Whitecross Estate	Residential	Departure to City west and Whitecross (2)

6.7.20. The analysis in Table 16 above, suggests that the largest sector movements at model zones in the Inter peak are also logical. The largest five selected-zone trip movements in the Inter peak were:

- From external east and northeast to Ledbury;

- From external north and northwest to Sainsbury, Grimmer Road;
- From city south, Ross Road and Redhill to Tesco / Abbotsmead Road;
- From city south, Ross Road and Redhill to Tesco / Bewell Street; and
- From city south, Ross Road and Redhill to Newton Farm.

Table 17: Hereford Base Model Trip Matrix PM Peak 2012: Selected Zones and Largest Sector Movements

Zone Details (Selected from 154 Zone Matrix)				Sector Details (from 14 Sector Matrix)
Selected Zone No.	Internal / External Zone Location	Selected Zone No.	Internal / External Location	Selected Zone No.
3	Internal	Tesco Bewell Street	Retail / Employment	Departure to City south, Ross Road and Red Hill (288)
9	Internal	St Owen Street	Employment	Departure to City west and Whitecross (130)
30	Internal	Rotherwas	Employment	Departure to City west and Whitecross (125)
31	Internal	Morrison Station Approach	Retail / Employment	Departure to City east and Tupsley (178)
34	Internal	Tesco Abbotsmead Road	Retail / Employment	Departure to City south west, Hunderton and Newton Farm (116)
36	Internal	Westfields Estate	Residential	Arrival from City centre north (124)
37	Internal	Centurion Way and Legion Way	Employment	Departure to External north and northwest (9)
41	Internal	6th Form College Folly Lane	Education / Employment	Departure to City east and Tupsley (106)
47	Internal	Eign Hill Estate	Residential	Arrival from City northeast and Aylestone Hill (116)
71	Internal	Aylestone Hill Estate	Residential	Arrival from External east and northeast (101)
72	Internal	Newton Farm Estate	Residential	Arrival from City north and Holmer industrial estate (186)
75	Internal	County Hospital Stonebow Road	Employment	Departure to External east and northeast (142)
77	Internal	Putson Estate	Residential	Arrival from External south and southeast (74)
81	External	Peterchurch	Residential / Employment	Arrival from City south, Ross Road and Red Hill (21)
83	External	Leominster	Residential / Employment	Arrival from External south and southeast (75)
84	External	Weobley	Residential / Employment	Arrival from External east and northeast (55)
85	External	Bromyard	Residential / Employment	Arrival from External north and northwest (63)
86	External	Ledbury	Residential / Employment	Arrival from External east and northeast (83)
87	External	Ross On Wye	Residential / Employment	Arrival from City south, Ross Road and Red Hill (121)
94	External	Credenhill	Residential / Employment	Arrival from External east and northeast (107)
97	Internal	Herefordshire Council Plough Lane	Employment	Departure to External north and northwest (47)
99	External	Abergavenny	Residential / Employment	Arrival from City centre core (71)
120	External	Monmouth	Residential / Employment	Arrival from External southwest (25)
133	Internal	Sainsbury Grimmer Road	Retail / Employment	Departure to City northwest and racecourse (116)
134	Internal	Holmer Road	Employment	Departure to External north and northwest (32)
151	Internal	Whitecross Estate	Residential	Arrival from External southwest (19)

6.7.21. From Table 17 above, it is also judged that the largest sector movements at model zones in the PM peak are realistic. The largest five selected-zone trip movements in the PM peak were:

- From Tesco / Bewell Street to city south, Ross Road and Redhill;
- From city north and Holmer Industrial Estate to Newton Farm;
- From Morrison / Station Approach to city east and Tupsley;
- From County Hospital / Stonebow Road to external east and northeast to Ledbury; and
- From St Owen Street to city west and Whitecross.

<u>Model Flow Validation</u>

6.7.22. The purpose of flow validation is to ensure that the modelled assignments are consistent with observed traffic survey data.

6.7.23. The model flow accuracy has been examined with reference to acceptability guidelines, as stated in the Design Manual for Roads and Bridges (DMRB) for flow validation/calibration and in TAG Unit M3.1.

6.7.24. Assigned flow validation is a comparison of modelled outputs with observed values, according to the following criteria:

- >85% flows to have GEH 5.0 or less, overall;
- >85% flows (<700pcu/h) to be within 100pcu/h, overall;
- >85% flows (700-2,700pcu/h) to be within 15%, overall;
- >85% flows (>2,700pcu/h) to be within 400pcu/h, overall;
- Total screen-line flows to be within 5%, for most datasets (say 80%); and
- Total screen-line flows to have GEH 4.0 or less, for most datasets (say 80%).

