Lincoln Eastern Bypass – Final Funding Submission

Local Model Validation Report

Lincolnshire
COUNTY COUNCIL
HIGHWAYS ALLIANCE

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1 Introduction

1.1 Background

Mouchel has been commissioned under the Lincolnshire County Council Technical Services Partnership to produce an updated set of models, forecasting and appraisal work in support of the Full Approval Application to the Department for Transport for the Lincoln Eastern Bypass.

The original modelling and appraisal was prepared by Jacobs to support the first Major Scheme Business Case (MSBC) submission for the scheme. However a subsequent assessment by the Department for Transport (DfT) highlighted a number of substantive issues relating to the quality and suitability of the modelling work.

At the request of Lincolnshire County Council (LCC), Mouchel carried out a review of the original modelling work and then developed a methodology and work programme for further development of the transport modelling, forecasting and appraisal using the Greater Lincoln Transport Model (GLTM), of which Mouchel is now the custodian.

1.2 Purpose of this Report

This Local Model Validation Report (LMVR) describes the development of the Greater Lincoln Transport Model and its validation against observed traffic data for 2006, based on criteria set out by the Department for Transport (DfT) in the Design Manual for Roads and Bridges (DMRB) Volume 12a. This report seeks to demonstrate that the model provides an accurate representation of highway travel patterns in the Greater Lincoln area.

It is to be read in conjunction with the GLTM Traffic Survey Report (July 2011), which describes the observed traffic datasets that have been used to build the model.

1.3 Additional Works

The LEB gained provisional funding status based on the 2011 BaFB, including the updated modelling work. The current focus is on establishing the final funding submission. This needs to establish that the case of LEB is still sound in the light of changes to the scheme and changes to the economic landscape, including values of time, growth and specific developments.

One specific condition imposed by DfT was the need to reinterpret the calibration in the light of changed WebTAG guidance relating to model calibration over the period 2006 to 2016.

1.4 Department for Transport (DfT) Requirements

The Value for Money guidance published by DfT includes a checklist of requirements for the Assignment Validation Report. These are listed in Table 1-1 below along with references to indicate where they have been addressed in this report.

Table 1-1 – DfT Checklist for the Assignment Validation Report

Requirements	Reference
Description of the road traffic and public transport passenger assignment model development, including model network and zone plans, details of treatment of congestion on the road system and crowding on the public transport system	Section 2.9, Chapter 4.
Description of the data used in model building and validation with a clear distinction made for any independent validation data	Section 3.5, Appendix B
Evidence of the validity of the networks employed, including range checks, link length checks, and route choice evidence	Chapter 4 and Section 4.9
Details of the segmentation used, including the rationale for that chosen	Chapter 5
Validation of the trip matrices, including estimation of measurement and sample errors	Chapter 5 and Annex A GLTM Matrix Build Report
Details of any 'matrix estimation' techniques used and evidence of the effect of the estimation process on the scale and pattern of the base travel matrices	Section 6.6 to Section 6.9
Validation of the trip assignment, including comparisons of flows (on links and across screenlines/cordons) and, for road traffic models, turning movements at key junctions	Chapter 7
Journey time validation, including, for road traffic models, checks on queue pattern and magnitudes of delays/queues	Chapter 7, Section 7.4
Detail of the assignment convergence	Section 6.10
Present year validation if the model is more than 5 years old	Separate cover
A diagram of modelled traffic flows, both in the immediate corridor and other relevant corridors	Chapter 7

1.5 Structure of this Report

This report is structured as follows:

- Section 2 – Model Overview: provides a brief summary of the main features of the highway model and also how it has been developed.
- Section 3 – Traffic Data: describes the traffic datasets that have been used to develop the model. Further detail on these is provided in the Traffic Survey Report.
- Section 4 – Network Development: describes the extent of the highway network included in the model and how it has been developed.
- Section 5 – Matrix Development: describes how the trip matrices, which represent travel patterns in the Greater Lincoln area, have been developed. A report detailing this process is included as Annex A; GLTM Matrix Build Report.
- Section 6 – Model Calibration: describes the processes that have been undertaken to adjust the transport model so that it more realistically reflects travel patterns and conditions in the Greater Lincoln area.

- Section 7 – Model Validation: summarises the work undertaken to prove that the model provides an accurate representation of travel patterns in the Greater Lincoln area, including details of comparisons made with independent datasets and its accordance with DMRB criteria.

2 Model Overview

2.1 Introduction

This section of the report provides a brief overview of the Greater Lincoln Transport Model (GLTM), which has been developed in accordance with the work programme set out in the "Transport Model Review and Work Programme" document.

