Herefordshire Council
Hereford Transport Model

Base Highway Model Comparison 2012/2008

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Contents

List of Figures

List of Tables

1. Introduction

1.1. Overview

1.1.1. The purpose of this report is twofold. First, it is to verify the accuracy of the base 2012 Hereford highway traffic model, which has been assembled as part of the Hereford multi-modal transport model upgrade. Second, it is to compare the outcomes from the updated 2012 model with those from the previous 2008 version. The aim is to identify if the two models show significant change in transport conditions over four years and, if so, advise if the changes have implications for future strategy.

1.1.2. The multi-modal structure of the Hereford model comprises SATURN highway, CUBE public transport (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.

1.1.3. A new base model validation for each travel mode has been undertaken at 2012, using new 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.

1.2. Scope of the Report

1.2.1. This report provides summary validation outcomes from the highway model, only. It is intended to reassure the Highways Agency that the 2012 highway model is reliable, fit for purpose and will withstand scrutiny. No further reference is made, here, to the PT, walk and cycle models, although they have been satisfactorily validated (except for the PT rail component, for which we are awaiting passenger trip data).

1.2.2. A commentary is also given, which compares the updated 2012 and previous 2008 AM and PM peak period weekday SATURN models. The comparison covers the following features:

- Trip demand, between zone origins and destinations;
- Route choice, on the respective modal networks; and
- Network performance, given the modelled travel patterns.

1.2.3. We have constrained the scope of analysis to give a digestible quantity of information. We have not compared all elements of the 2012 and 2008 models. For brevity, we have excluded comparison of the Inter peak highway models, although our full analysis of the IP is available. Also, we have not included detailed outputs from each of the model comparison tasks, although this data is available.

1.2.4. In the remainder of this report, section 2 describes the general structure of the Hereford model. Section 3 outlines the validation criteria that have been used to assess highway model accuracy. Section 4 summarises the 2012 highway model validation for AM peak, Inter peak and PM peak periods, respectively. Section 5 reviews the comparative AM and PM trip demands at 2012 and 2008, whilst section 6 compares the pattern of route choice and section 7 compares the relative network performance, in the respective models. Finally, section 8 draws some conclusions regarding the base model comparisons.

2. Structure of the 2012 Hereford Model

2.1. Overview

2.1.1. The Hereford model is configured to represent five aspects of transport decision-making, namely:

- Frequency of trip generation and attraction, at origin and destination (O-D) zones;
- Trip distribution between O & D;
- Travel mode split;
- Time of day choice for travel; and
- Network route choice assignment, with capacity constraint, by mode and time period.

2.1.2. In the base model, the objective is to replicate observed conditions, for each of the above five transport aspects, to an acceptable level of accuracy.

2.2. Key Features of the Highway Model

2.2.1. Main features of the updated base multi-modal structure are as follows:

- Modelled base year – 2012;
- Three modelled weekday time periods, for validation:
  - AM peak hour (08.00-09.00);
  - Inter peak hour (11.00-12.00); and
  - PM peak hour (17.00-18.00);
- Four travel modes and associated networks – Highway, PT, walk and cycle;
- Segmentation of travel demand by five trip purposes:
  - Home based work, home based education and 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);
- Seven levels within the 'stacked' highway trip matrix, comprising:
  - (1) Car HB work;
  - (2) Car HB Education;
  - (3) Car HB Other;
  - (4) Car HB and NHB Employer's Business;

- (5) Car NHB Other;
- (6) LGV Employer's Business; and
- (7) HGV Employer's Business;

- Highway network link and junction (node) format, consisting of core 'simulation' in Hereford City and outer 'buffer' in surrounding Herefordshire;
- Zoning system comprising 154 hierarchical (named) zones, of which:
  - 128 are in the Hereford city core;
  - 12 are in the Hereford city hinterland; and
  - 14 are external to Herefordshire;
- Highway trip movements and counted flows measured in PCU (not vehicles), using vehicle to PCU conversion factors from IHT:
- Values of time and vehicle operation (in pence), were derived from WebTAG unit 3.5.6:

2.2.2. The Hereford SATURN highway model uses a link-based, 'Wardrop Equilibrium', capacity-constrained assignment method, with volume averaging during an iterative, convergence process. The outcome is a minimised generalised cost travel pattern, for each time period.

2.2.3. Matrix estimation has been applied to the base AM, IP and PM models, in a carefully controlled process, in order to enhance poorly observed elements of the trip matrices. The process has been controlled, using the following techniques:

- Retaining existing journey purpose splits from the input pre-estimation matrix;
- Run maximum internal iterations and estimation loops, to ensure convergence between modelled flows and observed counts;
- Apply low matrix adjustment factor, 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; and
- Run estimation in two stages, the first under control of both flow counts and trip end constraints together, the second under control of flow counts alone.

2.2.4. The model zoning structure is as summarised in Table 1.

Table 1: 2012 Hereford Model Trip Matrix: Internal and External Zones (154)		
Hereford City (128 zones)	**Hereford City Hinterland (12 zones)**	**External to Herefordshire (14 zones)**
10001-10040 10042-10080 10091-10096 10098-10099 10105-10120 10122-10123 10133-10155	10081-10090 10097 10121	10100-10104 10124-10132

3. Highway Model Validation Criteria

3.1. Overview

3.1.1. 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).

3.1.2. The principal DfT criteria against which the Hereford 2012 base highway model has been validated are as follows:

- Assigned traffic flows in comparison with observed;
- Modelled journey times in comparison with observed; and
- Extent of model convergence and stability.

3.2. Flow Validation Criteria

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

- >85% flows to have GEH <5.0;
- >85% flows (<700pcu/h) to be within 100pcu/h;
- >85% flows (700-2,700pcu/h) to be within 15%;
- >85% flows (>2,700pcu/h) to be within 400pcu/h;
- Total screen-line flows to be within 5%; and
- Total screen-line flows to have GEH <4.0.

3.2.2. 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:

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

3.2.3. For the purpose of this report, assigned flows have been given in Passenger Car Units (PCU) rather than in vehicles. The difference is insignificant owing to the relatively low proportion of heavy goods vehicles in the modelled time periods.

3.2.4. Flows have been validated (as total vehicles) in each highway model for the following three sets of road links:

- An outer cordon of nine key roads, by direction;
- An inner cordon of nine key roads, by direction; and
- An east/west screen-line of five key roads, by direction.

3.3. Journey Time Validation Criteria

3.3.1. Journey time validation is a comparison of modelled outputs with observed values, according to the following criteria:

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

3.3.2. Journey times in each highway model have been analysed on six key routes, in both directions of travel.

3.4. Model Convergence Criteria

3.4.1. Consistency of the base model outcomes is reflected by the following:

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

3.4.2. Model convergence and stability are judged against the following criteria:

- %GAP (difference between total assigned/simulated costs and minimum route costs, as a proportion of total costs) – Target <1%; and
- %FLOWS (proportion of assigned flows within 5% of values from previous iteration) – Target >95%.

3.4.3. The Hereford highway model has been assembled such that any given model assignment will achieve both of the required convergence targets, before the iterative loops can cease.

4. Base 2012 Highway Model Validation

4.1. Overview

4.1.1. This section summarises the main outcomes from the base 2012 AM peak, Inter peak and PM peak highway models.

4.2. AM Peak Trip Matrix Total

4.2.1. For the AM peak model a comparison has been made between total trips in each vehicle class, by purpose, before and after matrix estimation. The results are shown in Table 2.

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

	Trip Volumes				
	Car		LGV	HGV	Total
Trip Purpose	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

4.2.2. 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.

4.3. AM Peak Flow Validation

4.3.1. Assigned flow validation statistics from the AM peak model are summarised in Table 3.

Table 3: AM Peak 2012 Highway Model Flow 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
All 6 Validation Count Sets (by Direction)	Total flow to be within 5% of observed	>90%	100%
	Total flow to have GEH 4.0 or less	>90%	100%

4.3.2. Table 3 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 thresholds.

4.4. AM Peak Journey Time Validation

4.4.1. Performance of the AM peak model with respect to journey time validation is summarised in Table 4.

Table 4: AM Peak 2012 Highway Journey Time Validation

Journey Time Route	Validation Criterion	Target value	Value Achieved
All 12 Validation Routes (by Direction)	Times to be within 15% of observed	>85%	92%
	Times (if modelled time > observed) to be within 1.0 minute of observed	>85%	50%

4.4.2. Table 4 shows that the AM peak model journey time accuracy is very good. Some 92% of validation routes have modelled times within 15% of observed.

4.4.3. Most routes are modelled faster than observed. Of the four routes with longer modelled times, two are acceptable, at less than one minute longer than observed. The shortfall on the remaining two routes is defensible, as they are within a 15% range of observed and are very long routes (28 minute and 33 minute durations, respectively). Their length means that the one minute accuracy threshold is unreasonably strict.

4.5. AM Peak Model Convergence

4.5.1. A summary of the AM peak highway model consistency and stability is provided in Table 5.

Table 5: 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 5% of values from previous iteration) Value Achieved	
	Target value	Value Achieved	Target value	Value Achieved
17	<1%	0.178%	>95%	98.4%
18	<1%	0.094%	>95%	97.0%
19	<1%	0.085%	>95%	98.7%
20	<1%	0.145%	>95%	98.3%

4.5.2. It is evident from Table 5, that the AM peak model achieves 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.