6.7.25. Flow validation is partly assessed using the GEH error statistic. It is a measure of the correspondence between observed and modelled data. It makes allowance for the fact that an apparently considerable difference between two large flows can be insignificant in terms of percentage difference and, conversely, an apparently large percentage difference between two small flows can be insignificant in absolute terms. The formula for calculating GEH is as follows:

$$\textbf{GEH} = \sqrt{[(\text{Modelled} - \text{Observed})^2 / (\text{Modelled} + \text{Observed})/2]}$$

6.7.26. As discussed earlier in this report, assigned flows have been extracted as Passenger Car Units (PCU) rather than as vehicles. Whilst this is not entirely consistent with DMRB flow accuracy criteria, measured in vehicles, the difference is insignificant, owing to the relatively low proportion of heavy goods vehicles in the modelled time periods.

6.7.27. Assigned flows have been extracted from the models as 'actual' flows (i.e. the portion of O-D trip 'demand flow' that reaches a given point on the network, where the count is located, during the 1-hour time period). This measure of actual flow is consistent with the recorded flow constituting each observed count and excludes the portion of trip demand between a pair of O-D zones that is delayed in queues.

6.7.28. The Hereford model assigned flow validation is summarised below, in two categories. The first category refers to 'secondary' validation, that is to say, comparison with classified link and junction turning counts, which were also used, by vehicle type, in calibration and matrix estimation. It is nevertheless very important for the validated model to show strong correlation against them. The second category refers to 'primary' validation against independent link flow counts, which were not used in model calibration or matrix estimation.

6.7.29. Detailed outcomes from the highway flow validation exercise are provided in Appendix E, for the AM, IP and PM models, respectively, in the following spread sheets:

- AM Highway Calibration and Validation for LMVR - 120813wg.xlsx;
- IP Highway Calibration and Validation for LMVR - 120813wg.xlsx; and
- PM Highway Calibration and Validation for LMVR - 120813wg.xlsx.

6.7.30. Note that the spread sheet analyses contain SATURN node numbers prior to being updated for the CUBE multi-modal model, whilst the SATURN models themselves do include the revised node numbering. The change entailed adding 400 to every node number in the highway network, for each time period. Hence, for example, node 654 in the highway model is shown as node 254 in the analysis spreadsheets.

<u>Junction Classified Link and Junction Turning Flow 'Secondary' Validation</u>

6.7.31. There were about 400 individual classified link and junction turning movements, used in model-building and matrix estimation, for which comparison of modelled and observed flows has been performed. Table 18 outlines the results of the classified count 'secondary' validation, for all vehicle classes combined, in the AM peak, Inter peak and PM peak models, respectively.

6.7.32. Table 18 confirms that the base 2012 highway models perform very reliably and achieved a high degree of accuracy for individual link and junction turning movements, at key locations, by comparison with DfT assigned flow criteria.

6.7.33. Note that none of the AM, IP or PM models contained any flow volumes greater than 2,700pcu per hour, so the applicable validation criterion was ignored in each case.

Table 18: Highway Classified Link and Junction Flow 'Secondary' Validation			
Count Set	**Validation Criterion**	**Target value**	**Value Achieved**
AM Peak Hour Model			
All Classified Counts	Flows to have GEH 5.0 or less	>85%	89%
	Flows (<700pcu/h) to be within 100pcu/h of observed	>85%	96%
	Flows (700-2,700pcu/h) to be within 15% of observed	>85%	92%
	Flows (>2,700pcu/h) to be within 400pcu/h of observed	>85%	N/A
Inter Peak Hour Model			
All Classified Counts	Flows to have GEH 5.0 or less	>85%	89%
	Flows (<700pcu/h) to be within 100pcu/h of observed	>85%	97%
	Flows (700-2,700pcu/h) to be within 15% of observed	>85%	87%
	Flows (>2,700pcu/h) to be within 400pcu/h of observed	>85%	N/A
PM Peak Hour Model			
All Classified Counts	Flows to have GEH 5.0 or less	>85%	92%
	Flows (<700pcu/h) to be within 100pcu/h of observed	>85%	98%
	Flows (700-2,700pcu/h) to be within 15% of observed	>85%	96%
	Flows (>2,700pcu/h) to be within 400pcu/h of observed	>85%	N/A

<u>Cordon/Screen-line Link Flow 'Primary' Validation</u>

6.7.34. A series of independent link flow counts was selected in the 'primary' validation, to give a reliable indication of model flow accuracy for movements towards, away from and through Hereford City.

6.7.35. Flows have been validated (as total PCU) in each highway model for the following three groups of road links in Hereford, constituting six directional validation datasets:

- An outer cordon of nine key roads, by direction;
- An inner cordon of nine key roads, by direction (including the two Wye river crossings); and
- An east/west screen-line of five key roads (east of the A49), by direction.

6.7.36. Assigned flow validation statistics from the highway models are summarised in Tables 19, 20 and 21, for the AM, IP and PM periods, respectively.