As noted earlier, the original model was prepared by Jacobs to provide a general foecasting tool for Lincoln and also to support a Major Scheme Business Case (MSBC) submission for funding for the Lincoln Eastern Bypass. Following concerns identified by the Department for Transport (DfT) in respect of the quality and suitability of the modelling work, a decision was reached to rebuild and update the model (GLTM).

This work was conducted and submitted in 2011. Subsequent to this and following Programme Entry approval in 2011 and Public Inquiries associated with Compulsory Purchase Orders and Side Road Orders, DfT required a Final Funding Application. LCC and their consultants Mouchel met with DfT in late 2015. As part of this submission DfT requested full model documentation and made commentary on the original model calibration and latest preferences to use updated Values of Time. Hence the model was revisited in terms of these aspects, together with zonal dis-aggregations (relevant from the detailed public inquiry work), improvements to coding protocols and updates to software versions.

Of necessity given the project timescale, this process was largely reliant on the original study data but included the following workstreams:

- **Stream A.** Matrix Build, Demand Model & Model System;
- **Stream B**. Data, Network Build & Supply Model; and
- **Stream C**. Forecasting & Appraisal.

This report, the LMVR, describes the first two stages of demand and supply modelling and the subsequent calibration and validation of the local highway model.

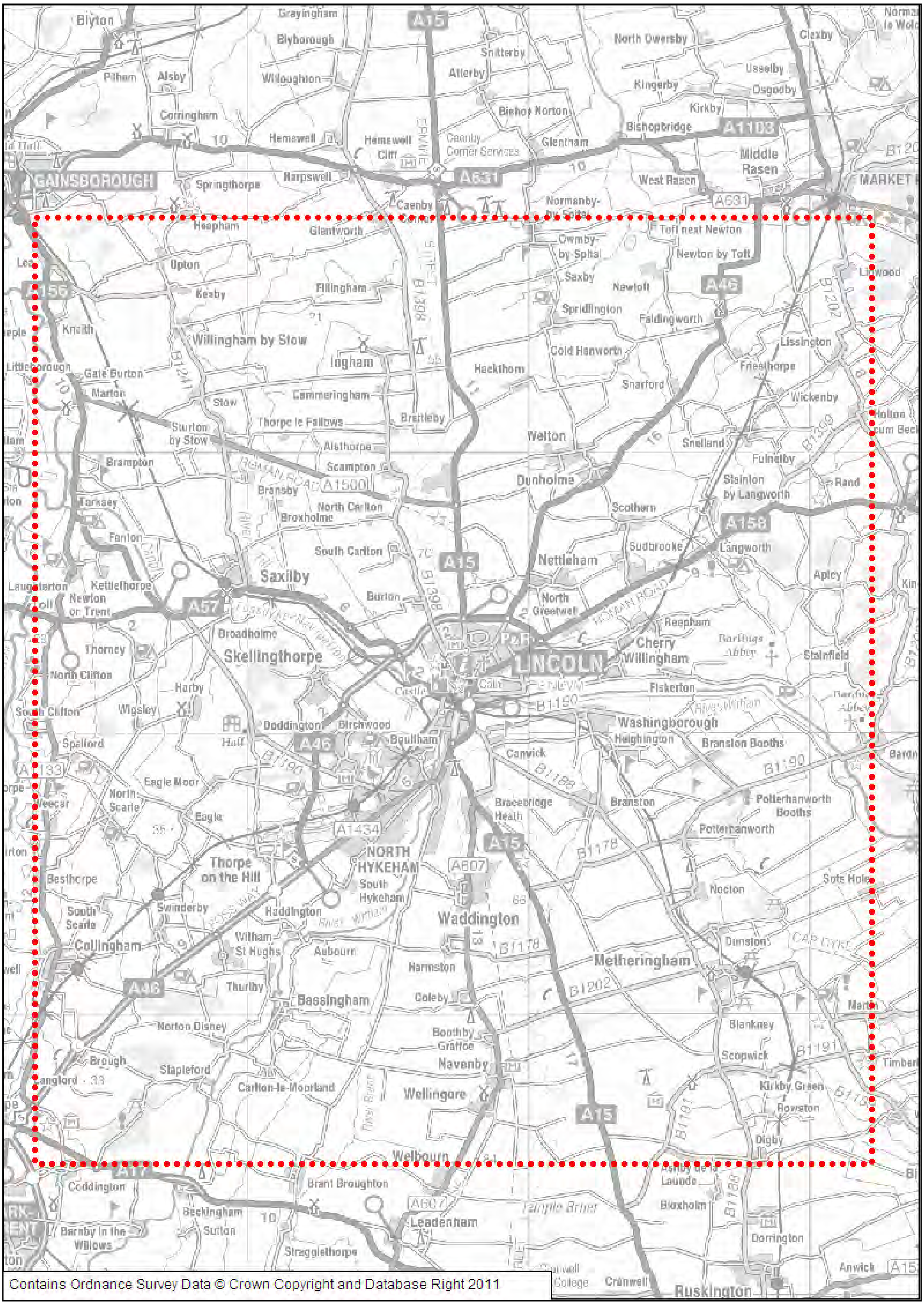
2.2 Modelling Software

The Greater Lincoln Transport Model was originally developed using PTV VISUM software V11.52-02. In the course of the current model update the model has been re-specified in V15.00-10.