4.6. Inter Peak Trip Matrix Total

4.6.1. An Inter peak model comparison has been made between total trips in each vehicle class, by purpose, before and after matrix estimation. The results are shown in Table 6.

Table 6: Inter Peak 2012 PCU Trips Before and After Matrix Estimation					
	Trip Volumes				
	Car		LGV	HGV	Total
Trip Purpose	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

4.6.2. Table 6 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 are enhanced. There was a greater shortage of observed O-D data in the Inter peak than in the AM or PM peaks. The overall demand in the Inter peak model is 18,121 PCU. There has been no significant change in journey purpose splits.

4.7. Inter Peak Flow Validation

4.7.1. Modelled flow validation statistics from the Inter peak are summarised in Table 7.

Table 7: Inter Peak 2012 Highway Model Flow 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
All 6 Validation Count Sets (by Direction)	Total flow to be within 5% of observed	>90%	100%
	Total flow to have GEH 4.0 or less	>90%	100%

4.7.2. Table 7 reveals that the Inter peak base model 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 exceeds all of the required thresholds.

4.8. Inter Peak Journey Time Validation

4.8.1. The Inter peak model journey time validation is summarised in Table 8.

Table 8: Inter Peak 2012 Highway Journey Time Validation

Journey Time Route	Validation Criterion	Target value	Value Achieved
All 12 Validation Routes (by direction)	Times to be within 15% of observed	>85%	92%
	Times (if modelled time > observed) to be within 1.0 minute of observed	>85%	0%

4.8.2. It can be seen from Table 8 that the Inter peak model journey time accuracy is good. Some 92% of validation routes have modelled times within 15% of observed.

4.8.3. Most routes are modelled faster than observed. Only one route has a longer modelled time, and whilst this falls marginally short of the one-minute accuracy threshold, it is defensible at only 87 seconds longer than observed.

4.9. Inter Peak Model Convergence

4.9.1. Table 9 gives a summary of the Inter peak highway model consistency and stability.

Table 9: 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 5% of values from previous iteration) Value Achieved	
	Target value	Value Achieved	Target value	Value Achieved
8	<1%	0.114%	>95%	96.7%
9	<1%	0.052%	>95%	96.6%
10	<1%	0.025%	>95%	98.7%
11	<1%	0.121%	>95%	97.6%

4.9.2. Table 9 shows clearly that the Inter peak model achieves acceptable convergence and stability with respect to threshold criteria. This indicates that the Inter peak model outcome is reliable and would not change if it was subject to further iterations.

4.10. PM Peak Trip Matrix Total

4.10.1. In the PM peak model a comparison has been made between total trips in each vehicle class, by purpose, before and after matrix estimation. The results are shown in Table 10.

Table 10: PM Peak 2012 PCU Trips Before and After Matrix Estimation					
	Trip Volumes				
	Car		LGV	HGV	Total
Trip Purpose	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	8374	44%	0	0	8374
HB Education	743	4%	0	0	743
HB Other	5610	29%	0	0	5610
HB and NHB Employers Business	1817	9%	2573	1016	5406
NHB Other	2660	14%	0	0	2660
All Trips	19204	100%	2573	1016	22793

4.10.2. Table 10 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 8%, 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). The overall demand in the PM peak model is 22,793 PCU. There has been no significant change in journey purpose splits.

4.11. PM Peak Flow Validation

4.11.1. Table 11 gives modelled flow validation statistics from the PM peak.

Table 11: PM Peak 2012 Highway Model Flow Validation

Count Set	Validation Criterion	Target value	Value Achieved
All Validation Links	Flows to have GEH 5.0 or less	>85%	93%
	Flows (<700pcu/h) to be within 100pcu/h of observed	>85%	93%
	Flows (700-2,700pcu/h) to be within 15% of observed	>85%	81%
	Flows (>2,700pcu/h) to be within 400pcu/h of observed	>85%	N/A
All 6 Validation Count Sets (by Direction)	Total flow to be within 5% of observed	>90%	83%
	Total flow to have GEH 4.0 or less	>90%	83%

4.11.2. From table 11 it can be seen that the PM peak base model has a good level of accuracy in comparison with DfT assigned flow criteria. Some 93% of validation links have an assigned flow with a GEH of 5.0 or less.

4.11.3. The model falls marginally short of the required threshold for the 700-2,700pcu/h flow range. However, this is defensible as 88% of these modelled flows are within 20% difference from observed (the threshold is 15% difference).

4.11.4. The model also slightly falls short of the required threshold 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 only one count set out of six that fails this test (the outer cordon outbound) and the difference from observed is only 10% (the threshold is 5%).

4.12. PM Peak Journey Time Validation

4.12.1. A breakdown of the PM peak model journey time validation is provided in Table 12.

Table 12: PM Peak 2012 Highway Journey Time Validation

Journey Time Route	Validation Criterion	Target value	Value Achieved
All Validation Routes	Times to be within 15% of observed	>85%	92%
	Times (if modelled time > observed) to be within 1.0 minute of observed	>85%	100%

4.12.2. It can be seen from Table 12 that the PM peak model journey time accuracy is very good and satisfies the threshold criteria. Some 92% of validation routes have modelled times within 15% of observed.

4.12.3. Most routes are modelled faster than observed. Only one route has a longer modelled time, and is acceptable at only 30 seconds longer than observed.

4.13. PM Peak Model Convergence

4.13.1. Highway model consistency and stability are summarised for the PM peak in Table 13.

Table 13: 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 5% of values from previous iteration) Value Achieved	
	Target value	Value Achieved	Target value	Value Achieved
30	<1%	0.115%	>95%	98.1%
31	<1%	0.145%	>95%	97.4%
32	<1%	0.116%	>95%	98.1%
33	<1%	0.123%	>95%	98.2%

4.13.2. Table 13 confirms that the PM peak model achieves acceptable convergence and stability with respect to threshold criteria. This indicates that the PM peak model outcome is reliable and would not change if it was subject to further iterations.

4.14. Conclusions from 2012 Base Highway Model Validation

4.14.1. The Hereford multi-modal transport model has been refined and updated to replicate conditions at base year 2012. An acceptable level of accuracy and reliability has been achieved in each of the highway, public transport, walk and cycle base models, in comparison with observed travel patterns.

4.14.2. This report has only made reference to the standard of the base 2012 SATURN highway model validation. The accuracy of the non-highway models will be documented in due course, in a full model validation report.

4.14.3. Each of the weekday AM peak, Inter peak and PM peak highway models has been satisfactorily validated against criteria and thresholds defined by DfT, with respect to assigned flows across cordons, route journey times and model convergence and stability.

4.14.4. The highway models have been assembled in accordance with best practice procedures. They have also been checked to ensure that they show sensible choice of routes between trip origin and destination (O-D) zones.

4.14.5. Matrix estimation has been applied to each of the base models, in line with advisable and accepted practice, to enhance poorly observed O-D movements. Outcomes have been scrutinised to confirm that changes made to the base trip matrices by matrix estimation are logical and suitably constrained.

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

4.14.7. The AM peak model shows good flow validation against all criteria. Overall, 91% of modelled flows have a GEH of <5.0 (target >85%). It also gives an accurate representation of journey times, with 92% of routes modelled within 15% of observed (target >85%). In the AM peak, there is also a satisfactory level of model convergence with respect to iterative changes in flows and travel costs.

4.14.8. The Inter peak model, similarly, shows strong flow validation against all criteria. Overall, 85% of modelled flows have a GEH of <5.0 (target >85%). It also gives a reliable representation of journey times, with 83% of routes modelled within 15% of observed (target >85%). The shortfall is defensible, because the one route that fails the journey time test exceeds the threshold by only 1%. The Inter peak model shows acceptable convergence and stability.

4.14.9. The PM peak model, similarly, shows reasonable flow validation against most criteria. Overall, 83% of modelled flows have a GEH of <5.0 (target >85%). The shortfall is defensible, because 85% of flows are modelled with GEH of <5.1. In the PM peak model, there is also a fair representation of journey times, with 83% of routes modelled within 15% of observed (target >85%). This shortfall is defensible, since 92% of routes are modelled within 15.5% of observed. Again, the PM peak model has an acceptable degree of convergence and stability.

4.14.10. Further checks on the robustness of the base highway models have been performed, by monitoring the calibration of assigned flows, at key links and junctions, against observed classified counts. These link and junction movements are omitted from the validation, because the counted flows have been used in matrix estimation.

4.14.11. In the AM peak, 85% of assigned flows have a GEH of <5.0 with respect to observed calibration data (target >85%).

4.14.12. Likewise, the Inter peak also shows 85% of assigned calibration flows having a GEH of <5.0 (target >85%).

4.14.13. Finally, in the PM peak model, there are, similarly, 86% of assigned flows having a GEH of <5.0, by comparison with calibration counts (target >85%).

4.14.14. In conclusion, we consider that each of the Hereford AM peak, Inter peak and PM peak base year 2012 highway models is suitably reliable and successfully validated, for further use in future year forecasting and scheme appraisal.

5. Modelled Peak Period Trip Demand at 2012 and 2008

5.1. Overview

5.1.1. In this section we focus on the quantity of trips in each of the highway models, their orientation and vehicle category proportions.