Table 19: AM Peak 2012 Highway Model Cordon and Screen line Flow 'Primary' Validation

Count Set	Validation Criterion	Target value	Value Achieved
All Validation Links	Flows to have GEH 5.0 or less	>85%	91%
	Flows (<700pcu/h) to be within 100pcu/h of observed	>85%	87%
	Flows (700-2,700pcu/h) to be within 15% of observed	>85%	94%
	Flows (>2,700pcu/h) to be within 400pcu/h of observed	>85%	N/A
Outer Cordon Inbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Outer Cordon Outbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Inner Cordon Inbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Inner Cordon Outbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Screen-Line Eastbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Screen-Line Westbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
All (6) Validation Count Sets (1-way)	Total flow to be within 5% of observed	'Nearly All' (assumed 80%)	100%
	Total flow to have GEH 4.0 or less	'Nearly All' (assumed 80%)	100%

6.7.37. Table 19 indicates that the AM peak base model performs very reliably and achieves a high degree of accuracy in comparison with DfT assigned flow criteria. Some 91% of validation links have an assigned flow with a GEH of 5.0 or less. The AM peak model exceeds all of the required accuracy thresholds, across all of the 'primary' validation cordons and screen-lines.

Table 20: Inter Peak 2012 Highway Model Cordon and Screen line Flow 'Primary' Validation

Count Set	Validation Criterion	Target value	Value Achieved
All Validation Links	Flows to have GEH 5.0 or less	>85%	89%
	Flows (<700pcu/h) to be within 100pcu/h of observed	>85%	91%
	Flows (700-2,700pcu/h) to be within 15% of observed	>85%	100%
	Flows (>2,700pcu/h) to be within 400pcu/h of observed	>85%	N/A
Outer Cordon Inbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Outer Cordon Outbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Inner Cordon Inbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Inner Cordon Outbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Screen-Line Eastbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Screen-Line Westbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
All (6) Validation Count Sets (1-way)	Total flow to be within 5% of observed	'Nearly All' (assumed 80%)	100%
	Total flow to have GEH 4.0 or less	'Nearly All' (assumed 80%)	100%

6.7.38. Table 20 confirms that the Inter peak base model also has a very good level of accuracy in comparison with DfT assigned flow criteria. Some 89% of validation links have an assigned flow with a GEH of 5.0 or less. The Inter peak model also exceeds all of the required accuracy thresholds.

Table 21: PM Peak 2012 Highway Model Cordon and Screen line Flow 'Primary' Validation			
Count Set	**Validation Criterion**	**Target value**	**Value Achieved**
All Validation Links	Flows to have GEH 5.0 or less	>85%	98%
	Flows (<700pcu/h) to be within 100pcu/h of observed	>85%	90%
	Flows (700-2,700pcu/h) to be within 15% of observed	>85%	94%
	Flows (>2,700pcu/h) to be within 400pcu/h of observed	>85%	N/A
Outer Cordon Inbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Outer Cordon Outbound	Total flow to be within 5% of observed		No
	Total flow to have GEH 4.0 or less		Yes
Inner Cordon Inbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Inner Cordon Outbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Screen-Line Eastbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
Screen-Line Westbound	Total flow to be within 5% of observed		Yes
	Total flow to have GEH 4.0 or less		Yes
All (6) Validation Count Sets (1-way)	Total flow to be within 5% of observed	'Nearly All' (assumed 80%)	83%
	Total flow to have GEH 4.0 or less	'Nearly All' (assumed 80%)	83%

6.7.39. From Table 21, it can be seen that the PM peak base model has a good level of accuracy in comparison with DfT assigned flow criteria. Some 98% of validation links have an assigned flow with a GEH of 5.0 or less.

6.7.40. The PM model satisfies the required accuracy thresholds for the proportion of count sets with total modelled flow within 5% of observed and with GEH of 4.0 or less. However, there is one count set out of six that fails each of these tests, namely the outer cordon outbound, for which the difference of modelled flows from observed is 11% (the threshold is 5%) and the GEH is 7.0 (the threshold is 4.0).

6.7.41. The excess of modelled flow, when compared with observed, across the outer cordon in the PM peak, is probably explained by the difficulty of representing, in an average 1-hour PM model, the severe short-term peaks in delay observed on the network. Hence, the strategic, 1-hour model tends to slightly underestimate delays and queues, such that, whilst PM trip demands are correct, the actual flows in the validation are slightly high. Across the nine links in the outer cordon, as a whole, the excess flow amounts to about 500pcu. The validation shortfall would be rectified if the assigned eastbound flow on Holme Lacy Road was reduced by 100pcu in the PM peak hour.

6.7.42. Considering each of the time periods together, the model assigned flow validation across the outer and inner cordons and the east-west screen-line, is very accurate. This indicates that the assignment mechanisms are robust and fit for purpose for future year demand forecasting and intervention testing.

Highway Link and Junction Turning Flows on A49

6.7.43. Additional model flow 'secondary' validation data have been extracted for the A49 trunk road, as it represents a key route affecting the performance of the wider highway network. Table 22 below shows the link and junction turning flow calibration statistics for key locations on the A49, for each time period.

Table 22: Highway Classified Link and Junction Flow 'Secondary' Validation on A49

Count Set	Validation Criterion	Target value	Value Achieved
AM Peak Hour Model			
All A49 Link Counts	Flows to have GEH 5.0 or less	>85%	89%
All A49 Junction Turning Counts	Flows to have GEH 5.0 or less	>85%	86%
Inter Peak Hour Model			
All A49 Link Counts	Flows to have GEH 5.0 or less	>85%	94%
All A49 Junction Turning Counts	Flows to have GEH 5.0 or less	>85%	85%
PM Peak Hour Model			
All A49 Link Counts	Flows to have GEH 5.0 or less	>85%	94%
All A49 Junction Turning Counts	Flows to have GEH 5.0 or less	>85%	84%

6.7.44. Each of the models successfully fits within the flow validation accuracy threshold of GEH 5.0 or less, for more than 85% of links and junctions, on the A49, except for the turning counts in the PM peak. The PM peak turning count validation achieves 84% of flows with GEH 5.0 or less, which is considered to show an acceptable level of model accuracy.

6.7.45. Further validation parameters have not been checked for the A49 datasets, in any of the models, because the A49 counts are not part of the 'primary' validation cordons or screen-lines and so the models are not required to comply fully with DfT criteria for the A49 data set.

Journey Time Validation

6.7.46. Journey time validation is a comparison of modelled outputs with observed route travel time components, according to the following criteria:

- >85% routes to be within 15%; and
- >85% routes (where modelled time > observed) to be within 1.0 minute.

6.7.47. The model journey time accuracy has been assessed with reference to acceptability guidelines, as stated in the Design Manual for Roads and Bridges (DMRB) and TAG Unit M3.1, for journey time validation.

6.7.48. Journey times in each highway model have been analysed on six key routes, in both directions of travel and are shown in Figure 12.

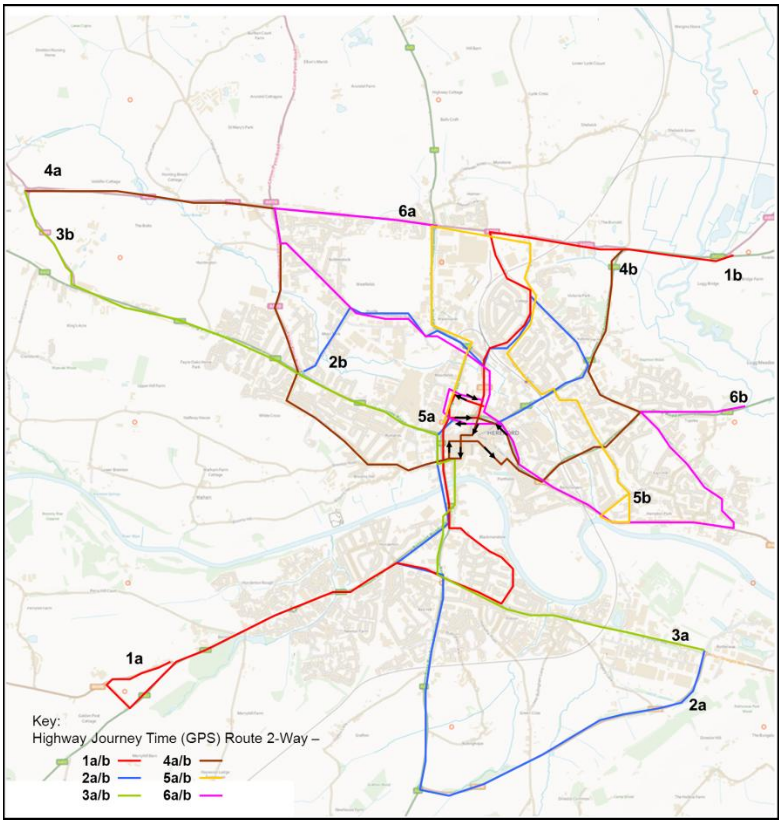


Figure 12: Highway Journey Time Survey Route Map

6.7.49. Accurate representation of free flow and congested traffic speeds and travel time delays is vital to ensuring realistic routeing and assignment of vehicles across the model network. The journey time validation gives a snapshot of modelled speeds and travel times for a selection of highway routes within Hereford. Performance of the AM, IP and PM models with respect to journey time validation is summarised in Table 23.

Table 23: Highway Journey Time Validation

Peak	Validation Criterion	Target value	Value Achieved
AM Peak	Times to be within 15% of observed	>85%	92% (11 out of 12)
	Times (if modelled time > observed) to be within 1.0 minute of observed	>85%	60% (3 out of 5)
Inter Peak	Times to be within 15% of observed	>85%	92% (11 out of 12)
	Times (if modelled time > observed) to be within 1.0 minute of observed	>85%	50% (1 out of 2)
PM Peak	Times to be within 15% of observed	>85%	92% (11 out of 12)
	Times (if modelled time > observed) to be within 1.0 minute of observed	>85%	25% (1 out of 4)

6.7.50. It can be seen from Table 23 that the model journey time accuracy is good and is sufficiently close to the threshold criteria for each of the models to be considered reliable. Some 92% of validation routes in all periods have modelled times within 15% of observed.