5.1.2. The elements of analysis that have been undertaken comprise the following:

- Overall trip volumes by transport mode;
- Trip purpose proportions (i.e. split of movements between 'work', 'employers business' and 'other' purposes);
- Pattern of O-D movements at a sector level (i.e. with model zones aggregated into key sectors);
- Trip orientation (i.e. relative volumes of external and internal trips);
- Pattern of destinations for trips departing from selected key zones;
- Pattern of origins for trips arriving at selected key zones; and
- Trip length distribution (i.e. proportion of trip departures and arrivals, at each O-D zone, which travel within certain distance bands, aggregated to a sector level).

5.2. Trip Volume by Vehicle Category

5.2.1. Table 14 shows the volume of trips in each of the highway models at 2012 and 2008, by vehicle category.

Table 14: Model Trip Totals after Matrix Estimation

	AM Peak		Inter Peak		PM Peak	
Vehicle Type	Amey Model Total (154 zones)	JMP Model Total (120 zones)	Amey Model Total (154 zones)	JMP Model Total (120 zones)	Amey Model Total (154 zones)	JMP Model Total (120 zones)
CAR	18461 (81%	13739 (86%)	14038 (78%)	10681 (82%)	19204 (84%)	14420 (87%)
LGV	2836 (12%)	1034 (7%)	2383 (13%)	1108 (9%	2573 (11%)	1357 (8%)
HGV	1467 (6%)	1139 (7%)	1700 (9%)	1178 (9%)	1016 (5%)	769 (5%)
Total	22764	15912	18121	12967	22793	16545

5.2.2. It can be seen that there are substantially more trips in the base highway model at 2012, than at 2008. The magnitude of increase is 43% in the AM, 40% in the IP and 39% in the PM. The reasons for the increase are as follows:

- The 2012 model has been assembled using substantially wider range of data sources, giving a greater coverage of actual trips, (e.g. where the 2012 household survey has recorded journeys that would not have passed through the 2008 roadside interview sites); and

- The 2012 model contains enhanced trip patterns in both the inner and outer areas, where movements have been derived from a broader combination of recorded O-D movements, zone trip end constraints, observed link flows and junction turning flows.

5.2.3. The increase in trips at 2012 is considered to be sensible, given the enhanced scope of the model. It should be noted that the 2012 trip volumes have not increased simply by matrix estimation infilling short-distance movements. We have verified this by checking that:

- Matrix estimation has not significantly changed the 2012 prior matrices (increases of 15% in the AM and 8% in the PM);
- Matrix estimation has not disproportionately altered the pattern of trip lengths; Figures 1 and 2 show trip length distribution before matrix estimation (stage 1) and after (stage 2), in the 2012 AM and PM models.

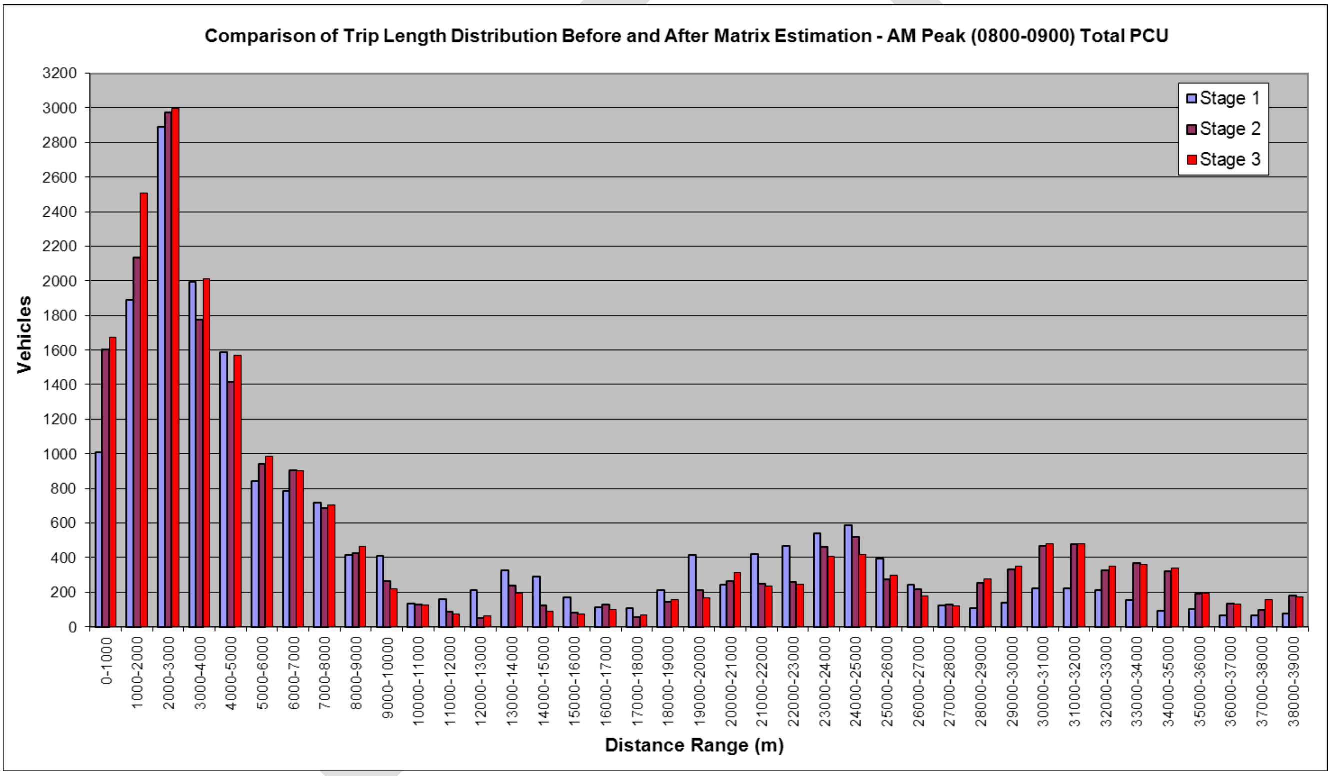

Figure 1: 2012 AM Trip Length Distribution Before and After Matrix Estimation

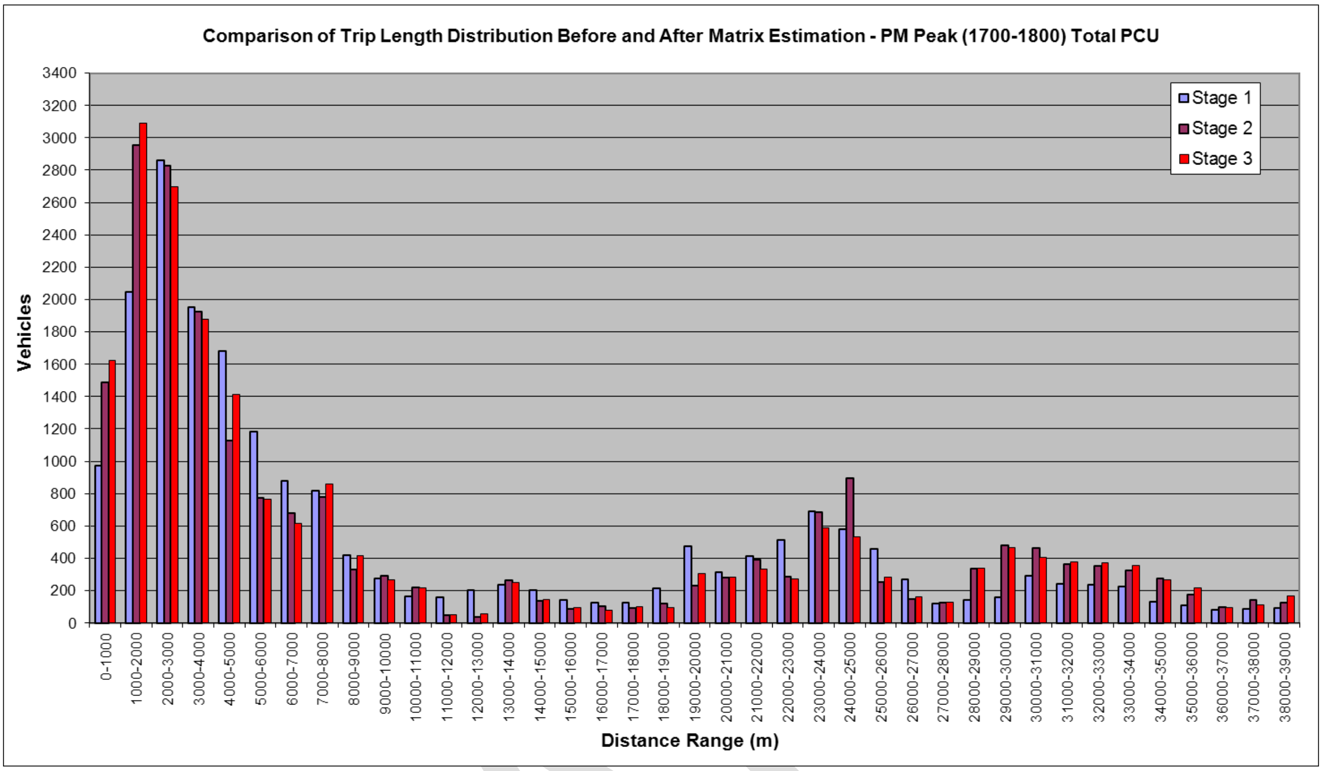

Figure 2: 2012 PM Trip Length Distribution Before and After Matrix Estimation

5.3. Trip Purpose Proportions

5.3.1. It has not been possible to compare trip purpose proportions in the base highway models, because there was no segmentation of purposes in 2008. However, the 2012 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 15.