6.7.51. There is a shortfall in model accuracy in terms of too many routes having modelled times more than 1.0 minute longer than observed. This reflects the long duration of the timed routes, averaging 23 minutes in the AM and PM peaks and 20 minutes in the Inter peak. Given the long route durations, an excess modelled time of more than 1.0 minute is not considered to indicate model weakness.

The shortfall in accuracy for those routes modelled longer than observed is defensible in all time periods, because in each instance the modelled time is still within 15% of observed. Furthermore:

- In the AM peak, the routes in question have very long observed times of 25 and 29 minutes;
- In the Inter peak, the route in question has an observed time of 18 minutes and is modelled only 1½ minutes too slow; and
- In the PM peak, the routes in question have very long observed times of 19, 26 and 28 minutes.

Highway Modelled journey Times on A49

6.7.52. It was considered important to verify the accuracy of the highway models in terms of travel times on the A49 trunk road through Hereford, as it represents a key route affecting the performance of the wider highway network. Using the journey time routes surveyed in spring 2012, many of which covered a part of the A49 trunk road through Hereford, full-length 'composite' A49 observed journey times have been derived.

6.7.53. Table 24 shows the accuracy of the respective models with respect to the composite A49 journey times. For completeness, the table also includes the model performance against the remaining survey routes, in each of the AM, IP and PM periods. The overall journey time validation was enhanced from earlier versions of the models, as a result of small network changes and re-running the models to improve convergence levels.

Table 24: Highway Journey Time Validation			
Peak	**Validation Criterion**	**Target value**	**Value Achieved**
AM Peak	Times to be within 15% of observed	>85%	100% (2 of 2)
	Times (if modelled time > observed) to be within 1.0 minute of observed	>85%	N/A
Inter Peak	Times to be within 15% of observed	>85%	100% (2 of 2)
	Times (if modelled time > observed) to be within 1.0 minute of observed	>85%	0% (0 of 1)
PM Peak	Times to be within 15% of observed	>85%	100% (2 of 2)
	Times (if modelled time > observed) to be within 1.0 minute of observed	>85%	0% (0 of 1)

6.7.54. It can be seen that, in terms of journey time accuracy compared with the A49 composite timed routes, the AM, IP and PM models again perform well. In each case, both A49 routes have modelled times within 15% of observed (rounded values), in both directions. There is a shortfall in accuracy for modelled times longer than observed, but this amounts to barely more than one minute in the Inter peak and about two minutes in the PM peak. Again, all routes are within the 15% threshold of reliability.

6.8. Public Transport Model Assignment Procedure

6.8.1. The public transport passenger demand matrices, as derived after matrix estimation, were assigned to the PT network in Cube Voyager according to the 'user equilibrium' principle, which used a perceived journey time cost function for each O-D movement. Each of the AM, IP and PM time period assignments were configured to achieve a satisfactory state of supply / demand convergence and route choice stability.

6.8.2. The perceived journey time costs included the following:

- Value of time;
- In-vehicle time factors;
- Walk and wait time factors;
- Boarding and interchange penalties; and
- Wait curves.

6.9. Public Transport Assignment Validation

6.9.1. The validation of the public transport assignment model has entailed the following:

- Comparison of modelled and timetabled bus journey times; and
- Comparison of modelled and observed bus and rail passenger flows on transit links.

<u>Passenger Flow Validation</u>

6.9.2. Public transport passenger flow validation was carried out in accordance with TAG Unit M3.2 and former WebTAG Unit 3.11.2. These suggest the following validation targets for comparison of modelled and observed passenger flows:

- Modelled passenger flows should be within 15% of the observed values on screen-lines and cordons; and
- Modelled passenger flows should be within 25% of individual counts, where observed flow volumes exceed 150 passengers.

6.9.3. In addition to the PT validation criteria outlined above, the following have also been adopted, for consistency with the highway model validation:

- >85% flows to have GEH of 5.0 or less; and
- Total screen-line flows to have GEH of 4.0 or less.

6.9.4. PT passenger flows (on bus and rail, together) were monitored by inbound and outbound direction, across a cordon around Hereford City, comprising the following transit links:

- A49 (north) – Edgar Street;
- A465 (north east) – Commercial Road;
- A465 (south west) – Belmont Road;
- A49 (south) – Ross Road / Greyfriars;
- Strategic route to and from Leominster;
- Strategic route to and from Ledbury; and
- Strategic route to and from Abergavenny.

6.9.5. Detailed outcomes from the PT flow validation exercise are provided in Appendix E, for the AM, IP and PM models, respectively, in the following spread sheets:

- PT_Validation_-_AM_Peak_CUBEwg.xlsx;
- PT_Validation_-_IP_Peak_CUBEwg.xlsx; and
- PT_Validation_-_PM_Peak_CUBEwg.xlsx.

6.9.6. The bus and train passenger flow comparison procedure was a 'secondary' validation, because the respective counts were also used in model calibration and matrix estimation. Table 25 shows the number of screen-lines and cordons that fulfilled the validation criterion of modelled flows within 15% of the observed values. It also indicates the percentage of links on each screen-line and cordon that satisfied the validation criterion of modelled flows within 25% of individual counts, where observed flow volumes are greater than 150 passengers.

Table 25: Public Transport Flow Validation

Count Set	Validation Criterion	Target value	Value Achieved
AM Peak Hour Model			
All Validation Counts	Flows to have GEH 5.0 or less	>85%	86%
	Flows (>150) to be within 25% of observed	100%	75%
Total Cordon Flows (by direction)	Total flow to be within 15% of observed		100%
Inter Peak Hour Model			
All Validation Counts	Flows to have GEH <5. 0	>85%	93%
	Flows (>150) to be within 25% of observed	100%	N/A
Total Cordon Flows (by direction)	Total flow to be within 15% of observed		100%
PM Peak Hour Model			
All Validation Counts	Flows to have GEH <5. 0	>85%	100%
	Flows (>150) to be within 25% of observed	100%	50%
Total Cordon Flows (by direction)	Total flow to be within 15% of observed		100%

6.9.7. Table 25 indicates that the base PT model performs reasonably reliably across all time periods, with DfT accuracy criteria being met in all instances except for two counts, one in the AM peak and one in the PM peak. Here, the model falls short of the required threshold for flows, greater than 150 passengers per hour, to be within 25% of observed. The difference from observed is -41% (only 80 passengers) in the AM peak and -33% (only 55 passengers) in the PM peak. These differences are outside Hereford and are not judged to weaken significantly the PT model reliability.

<u>Bus Journey Time Validation</u>

6.9.8. A comparison of modelled PT travel times with observed provides a good indication of the ability of the Hereford model to represent accurately passengers' reasons for choosing bus and train services and routes. It also confirms if the model's route connectivity, service speeds, headways and delays are a good representation of reality.

6.9.9. The model journey time assessment has been made against scheduled bus timetables, on all main services to, from and within, Hereford. These bus schedules reflect typical average journey times. This provides an independent check of the validity of the model and the ability of CUBE to replicate route delays accurately.

6.9.10. Bus journey time validation entails a comparison of modelled outputs with observed values, according to the following criterion:

- >85% routes to be within 15%.

6.9.11. Performance of the AM, IP and PM models with respect to bus journey time validation is summarised in Table 26.

Table 26: Bus Journey Time Validation

Journey Time Route	Validation Criterion	Target value	Value Achieved
AM Peak	Times to be within 15% of observed	>85%	85%
Inter Peak	Times to be within 15% of observed	>85%	85%
PM Peak	Times to be within 15% of observed	>85%	85%

6.9.12. Table 26 demonstrates that modelled journey times on the main bus routes are sufficiently accurate in each of the AM, IP and PM time periods for the models to be reliable.

6.10. Walk and Cycle Assignment Procedure

6.10.1. The final base year 2012 walk and cycle trip demand matrices were loaded on to the respective Cube Voyager model networks by means of a 'user equilibrium' assignment method. This entailed route selection being made according to a perceived journey time cost function between a given OD pair. The walk and cycle models were run through sufficient iterations to achieve satisfactory convergence and stability.

6.10.2. The cycle network consisted of all roads open to cyclists together with off-carriageway cycle-tracks. Cycling speeds on links were fixed at 15kph. The walk network was identical, but also included dedicated off-street pedestrian routes. Walking speeds on links were fixed at 4kph.

6.11. Walk and Cycle Flow Validation

6.11.1. There are no clearly defined DfT criteria for comparing modelled and observed pedestrian and cyclist movements. Therefore, assigned flows in the walk and cycle models have been validated against the TAG Unit M3.1 highway criterion of:

- >85% flows to have GEH 5.0 or less.

6.11.2. In addition, TAG Unit M3.2 and former WebTAG Unit 3.11.2 suggest validation targets for comparing modelled and observed passenger flows by public transport. In the absence of specific guidance, the same PT validation criteria have also been adopted for the validation of movements by walk and cycle modes, as follows:

- Modelled flows should be within 15% of the observed values on screen-lines and cordons; and
- Modelled flows should be within 25% of individual counts where observed flows exceed 150 passengers.

6.11.3. Flow validation in the walk and cycle models was judged against directional movements across an inner and outer cordon of main routes accessing Hereford City. The pedestrian and cyclist flow comparison procedure was a 'secondary' validation, because the respective counts were also used in model calibration and matrix estimation.

6.11.4. Detailed outcomes from the Walk and Cycle flow validation exercise are provided in Appendix E, for the AM, IP and PM models, respectively, in the following spread sheets:

- Walk_Calibration_and_Validation_CUBErev - 020513wg.xls; and
- Cycle_Calibration_and_Validation_CUBErev - 020513wg.xls.