Table 15: Trip Purpose Splits in 2012 Model and NTEM V6.2 at 2011

	AM Peak		Inter Peak		PM Peak	
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%	44%	40%
HB Education	7%	8%	7%	6%	4%	3%
HB Other	26%	20%	43%	52%	29%	41%
HB and NHB Employers Business	11%	9%	13%	10%	9%	7%
NHB Other	12%	9%	25%	17%	14%	9%
All Trips	100%	100%	100%	100%	100%	100%

5.4. Sectored O-D Movements

5.4.1. All trip movements in the 2012 and 2008 models have been aggregated from zones to sectors, for comparison. Fourteen sectors have been defined, 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.

5.4.2. The boundaries of the designated sectors are shown in Figure 3.

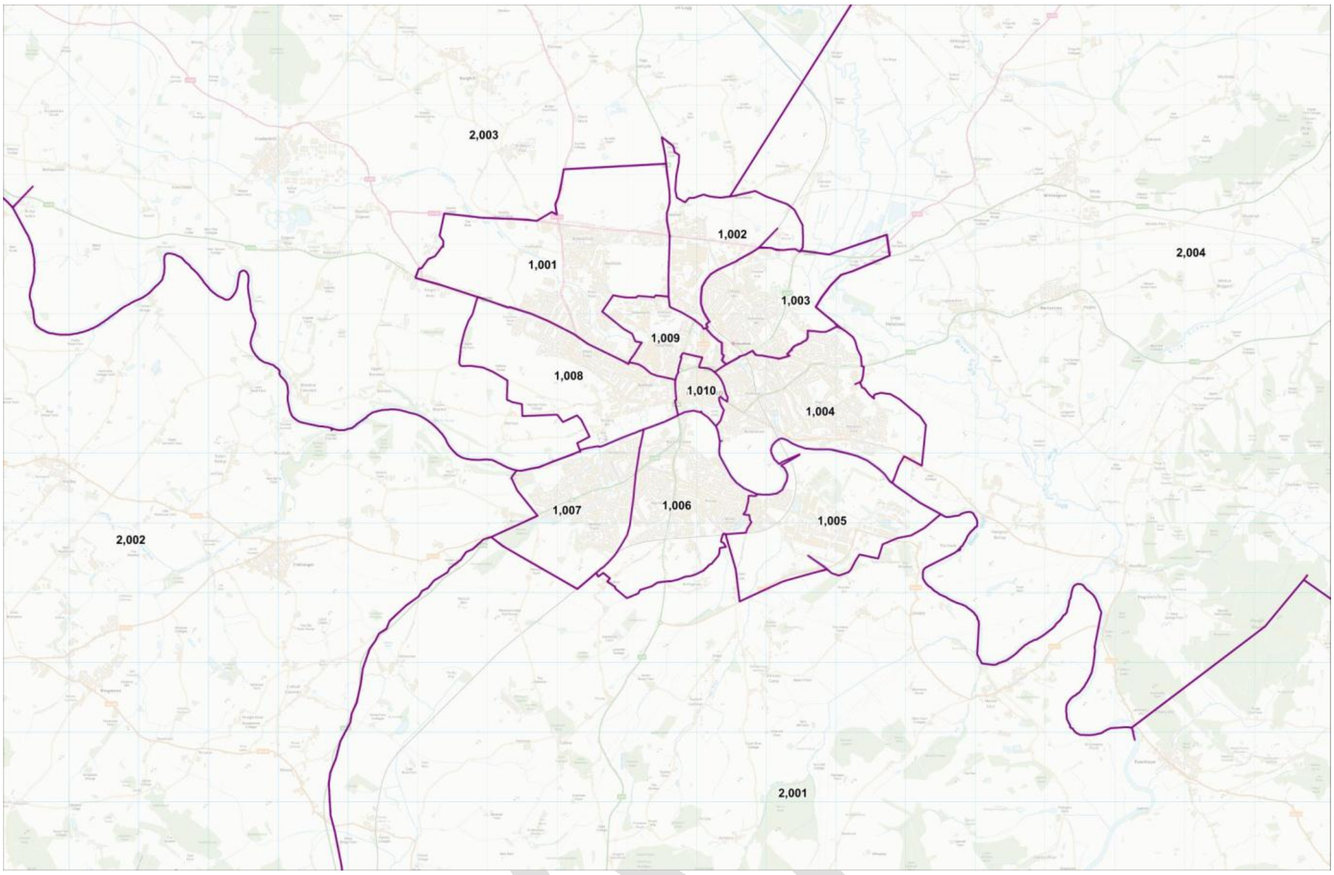

Figure 3: Hereford Sector Boundaries

5.4.3. The volume of O-D trips has been used to rank sector-to-sector movements, in decreasing order of magnitude, in each model. Table 16 shows the top 30 movements during the AM peak for the 2012 and 2008 models. Table 17 shows equivalent top 30 values for the PM peak.

Table 16: Comparison of Top 30 Largest Sector-to-Sector O-D Movements in AM Peak

2012 AM Peak			2008 AM Peak		
2012 Modelled Purpose Split	2011 NTEM Purpose Split	2012 Modelled Purpose Split	2011 NTEM Purpose Split	2012 Modelled Purpose Split	2011 NTEM Purpose Split
2004	2004	639	2004	1010	395
1004	1004	556	2004	1004	390
2004	1004	512	2003	1009	388
1004	2004	463	2001	1006	352
1003	1003	430	1006	2001	318
2003	2003	413	1004	2004	299
2003	2004	370	1004	1010	280
2004	1003	365	1001	2004	249
1004	1003	335	2003	1003	238
1003	1004	326	1010	1004	222
2003	1001	324	2003	1008	203
2004	1010	322	2001	1009	201
2004	2003	316	2001	1010	195
1001	1001	301	1002	1009	193
1006	1006	300	2001	2003	184
1007	1007	289	1006	1006	179
2004	2001	274	1010	2004	169
2003	1009	273	2003	2002	167
1004	1010	272	1003	2003	166
1006	2001	270	2003	2001	165
1004	1002	259	1008	1010	157
2003	1003	256	2003	1004	154
1001	1009	251	2002	1010	154
1007	1006	248	1004	1004	147
1008	1010	238	1001	1008	146
1006	1005	235	2003	1010	143
1008	2001	235	2004	2002	143
1008	1001	234	1010	1010	143
2003	2002	231	1004	1003	138
1001	1003	230	2002	2003	135

Table 17: Comparison of Top 30 Largest Sector-to-Sector O-D Movements in PM Peak

2012 PM Peak			2008 PM Peak		
2012 Modelled Purpose Split	2011 NTEM Purpose Split	2012 Modelled Purpose Split	2011 NTEM Purpose Split	2012 Modelled Purpose Split	2011 NTEM Purpose Split
2004	2004	794	1010	2004	396
1004	1004	569	1010	1004	357
2004	2003	521	1009	2003	326
2003	2003	493	2001	1006	285
1004	2004	458	2004	1004	225
1007	1007	435	1010	2001	217
1010	1004	423	2003	1003	205
1003	1004	422	1006	1007	192
2004	1003	404	2002	2003	182
1006	2001	355	2003	1009	178
1010	1006	346	2003	1004	175
1006	1006	343	1010	2003	175
2003	2004	327	1001	1008	170
1004	1003	322	1010	2002	164
2001	2004	316	1006	2001	164
1003	2004	315	1007	1006	162
2004	1004	314	1003	2004	157
2003	1006	313	1008	2003	155
1008	1001	299	2003	1008	155
1004	1010	273	2003	2001	151
1003	1003	267	1004	2003	150
1010	2002	241	1004	2004	150
1009	1001	238	1006	2002	150
1007	1006	236	2003	2002	148
1010	2003	230	1003	1004	146
2003	1001	222	1009	1001	143
1010	1010	221	2004	1007	135
2002	2003	219	2004	1006	133
1001	2004	217	1009	1003	133
1009	2003	207	1009	2001	132

5.4.4. Table 16 reveals that, of the top 30 largest movements in the AM peak, there are 12 that are between the same sectors in the 2012 and 2008 models (shaded grey). These 12 movements entail broadly similar trip volumes, although they are generally higher in the 2012 model, for reasons given in section 5.2. The comparison is hampered by there being more trips in the 2012 model, which means that some similar movements do not appear in the 2012 top 30 analysis.

5.4.5. Generally there are more trips within peripheral sectors (i.e. 2001, 2002, 2003 and 2004) in the 2012 AM model owing to the enhanced outer area matrix. There are also significantly more trips within sectors inside Hereford in the 2012 AM model, owing to the better capture of localised school and college journeys and shorter-distance movements.