6.11.5. Tables 27 and 28 show flow validation outcomes for the Hereford walk and cycle models, respectively. They show the number of screen-lines and cordons that fulfilled the validation criterion of modelled flows within 15% of the observed values. The tables also indicate the percentage of links on each screen-line and cordon that satisfied the validation criterion of modelled flows within 25% of individual counts, where observed flow volumes are greater than 150 per hour.

Table 27: Walk Flow Validation

Count Set	Validation Criterion	Target value	Value Achieved
AM Peak Hour Model			
All Validation Counts	Flows to have GEH 5.0 or less	>85%	100%
	Flows (>150) to be within 25% of observed	100%	100%
Total Cordon Flows (by direction)	Total flow to be within 15% of observed		100%
Inter Peak Hour Model			
All Validation Counts	Flows to have GEH 5.0 or less	>85%	95%
	Flows (>150) to be within 25% of observed	100%	100%
Total Cordon Flows (by direction)	Total flow to be within 15% of observed		100%
PM Peak Hour Model			
All Validation Counts	Flows to have GEH 5.0 or less	>85%	98%
	Flows (>150) to be within 25% of observed	100%	100%
Total Cordon Flows (by direction)	Total flow to be within 15% of observed		100%

6.11.6. Table 27 confirms that, in terms of the limited flow validation criteria available, the AM, IP and PM walk models, for base year 2012, achieved an acceptable level of flow accuracy and reliability.

Table 28: Cycle Flow Validation

Count Set	Validation Criterion	Target value	Value Achieved
AM Peak Hour Model			
All Validation Counts	Flows to have GEH 5.0 or less	>85%	87%
	Flows (>150) to be within 25% of observed	100%	N/A
Total Cordon Flows (by direction)	Total flow to be within 15% of observed		N/A
Inter Peak Hour Model			
All Validation Counts	Flows to have GEH 5.0 or less	>85%	100%
	Flows (>150) to be within 25% of observed	100%	N/A
Total Cordon Flows (by direction)	Total flow to be within 15% of observed		N/A
PM Peak Hour Model			
All Validation Counts	Flows to have GEH 5.0 or less	>85%	87%
	Flows (>150) to be within 25% of observed	100%	N/A
Total Cordon Flows (by direction)	Total flow to be within 15% of observed		N/A

6.11.7. Table 28 verifies that, in terms of the limited flow validation criteria available, the AM, IP and PM cycle models, for base year 2012, achieved an acceptable level of flow accuracy and reliability.

7. Conclusions and Recommendations

7.1. Summary of Key Findings

7.1.1. This model validation report has described the development methods and performance of the highway, public transport, walk and cycle components of the refined and updated base year 2012 Hereford multi-modal transport assignment model.

7.1.2. An acceptable level of accuracy and reliability has been achieved in each of the highway, public transport, walk and cycle base models, in relation to observed travel patterns, local knowledge and documented data sources, when compared with accepted DfT validation guidelines.

7.1.3. Each of the weekday AM peak, Inter peak and PM peak models has been satisfactorily validated against criteria and thresholds defined by DfT, with respect to assigned flows, route journey times, trip matrix origin and destination (O-D) patterns and model convergence and stability.

7.1.4. The multi modal models have been assembled in accordance with best practice procedures. They have also been checked to ensure that they show sensible choice of network routes between O and D zones.

7.1.5. Matrix estimation has been applied to each of the base models, in line with advised and accepted practice, to enhance only those O-D movements that were poorly observed. Outcomes have been carefully controlled and scrutinised to confirm that changes made to the base trip matrices by matrix estimation are logical, sensibly proportioned and suitably constrained.

7.1.6. Trip length distribution in each of the validated highway trip matrices is sufficiently well aligned with the pre-estimation pattern, to indicate that matrix estimation has been applied satisfactorily.

7.1.7. Journey purpose proportions in the 2012 highway model are reliable, when compared with similar proportions in the NTEM database for 2012.

7.1.8. The relative orientation of trips between internal (i.e. Hereford) and external segments of the AM and PM highway models is logical. At 2012, this amounts to approximately: 45% within Hereford; 40% to and from Hereford; and 15% outside and through Hereford, during the peaks. In the Inter peak the equivalent proportions were broadly 40% within, 35% to and from and 25% outside, Hereford.

7.1.9. Highway traffic volumes between external areas, which could potentially pass through Hereford, amount to about 6% of overall trips in the AM and PM peaks and 8% in the Inter peak, at 2012.

7.1.10. Choice of preferred (least cost) routes between key O-D zones is sensible in each of the 2012 multi modal models. Investigation of modelled travel times and distances between key zones in the respective models show logical outcomes at 2012.