5.4.6. A similar picture emerges from Table 17. This also indicates that, of the top 30 largest movements in the PM peak, there are 12 that are between the same sectors in the 2012 and 2008 models (shaded grey). These 12 movements show fairly similar trip volumes, although, again, they are higher in the 2012 model,

5.4.7. Overall, the AM and PM sector-to-sector analyses seem to show that the 2012 model has entailed an infilling and enhancement of trip movements that were previously unobserved in the 2008 model. This is considered to be a positive strength of the new model.

5.5. Trip Orientation (Internal and External Trips)

5.5.1. We have examined the volume and proportion of trips in each model that constitute each of four key movements, namely: internal to internal; internal to external; external to internal and external to external. ‘Internal’ designates zones in Hereford city. ‘External’ designates zones outside Hereford.

5.5.2. Table 18 shows the volume of trips in each of the highway models at 2012 and 2008, by each movement category.

Table 18: Comparison of 2012 Model Trip Orientation with 2008 Model (Total PCU)

	2012 AM Peak		2008 AM Peak		2012 PM Peak		2008 PM Peak	
Trip Movement Category	No. Trips	%	No. Trips	%	No. Trips	%	No. Trips	%
Internal to Internal	10064	44%	6395	40%	9964	44%	7276	44%
External to Internal	5026	22%	4834	30%	4977	22%	4375	26%
Internal to External	4318	19%	3354	21%	3938	17%	3643	22%
External to External	3356	15%	1328	8%	3914	17%	1252	8%
Total Trips	22764	100%	15912	100%	22793	100%	16545	100%

5.5.3. The breakdown in Table 18 indicates that whilst the 2012 AM and PM models contain a larger volume of trips than the 2008 models, they are very similar with respect to the proportion of all movements except external to external flows. The 2012 models contain substantially more external to external trips, because they capture more trip data in the peripheral areas of Herefordshire, for movements that do not travel near or through Hereford.

5.5.4. We have examined the number of trips in each model that travel between peripheral sectors in the south/southeast/southwest areas and the north/northeast/northwest areas, in both directions. These trips roughly represent potential through movements in Hereford, although some will bypass the city on rural routes. Table 19 gives a summary of these movements in each model.

Table 19: Comparison of 2012 Model External Trip Movements with 2008 Model (Total PCU)

	2012 AM Peak		2008 AM Peak		2012 PM Peak		2008 PM Peak	
Sectored Trip Movement	No. Trips	% of Total Matrix Trips	No. Trips	% of Total Matrix Trips	No. Trips	% of Total Matrix Trips	No. Trips	% of Total Matrix Trips
From 2001 to 2003	113	0.5%	184	1.2%	160	0.7%	123	0.7%
From 2003 to 2001	126	0.6%	165	1.0%	133	0.6%	151	0.9%
From 2002 to 2003	163	0.7%	135	0.8%	219	1.0%	182	1.1%
From 2003 to 2002	231	1.0%	167	1.1%	170	0.7%	148	0.9%
From 2001 to 2004	191	0.8%	51	0.3%	316	1.4%	34	0.2%
From 2004 to 2001	274	1.2%	43	0.3%	164	0.7%	67	0.4%
From 2002 to 2004	108	0.5%	107	0.7%	133	0.6%	123	0.7%
From 2004 to 2002	143	0.6%	143	0.9%	111	0.5%	86	0.5%
Total Matrix Trips	22764	5.9%	15912	6.2%	22793	6.2%	16545	5.5%

5.5.5. It is evident from Table 19 that the 2012 and 2008 models both contain a similar proportion of trips that could potentially travel through or around Hereford city, between more distant zones. Taking all of the ‘cross-city’ movements together, they represent about 6% of the total matrix trips in each of the 2012 and 2008 AM and PM models.

5.6. Pattern of Trip Origin and Destination Movements at Key Zones

5.6.1. We have undertaken a selective analysis of trip patterns at a number of key zones in the Hereford model. These zones are itemised in Table 20.

Table 20: 2012 Hereford Model Trip Matrix: Selected Zones for Comparison of Trip Movements

Trip Matrix Details (154 Zones)				O-D Direction to be Analysed		
No.	Internal / External	Zone Location	Main Land Use	AM Peak	Inter Peak	PM Peak

Table 20: 2012 Hereford Model Trip Matrix: Selected Zones for Comparison of Trip Movements

Trip Matrix Details (154 Zones)				O-D Direction to be Analysed		
No.	**Internal / External**	**Zone Location**	**Main Land Use**	**AM Peak**	**Inter Peak**	**PM Peak**
10003	Internal	Tesco Bewell Street	Retail / Employment	Arrival	Arrival	Departure
10009	Internal	St Owen Street	Employment	Arrival	Arrival	Departure
10030	Internal	Rotherwas	Employment	Arrival	Departure	Departure
10031	Internal	Morrison Station Approach	Retail / Employment	Arrival	Arrival	Departure
10034	Internal	Tesco Abbotsmead Road	Retail / Employment	Arrival	Arrival	Departure
10036	Internal	Westfields Estate	Residential	Departure	Departure	Arrival
10037	Internal	Centurion Way and Legion Way	Employment	Arrival	Departure	Departure
10042	Internal	6th Form College Folly Lane	Education / Employment	Arrival	Arrival	Departure
10048	Internal	Eign Hill Estate	Residential	Departure	Departure	Arrival
10072	Internal	Aylestone Hill Estate	Residential	Departure	Departure	Arrival
10073	Internal	Newton Farm Estate	Residential	Departure	Departure	Arrival
10076	Internal	County Hospital Stonebow Road	Employment	Arrival	Arrival	Departure
10078	Internal	Putson Estate	Residential	Departure	Departure	Arrival
10082	External	Peterchurch	Residential / Employment	Departure	Arrival	Arrival
10084	External	Leominster	Residential / Employment	Departure	Arrival	Arrival
10085	External	Weobley	Residential / Employment	Departure	Departure	Arrival
10086	External	Bromyard	Residential / Employment	Departure	Arrival	Arrival
10087	External	Ledbury	Residential / Employment	Departure	Arrival	Arrival
10088	External	Ross On Wye	Residential / Employment	Departure	Arrival	Arrival
10095	External	Credenhill	Residential / Employment	Departure	Departure	Arrival
10098	Internal	Herefordshire Council Plough Lane	Employment	Arrival	Arrival	Departure
10100	External	Abergavenny	Residential / Employment	Departure	Arrival	Arrival
10121	External	Monmouth	Residential / Employment	Departure	Arrival	Arrival
10134	Internal	Sainsbury Grimmer Road	Retail / Employment	Arrival	Arrival	Departure
10135	Internal	Holmer Road	Employment	Arrival	Arrival	Departure
10152	Internal	Whitecross Estate	Residential	Departure	Departure	Arrival

5.6.2. For each of the zones in Table 20, the pattern of trips has been analysed in the selected direction of arrival or departure movement (depending upon the dominant land use and time of day). Movements have been examined using a select link procedure. The resulting matrices have been compressed to 14 sectors and movements ranked by the top 30 largest trip volumes.

5.6.3. We can provide the detailed tabulated analysis outputs, as required. However, for this report we note that the patterns of arrivals and departures at the selected zones are sensible in the 2012 AM and PM models, consistent with the types of land use and scales of activity, in each zone. In almost all of the selected zones there are significantly more trips in the 2012 highway model, than at 2008, owing to the wider range of data used to derive trip records.

5.7. Trip Length Distribution at Key Zones

5.7.1. In respect of the selected model zones, referred to in section 5.6, we have also investigated the trip length distribution at 2012 and 2008, for AM and PM peaks. An analysis has been made of the range of trip lengths in each model, for movements in the selected direction of travel.

5.7.2. Again, we can supply the detailed graphical outcomes from the analysis as required. However, for brevity in this report we conclude that the 2012 model includes significantly more trips than at 2008, in the distance bands below 8km. This reflects the enhanced trip details that were assembled for the 2012 model, giving greater coverage of short and medium distance journeys.

6. Modelled Peak Period Route Choice at 2012 and 2008

6.1. Overview

6.1.1. This section considers the pattern of route choice shown in the respective highway model assignments at 2012 and 2008.

6.1.2. There are three ways in which we have examined route choice, namely:

- By examining selected network links and zones to determine the pattern of all sectored zones served by each selected link and conversely, the pattern of key links used to access each selected zone;
- By extracting a forest of preferred routes chosen for travelling between each pair of selected zones, in the specified direction; and
- By extracting the skimmed travel time and travel distance between each pair of selected model zones, in the most significant direction of travel.

6.1.3. The zones selected for this analysis are those shown in Table 20. The key links for which data has been analysed are as shown in Table 21.

Table 21: 2012 Hereford Model Network: Links for Analysis

Link Description				Network Node to Node Movement	
	Link No.	Link Location	Direction	From Node	To Node
Cordon	1	A49 Ross Road	North bound	9318	235
			South bound	235	9318
	2	A465 Belmont Road	Northeast bound	184	193
			Southwest bound	193	184
	16	Barton Road	East bound	25	287
			West bound	287	25
	3	A438 Whitecross Road	East bound	23	970
			West bound	970	23
	4	A49 Newtown Road	South bound	153	154
			North bound	154	153
	17	College Road	South bound	219	8067
			North bound	8067	219
	5	A465 Aylestone Hill	Southwest bound	223	56
			Northeast bound	56	223
	6	A438 Ledbury Road	West bound	9322	226
			East bound	226	9322
	7	B4224 Hampton Park Road	West bound	231	179
			East bound	179	231
North/South Screen Line	8	A49 Greyfriars	North bound	254	282
			South bound	282	254
	9	St Martins Street	North bound	9301	9303

Table 21: 2012 Hereford Model Network: Links for Analysis

Link Description				Network Node to Node Movement	
	Link No.	Link Location	Direction	From Node	To Node
			South bound	9303	9301
West/East Screen Line	10	B4399 Rotherwas Access Road	Southwest bound	863	862
			Northeast bound	862	863
	11	Holme Lacy Road	West bound	191	188
			East bound	188	191
	12	Hinton Road	West bound	143	35
			East bound	35	143
	13	A438 Newmarket Street	West bound	1121	112
			East bound	112	1121
	14	B4359 Widemarsh Street	North bound	157	225
			South bound	225	157
	15	A4103 Roman Road	West bound	971	990
			East bound	990	971

6.1.4. Even considering our restricted analysis of relatively few zones and links in the model, there is too much information to summarise in this report. However, we do note that the 2012 AM and PM models contain noticeably higher traffic volumes, than in 2008, on almost all of the key links, in both directions. This difference is attributable to the following:

- The broader range of O-D data sources used in 2012, which recorded significantly more local, shorter-distance journeys than in 2008, alongside similar volumes of longer-distance trips;
- The greater amount of traffic counts and zone trip-end constraints available to use in the 2012 matrix estimation, which has also tended to introduce trips that were unobserved in 2008.

6.1.5. The select link and zone analysis does show significant differences in the relative magnitudes of O-D movements, between the 2012 and 2008 models. However, the pattern of preferred route choices between key zones, as shown by the network plots (‘forests’) is very similar in the two models.

6.1.6. Overall, we are confident that the 2012 route patterns and flow volumes are reliable.

6.1.7. The time and distance analysis for key O-D zone movements shows strong similarity between the models. It is difficult to compare external zones, as their precise definitions and connecting points have been refined in the 2012 model. However, for internal movements, the average differences between the models with respect to O-D times and distances are small, as follows:

- AM peak average difference in O-D travel time for internal trips: 109 seconds;
- AM peak average difference in O-D travel distance for internal trips: 321 metres;
- PM peak average difference in O-D travel time for internal trips: 2 seconds;

- PM peak average difference in O-D travel distance for internal trips: 87 metres;

6.1.8. Overall, the 2012 model has marginally greater travel times and distances than the 2008 model, owing to the presence of more traffic and additional zone connectors, in the 2012 situation.

7. Modelled Peak Period Network Performance at 2012 and 2008

7.1. Overview

7.1.1. In this section there is a discussion of how the base highway models perform in terms of network operation. We have analysed the following aspects of highway performance:

- Traffic volumes on key links;
- Traffic inflow volumes at key junctions; and
- Junction delays and ratios of flow to capacity (RFC).

7.2. Link Traffic Volumes

7.2.1. Link flow volumes have been extracted from the 2012 and 2008 models for the road sections identified in Table 21, by direction.

7.2.2. Table 22, below, gives a summary of actual flows and differences between the models for the AM peak. It shows reasonably close similarity between the models in terms of assigned flow volumes on key links. Taking an overview of the AM peak comparison, the following features emerge:

- Total 2-way AM flow across all links, in 2012, is 21,178 pcu;
- Average 2-way AM flow, across all links, is greater in 2012 by 83 pcu/hour;
- Average 2-way AM flow, across cordon links, is greater in 2012 by 84 pcu/hour;
- Average 2-way AM flow, across east/west screen-line links, is greater in 2012 by 64 pcu/hour;
- Average 2-way AM flow, across north/south screen-line links, is greater in 2012 by 135 pcu/hour;
- Overall increase in AM modelled flow across the cordon links is 15%;
- Overall increase in AM modelled flow across the east/west screen-line links is 12%;
- Overall increase in AM modelled flow across the north/south screen-line links is 15%;

7.2.3. The above differences are not considered to be significant given a range of acceptable inaccuracy in the modelled flows.

Table 22: Comparison of Key Link Traffic Flows AM Peak (Actual Flow, All Vehicles)

Link No.	Link Location	Link Direction	2012 Model	2008 Model	Flow Difference in 2012
1	A49 Ross Road	North bound	983	753	230
		South bound	715	467	248
2	A465 Belmont Road	Northeast bound	970	666	304
		Southwest bound	726	635	91
16	Barton Road	East bound	72	203	-132
		West bound	190	30	160
3	A438 Whitecross Road	East bound	487	744	-257
		West bound	527	474	53
4	A49 Newtown Road	South bound	1150	1068	83
		North bound	764	673	92
17	College Road	South bound	454	284	170
		North bound	207	238	-31
5	A465 Aylestone Hill	Southwest bound	758	744	15
		Northeast bound	680	409	271
6	A438 Ledbury Road	East bound	278	364	-86
		West Bound	478	482	-4
7	B4224 Hampton Park Road	West bound	405	188	218
		East bound	204	108	95
8	A49 Greyfriars	North bound	2176	1783	393
		South bound	1628	1563	65
9	St Martins Street	North bound	152	73	80
		South bound	102	99	3
10	B4399 Rotherwas Access Road	Northeast bound	254	95	160
		Southwest bound	134	31	103
11	Holme Lacy Road	West bound	747	667	80
		East bound	546	666	-120
12	Hinton Road	East bound	329	147	182
		West bound	116	53	63
13	A438 Newmarket Street	East bound	1200	1135	66
		West bound	1140	1210	-70
14	B4359 Widemarsh Street	North bound	256	392	-136
		South bound	621	580	42
15	A4103 Roman Road	West bound	746	653	93
		East bound	980	676	304

7.2.4. Table 23, below, contains an equivalent summary of actual flows and differences between the models for the PM peak. Again, it shows reasonably good similarity between the models in terms of assigned flows. Overall, the PM peak comparison shows the following characteristics:

- Total 2-way PM flow across all links, in 2012, is 20,507 pcu;
- Average 2-way PM flow, across all links, is greater in 2012 by 39 pcu/hour;
- Average 2-way PM flow, across cordon links, is greater in 2012 by 34 pcu/hour;
- Average 2-way PM flow, across east/west screen-line links, is greater in 2012 by 56 pcu/hour;
- Average 2-way PM flow, across north/south screen-line links, is greater in 2012 by 13 pcu/hour;
- Overall increase in PM modelled flow across the cordon links is 6%;
- Overall increase in PM modelled flow across the east/west screen-line links is 12%;
- Overall increase in PM modelled flow across the north/south screen-line links is 1%;

7.2.5. These PM flow differences are very small and insignificant given a range of acceptable inaccuracy in the modelled flows.

Table 23: Comparison of Key Link Traffic Flows PM Peak (Actual Flow, All Vehicles)

Link No.	Link Location	Link Direction	2012 Model	2008 Model	Flow Difference in 2012
1	A49 Ross Road	North bound	761	521	239
		South bound	780	565	215
2	A465 Belmont Road	Northeast bound	927	986	-59
		Southwest bound	1097	1240	-142
16	Barton Road	East bound	103	72	31
		West bound	94	198	-104
3	A438 Whitecross Road	East bound	478	542	-64
		West bound	742	790	-49
4	A49 Newtown Road	South bound	871	820	51
		North bound	938	943	-5
17	College Road	South bound	289	237	52
		North bound	308	261	47
5	A465 Aylestone Hill	Southwest bound	528	591	-63
		Northeast bound	739	544	195
6	A438 Ledbury Road	East bound	386	473	-87
		West Bound	295	232	63
7	B4224 Hampton Park Road	West bound	222	57	165
		East bound	348	230	118
8	A49 Greyfriars	North bound	1746	1823	-77
		South bound	2174	2085	89
9	St Martins Street	North bound	168	120	48
		South bound	92	97	-6
10	B4399 Rotherwas Access Road	Northeast bound	100	26	74
		Southwest bound	157	107	50
11	Holme Lacy Road	West bound	932	754	179
		East bound	554	544	10
12	Hinton Road	East bound	397	137	260
		West bound	166	65	101
13	A438 Newmarket Street	East bound	950	965	-15
		West bound	1002	999	3
14	B4359 Widemarsh Street	North bound	246	376	-130
		South bound	351	363	-13
15	A4103 Roman Road	West bound	786	737	49
		East bound	783	674	109

7.3. Junction Traffic Inflows

7.3.1. We have investigated junction performance in each of the 2012 and 2008 models. The key junction locations are as shown in Table 24.