AM Peak Model Validation

7.1.11. The AM peak highway model achieved good cordon and screen-line flow ‘primary’ validation against observed data, for all criteria. Overall, 91% of modelled flows have a GEH of 5.0 or less (target >85%). A further ‘secondary’ AM validation showed 89% of modelled flows at key junctions and 89% of A49 link flows and 86% of A49 junction turns, have a GEH of 5.0 or less (target >85%).

7.1.12. The AM peak highway model also gives a reasonably accurate representation of journey times, with 92% of area-wide routes and 100% of A49 routes modelled within 15% of observed (target >85%). In the AM peak, there is also a satisfactory level of highway model convergence with respect to iterative changes in flows and travel costs.

7.1.13. The AM peak public transport, walk and cycle models also show good validation against all criteria. Overall, 86% of public transport passenger flows have a GEH of 5.0 or less and 100% of modelled walk flows have a GEH of 5.0 or less. The cycle model achieves 87% of validation flows with a GEH of 5.0 or less.

7.1.14. The AM public transport model gives an accurate representation of journey times, with 85% of routes modelled within 15% of observed (target >85%).

Inter Peak Model Validation

7.1.15. The Inter peak highway model gave robust cordon and screen-line flow ‘primary’ validation against observed data, for all criteria. Overall, 89% of modelled flows have a GEH of 5.0 or less (target >85%). A further ‘secondary’ IP validation showed 89% of modelled flows at key junctions and 94% of A49 link flows and 85% of A49 junction turns, have a GEH of 5.0 or less (target >85%).

7.1.16. The Inter peak highway model also gives a reasonably reliable representation of journey times, with 92% of area-wide routes and 100% of A49 routes modelled within 15% of observed (target >85%). The Inter peak highway model shows acceptable convergence and stability.

7.1.17. The Inter peak public transport, walk and cycle models also provide good validation against all criteria. Overall, 93% of public transport passenger flows have a GEH 5.0 or less and 95% of modelled walk flows have a GEH of 5.0 or less (target >85%). The cycle model achieves 100% of validation flows with a GEH of 5.0 or less.

7.1.18. The Inter peak public transport model gives an accurate representation of journey times, with 85% of routes modelled within 15% of observed (target >85%).

PM Peak Model Validation

7.1.19. The PM peak highway model showed reliable cordon and screen-line flow validation against observed data, for most criteria. Overall, 98% of modelled flows have a GEH of 5.0 or less (target >85%). A further ‘secondary’ PM validation showed 92% of modelled flows at key junctions and 94% of A49 link flows and 84% of A49 junction turns, have a GEH of 5.0 or less (target >85%).

7.1.20. The PM peak highway model also gives a strong representation of journey times, with 92% of area-wide routes and 100% of A49 routes modelled within 15% of observed (target >85%). The PM peak highway model has an acceptable degree of convergence and stability.

7.1.21. The PM peak public transport, walk and cycle models also provide good validation against all criteria. The PM peak PT model has better validation than the AM peak and Inter peak, with 100% of PM public transport passenger flows having a GEH of 5.0 or less. The PM model shows 98% of modelled walk flows with a GEH of 5.0 or less. The PM cycle model achieves 87% of validation flows with a GEH of 5.0 or less.

7.1.22. The PM peak public transport model gives an accurate representation of journey times, with 85% of routes modelled within 15% of observed (target >85%).

7.2. Recommendations

7.2.1. It is concluded that the Hereford AM peak, Inter peak and PM peak base year 2012 highway models are suitably reliable, successfully validated and verified as being fit-for-purpose.

7.2.2. Each of the Hereford multi-modal models is ready for further use in future year forecasting and scheme appraisal.

7.2.3. There are, inevitably some shortcomings and compromises in the scope and performance of the base year models, but these are not considered to detract from the core strength of the models, which is their accuracy within Hereford. The main shortcomings of the models relate to the following:

- Shortfall of observed trip O-D data from household and workplace travel surveys and car parking O-D surveys, which raised difficulties of identifying and removing duplicate trips and which was resolved by relying on matrix estimation in each of the highway, PT, walk and cycle models, together with land-use trip end constraints.
- Inadequacy of O-D survey data for modelling linked outward/return trips, or ‘tours’ during the day (i.e. production/attraction trip format) and trip linkages between intermediate (e.g. car park) and ultimate (e.g. city centre) origins or destinations.
- Shortage of some trip purposes from the surveyed O-D data, especially education trips and absence of surveyed O-D movements outside Hereford.
- Use of best judgement and available count / trip-end data to allocate matched vehicle registrations to precise model zones within the Hereford outer and inner cordons.
- Variability of surveyed highway journey times, which inhibited accurate modelling of travel times and delays through Hereford.
- Reliance on PT part-trip ticket sales data to assemble PT O-D matrices, rather than full-trip passenger records, which were lacking in the household and workplace surveys.

Appendix A

Model Trip Matrix Building Spread Sheets

Appendix B

Highway Trip Length Distribution Plots

Appendix C

Highway Route Choice Plots

Appendix D

Highway Matrix Trip End Plots

Appendix E

Highway Assigned Flow Validation Spread-Sheets