Table 24: 2012 Hereford Model Network: Junctions for Analysis

Junction No.	Junction Location	Network Node
1	A49 Ross Rd / Holme Lacy Rd / Walnut Tree Av	188
2	A465 / Walnut Tree Av	192
3	A465 Belmont Rd / Southolme Rd	246
4	A49 Ross / Hinton Rd	143
5	A49 Ross Rd / A465 Belmont Rd / Asda	871, 875, 876, 877, 878
6	A49 Greyfriars / St Martins St	254
7	A49 Greyfriars / Barton Rd / St Nicholas St	282
8	A49 Victoria St / A438 Eign St	281
9	A49 Edgar St / A438 Newmarket St	1101, 1102, 1103, 1104
10	B4359 Widemarsh St / A438 Blueschool St	112
11	A465 Commercial Rd / A438 Union St	114
12	A438 Bath St / St Owen St	121
13	A438 Ledbury Rd / Eign Rd / St Owen St	139
14	B4224 Hampton Park Rd / Vineyard Rd	179
15	A438 Ledbury Rd / Bodenham Rd / Hafod Rd	168
16	A438 Ledbury Rd / Folly La / Church Rd	226
17	A465 Aylestone Hill / Venns La	423
18	A465 Aylestone Hill / Folly La	223
19	A465 Aylestone Hill / Southbank Rd	164
20	A465 Aylestone Hill / Barrs Court Rd	163
21	Barrs Court Rd / College Rd	459
22	B4359 Newtown Rd / Widemarsh St	157
23	A49 Edgar St / B4359 Newtown Rd	255
24	A49 Holmer Rd / Priory Pl	153
25	A438 Eign St / Grimmer Rd	129
26	A438 Whitecross Rd / A4110 Three Elms Rd / Yazor Rd / Wordsworth Rd	199
27	Grandstand Rd / Yazor Rd	203
28	A4110 Three Elms Rd / Grandstand Rd	711
29	A4103 Roman Rd / A4110 Cannon Pyon Rd	253
30	A49 Holmer Rd / A4103 Roman Rd	215
31	A4103 Roman Rd / Old School La	216
32	A4103 Roman Rd / College Rd	217
33	College Rd / Venns La / Old School La	219
34	A465 Aylestone Hill / A4103 Roman Rd	257
35	B4399 Rotherwas Access Rd / The Straight Mile	509
36	B4399 Rotherwas Access Rd / A49 Ross Rd	863
37	Holme Lacy Rd / Hoarwithy Rd	185

7.3.2. Differences in assigned junction inflows, RFC and delays, in the respective 2012 and 2008 AM peak models are summarised in Table 25.

Table 25: Comparison of Key Junction Inflows and Performance AM Peak (Actual Flow, All Vehicles)

Jct. No.	Junction Location	2012 Max Turn RFC (%)	2012 Max Turn Delay (secs)	2012 Junction Inflow (PCU)	2008 Max Turn RFC (%)	2008 Max Turn Delay (secs)	2008 Junction Inflow (PCU)	RFC Difference	Delay Difference	Inflow Difference
1	A49 Ross Rd / Holme Lacy Rd / Walnut Tree Av	105.7%	237	2794	100.3%	107	2527	5.3%	130	267
2	A465 / Walnut Tree Av	101.7%	121	2195	65.5%	44	1838	36.2%	77	358
3	A465 Belmont Rd / Southolme Rd	43.2%	21	1926	26.2%	11	1159	17.1%	9	767
4	A49 Ross / Hinton Rd	106.8%	219	2571	97.6%	194	2095	9.2%	25	476
5	A49 Ross Rd / A465 Belmont Rd / Asda	84.5%	74	4304	88.8%	52	3822	-4.3%	23	482
6	A49 Greyfriars / St Martins St	98.0%	64	4087	62.6%	67	3542	35.4%	-3	545
7	A49 Greyfriars / Barton Rd / St Nicholas St	100.0%	175	4241	101.0%	176	3801	-1.0%	-1	440
8	A49 Victoria St / A438 Eign St	103.3%	140	4839	101.1%	88	4503	2.2%	52	336
9	A49 Edgar St / A438 Newmarket St	97.7%	98	4630	101.3%	95	4456	-3.6%	3	174
10	B4359 Widemarsh St / A438 Blueschool St	59.3%	71	2663	77.4%	64	2558	-18.1%	7	105
11	A465 Commercial Rd / A438 Union St	51.4%	46	2927	80.0%	71	2776	-28.6%	-25	152
12	A438 Bath St / St Owen St	79.8%	56	1622	98.1%	146	1566	-18.3%	-90	56
13	A438 Ledbury Rd / Eign Rd / St Owen St	63.8%	12	1363	58.3%	8	1325	5.6%	4	39
14	B4224 Hampton Park Rd / Vineyard Rd	19.2%	9	703	28.3%	6	518	-9.0%	3	184
15	A438 Ledbury Rd / Bodenham Rd / Hafod Rd	73.8%	19	1733	44.1%	14	1645	29.7%	4	89
16	A438 Ledbury Rd / Folly La / Church Rd	101.3%	160	1206	82.8%	67	1141	18.6%	93	66
17	A465 Aylestone Hill / Venns La	64.0%	15	1410	41.9%	7	1340	22.1%	7	69
18	A465 Aylestone Hill / Folly La	110.8%	183	2073	64.9%	12	1754	45.9%	171	320
19	A465 Aylestone Hill / Southbank Rd	90.9%	32	2065	101.0%	82	1759	-10.1%	-49	305
20	A465 Aylestone Hill / Barrs Court Rd	68.5%	13	2127	94.0%	72	2002	-25.5%	-59	125
21	Barrs Court Rd / College Rd	60.6%	17	1559	45.0%	8	1572	15.6%	9	-13
22	B4359 Newtown Rd /	64.7%	14	1329	62.5%	9	1382	2.1%	5	-53

Table 25: Comparison of Key Junction Inflows and Performance AM Peak (Actual Flow, All Vehicles)

Jct. No.	Junction Location	2012 Max Turn RFC (%)	2012 Max Turn Delay (secs)	2012 Junction Inflow (PCU)	2008 Max Turn RFC (%)	2008 Max Turn Delay (secs)	2008 Junction Inflow (PCU)	RFC Difference	Delay Difference	Inflow Difference
	Widemarsh St									
23	A49 Edgar St / B4359 Newtown Rd	98.9%	33	2459	90.6%	74	2446	8.4%	-42	13
24	A49 Holmer Rd / Priory Pl	108.7%	156	2169	93.5%	28	1968	15.1%	128	201
25	A438 Eign St / Grimmer Rd	118.6%	329	1893	97.8%	55	1720	20.9%	274	173
26	A438 Whitecross Rd / A4110 Three Elms Rd / Yazor Rd / Wordsworth Rd	43.7%	18	1971	53.9%	15	1818	-10.2%	3	154
27	Grandstand Rd / Yazor Rd	87.9%	28	1050	68.9%	14	980	19.0%	15	70
28	A4110 Three Elms Rd / Grandstand Rd	22.3%	8	1042	36.1%	8	975	-13.8%	0	67
29	A4103 Roman Rd / A4110 Cannon Pyon Rd	118.8%	434	1660	77.4%	58	1279	41.4%	376	381
30	A49 Holmer Rd / A4103 Roman Rd	74.7%	29	3032	80.4%	26	2777	-5.7%	2	255
31	A4103 Roman Rd / Old School La	91.8%	14	1824	93.7%	37	1373	-1.8%	-24	451
32	A4103 Roman Rd / College Rd	75.8%	20	1485	61.8%	19	1257	14.0%	1	228
33	College Rd / Venns La / Old School La	100.0%	127	1242	78.3%	38	1143	21.7%	88	99
34	A465 Aylestone Hill / A4103 Roman Rd	43.6%	19	1899	29.7%	8	1487	14.0%	10	412
35	B4399 Rotherwas Access Rd / The Straight Mile	19.9%	16	896	19.4%	15	825	0.5%	2	71
36	B4399 Rotherwas Access Rd / A49 Ross Rd	42.1%	16	1489	35.5%	15	895	6.6%	1	594
37	Holme Lacy Rd / Hoarwithy Rd	52.8%	13	1316	33.8%	11	1236	19.0%	2	80

7.3.3. Regarding overall junction performance in the AM peak models, we have drawn out the following comparison details:

- Average difference in AM junction RFC (highest turn): 7.5%;
- Average difference in AM junction delay (highest turn): 33 seconds;
- Average difference in AM junction inflow: 231 pcu;

7.3.4. We consider that the above differences are small, indicating that the AM peak models have an acceptable level of consistency in performance. The junctions that suffer greatest stress (i.e. highest RFC exceeds 100%) are more evident in the 2012 model, owing to the higher overall level of traffic than at 2008.

7.3.5. Of the 10 key junctions on the A49, in the AM peak, five have flows exceeding capacity in 2012, whilst four are above capacity in 2008.

7.3.6. An equivalent comparison of junction performance in the PM peak models is given in Table 26.

Table 26: Comparison of Key Junction Inflows and Performance PM Peak (Actual Flow, All Vehicles)

Jct. No.	Junction Location	2012 Max Turn RFC (%)	2012 Max Turn Delay (secs)	2012 Junction Inflow (PCU)	2008 Max Turn RFC (%)	2008 Max Turn Delay (secs)	2008 Junction Inflow (PCU)	RFC Difference	Delay Difference	Inflow Difference
1	A49 Ross Rd / Holme Lacy Rd / Walnut Tree Av	104.8%	199	2838	104.5%	240	2510	0.3%	-41	328
2	A465 / Walnut Tree Av	70.8%	16	2257	108.6%	248	2455	-37.9%	-233	-198
3	A465 Belmont Rd / Southolme Rd	71.1%	23	2380	92.6%	40	2413	-21.5%	-17	-33
4	A49 Ross / Hinton Rd	64.1%	26	2417	109.7%	358	2046	-45.7%	-332	371
5	A49 Ross Rd / A465 Belmont Rd / Asda	91.0%	93	4304	112.7%	392	3822	-21.7%	-299	482
6	A49 Greyfriars / St Martins St	88.4%	115	4206	69.6%	84	4052	18.8%	31	155
7	A49 Greyfriars / Barton Rd / St Nicholas St	106.9%	324	4254	103.7%	246	4319	3.2%	78	-65
8	A49 Victoria St / A438 Eign St	100.0%	107	4924	80.1%	28	4916	19.9%	79	8
9	A49 Edgar St / A438 Newmarket St	117.5%	268	4630	105.7%	177	4456	11.8%	91	174
10	B4359 Widemarsh St / A438 Blueschool St	83.5%	92	2375	74.9%	63	2331	8.6%	29	43
11	A465 Commercial Rd / A438 Union St	56.5%	57	2524	99.4%	116	2955	-42.9%	-59	-432
12	A438 Bath St / St Owen St	65.9%	49	1539	84.9%	49	1551	-19.1%	-1	-12
13	A438 Ledbury Rd / Eign Rd / St Owen St	58.2%	8	1326	43.1%	7	1168	15.1%	1	157
14	B4224 Hampton Park Rd / Vineyard Rd	16.8%	9	750	16.9%	6	539	0.0%	4	210
15	A438 Ledbury Rd / Bodenham Rd / Hafod Rd	62.5%	17	1665	40.0%	12	1447	22.5%	5	218
16	A438 Ledbury Rd / Folly La / Church Rd	89.7%	170	987	81.6%	75	1037	8.1%	95	-50
17	A465 Aylestone Hill / Venns La	89.4%	30	1497	59.3%	10	1687	30.1%	20	-190

Table 26: Comparison of Key Junction Inflows and Performance PM Peak (Actual Flow, All Vehicles)

Jct. No.	Junction Location	2012 Max Turn RFC (%)	2012 Max Turn Delay (secs)	2012 Junction Inflow (PCU)	2008 Max Turn RFC (%)	2008 Max Turn Delay (secs)	2008 Junction Inflow (PCU)	RFC Difference	Delay Difference	Inflow Difference
18	A465 Aylestone Hill / Folly La	102.8%	74	1895	57.1%	10	1768	45.7%	64	126
19	A465 Aylestone Hill / Southbank Rd	62.1%	17	1891	83.3%	33	1852	-21.2%	-16	39
20	A465 Aylestone Hill / Barrs Court Rd	62.0%	16	2078	98.1%	74	2038	-36.1%	-59	39
21	Barrs Court Rd / College Rd	52.7%	15	1304	34.1%	7	1448	18.6%	8	-145
22	B4359 Newtown Rd / Widemarsh St	36.7%	11	1092	34.0%	8	1164	2.7%	3	-72
23	A49 Edgar St / B4359 Newtown Rd	74.8%	24	2363	98.0%	67	2438	-23.2%	-43	-75
24	A49 Holmer Rd / Priory Pl	100.2%	37	2182	77.8%	13	2159	22.4%	24	23
25	A438 Eign St / Grimmer Rd	71.5%	39	1563	89.4%	116	2229	-17.9%	-77	-666
26	A438 Whitecross Rd / A4110 Three Elms Rd / Yazor Rd / Wordsworth Rd	88.1%	28	2114	66.6%	21	2260	21.6%	7	-146
27	Grandstand Rd / Yazor Rd	68.8%	18	1221	63.6%	10	1083	5.2%	8	138
28	A4110 Three Elms Rd / Grandstand Rd	43.4%	11	1168	38.8%	11	922	4.6%	1	246
29	A4103 Roman Rd / A4110 Cannon Pyon Rd	95.9%	81	1457	99.2%	188	1551	-3.4%	-107	-94
30	A49 Holmer Rd / A4103 Roman Rd	58.0%	25	3011	61.5%	19	2793	-3.5%	6	218
31	A4103 Roman Rd / Old School La	71.1%	17	1654	75.4%	13	1290	-4.3%	4	365
32	A4103 Roman Rd / College Rd	42.6%	10	1360	59.8%	18	1269	-17.2%	-9	91
33	College Rd / Venns La / Old School La	75.7%	50	1054	70.8%	25	1206	4.9%	25	-152
34	A465 Aylestone Hill / A4103 Roman Rd	33.2%	18	1734	25.5%	8	1301	7.7%	10	433
35	B4399 Rotherwas Access Rd / The Straight Mile	23.2%	17	682	13.7%	14	657	9.5%	3	25
36	B4399 Rotherwas Access Rd / A49 Ross Rd	36.3%	16	1278	27.3%	16	804	9.0%	0	474
37	Holme Lacy Rd / Hoarwithy Rd	78.9%	16	1439	33.9%	12	1116	45.0%	4	323

7.3.7. Overall junction performance in the PM peak models shows the following characteristics:

- Average difference in PM junction RFC (highest turn): 0.5%;

- Average difference in PM junction delay (highest turn): -19 seconds;
- Average difference in PM junction inflow: 64 pcu;

7.3.8. The above differences in performance are again small, confirming that the PM peak models have an acceptable level of consistency. The junctions that suffer greatest stress (i.e. highest RFC exceeds 100%) are more evident in the 2012 model, owing to the higher overall level of traffic than at 2008.

7.3.9. Of the 10 key junctions on the A49, in the PM peak, five have flows exceeding capacity in 2012 and in 2008.

8. Conclusions From the 2012 and 2008 Base Highway Models

8.1. Summary

8.1.1. We have reviewed and compared the outcomes from the new and existing transport models of Hereford, which have been developed in 2012 and 2008, respectively. Our analysis has considered the AM and PM peak highway models, only, at this stage.

8.1.2. The aspects of the base model that we have investigated comprise:

- Accuracy of the 2012 model in comparison with accepted validation criteria;
- Patterns of overall trip demand at origin – destination level;
- Patterns of movement and route choice between key zones and on key links; and
- Network performance indicators, including flows, delays and ratios of flow to capacity;

8.2. Conclusions

8.2.1. The base 2012 highway models have achieved an acceptable level of accuracy when compared with guideline traffic flow, journey time and convergence criteria.

8.2.2. Against a target of 85%, the AM peak model has 91% of validation link flows with a GEH of 5 or less, whilst the PM peak has 93% of link flows with a GEH of 5 or less.

8.2.3. Also against a target of 85%, the AM model has 92% of journey time routes within 15% of observed, whilst the PM model also has 92% of routes within 15% of observed.

8.2.4. Use of matrix estimation to enhance the poorly observed O-D segments of the model, has been carefully controlled to ensure that journey purposes and trip lengths are not distorted.

8.2.5. The 2012 highway model entails significantly more O-D trip movements than in 2008. The increases amount to 43% in the AM peak and 39% in the PM peak. The increases are attributable to the enhanced representation of localised trips within Hereford and longer-distance trips in outer areas of Herefordshire, rather than being a consequence of any background growth in flows.

8.2.6. Journey purpose proportions in the 2012 model are reliable, when compared with similar proportions in the NTEM database for 2011.

8.2.7. In the AM and PM, of the top 30 largest sector-to-sector movements, 12 movements are consistent between the 2012 and 2008 models. The inconsistent movements reflect the greater volumes of trips in the 2012 model, which distort the ranking.

8.2.8. The relative orientation of trips between internal (i.e. Hereford) and external segments of the AM and PM models is similar between 2012 and 2008. At 2012, this amounts to about 44% within Hereford, 22% from outside into Hereford, 18% from Hereford to outside and 16% wholly outside Hereford.

8.2.9. Traffic volumes between external areas, which could potentially pass through Hereford, are very similar at 2012 and 2008, amounting to about 6% of overall trips.

8.2.10. Choice of preferred (least cost) routes between key O-D zones is sensible and comparable in the 2012 and 2008 models. However, the relative magnitude of major trip movements is different in the models, because at 2012 there is additional trip data incorporated in the AM and PM, as a result of applying land use trip end constraints and including a broader range of survey information.

8.2.11. Comparison of travel times and distances between key zones shows strong similarities at 2012 and 2008. The average time difference is less than 2.0 minutes in the AM and PM, whilst the average distance difference is less than 1/3 kilometre.

8.2.12. Assigned flows on 17 key network links are similar in the 2012 and 2008 models, but are slightly higher at 2012, owing to inclusion of trips in the new model that could not be represented previously. Two-way flows across the Hereford city cordon are higher in the 2012 model by 15% in the AM and 6% in the PM.

8.2.13. Likewise, the pattern of traffic inflows at 37 key junctions is similar, but slightly higher, at 2012, when compared with 2008. Average difference between the models in maximum RFC, averaged across key junctions, is only 7.5% in the AM and 0.5% in the PM. The equivalent differences in maximum delay, averaged across junctions, are 33 seconds and -19 seconds, in the AM and PM, whilst differences in inflow, averaged, are 231pcu and 64pcu, respectively.

8.2.14. Overall, on the basis of this analysis, Amey considers that the updated 2012 highway model is fit for purpose for future traffic forecasting and scheme appraisal. It represents an enhancement to the previous 2008 model and introduces modest changes that are defensible and explicable.

Appendix A