2.3 Study Area

The model covers the urban area of Lincoln and surrounding countryside, and broadly aligns with the Lincoln Planning Area (LPA). The study area is shown in Figure 2-1.

Figure 2-1 – Map of Study Area



2.4 Zoning System

A zoning system aggregates geographical areas into individual blocks and so reduces the amount of detail in the model. The zoning system designed for the Greater Lincoln Transport Model now comprises 178 zones, of which 143 are internal zones, within the study area, and 35 are external zones.

In order to represent traffic patterns to an adequate level of detail, the zoning system in Lincoln encompasses a number of smaller sized zones. Outside the study area the zoning system is much less detailed with a smaller number of larger zones defined around major travel routes into the Greater Lincoln area.

2.5 Modelled Time Periods

Three time periods have been modelled in order to represent the different travel patterns that exist during a typical weekday:

- AM Peak hour (08:00 – 09:00);
- PM Peak hour (17:00 – 18:00);
- Average Inter Peak hour (10:00 – 16:00).

The above AM and PM Peak hours were identified through the analysis of Automatic Traffic Count (ATC) data described in the Traffic Survey Report.

2.6 Vehicle Classes

Three vehicle classes have been modelled; Cars, Light Goods Vehicles (LGVs) and Other Goods Vehicles (OGVs).

2.7 Modelled Highway Network

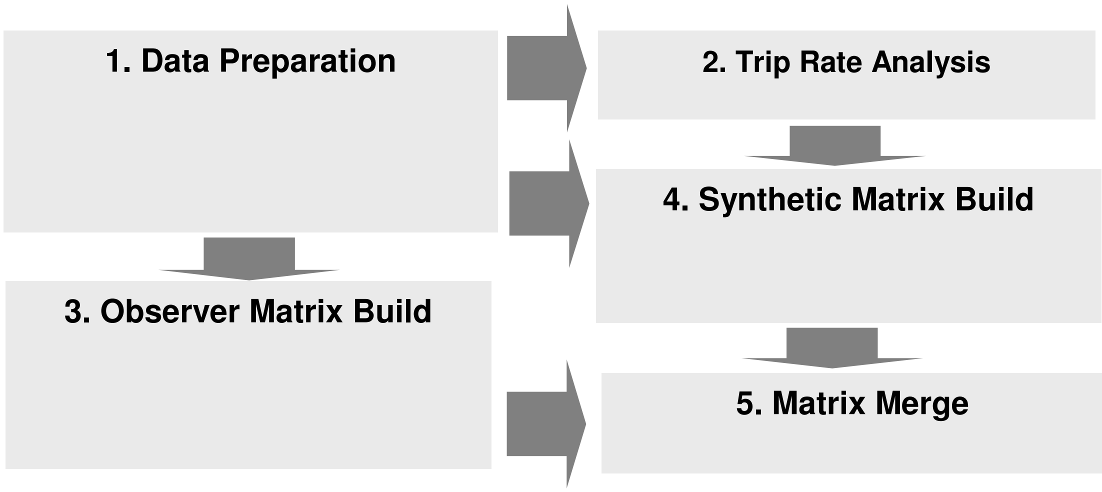
Within the study area, the modelled network includes all ‘A’ and ‘B’ class roads and most minor roads. Within Lincoln, residential roads that act as distributor routes or rat-runs have also been included in the model. The network has been coded in detail to reproduce the effects of traffic queues and delays on vehicle routing patterns.

Outside the study area, a coarse network of buffer links have been defined to include all major ‘A’ roads; from the A1 in the west to the A153 in the east, and from the M180 in the north to the A52 south. This ensures that all long distance traffic is properly routed into and around the Lincoln area.

2.8 Matrix Development

The process of demand modelling was essentially the same as in the earlier version of the model, albeit based on a comprehensive review of available data sources and their application. Construction of the base year matrices are therefore as illustrated below.

Following analysis of available survey data and other data sources, the principle task included construction of the observed trip matrices, largely from the Lincoln cordon survey, and development of complementary, synthetic matrices to represent the unobserved demand components. The observed and synthetic matrices were merged to form the final base year model demand matrices.



2.9 Blocking back and Flow Metering

Blocking back and flow metering was activated in the highway assignment model. The average car length is assumed to be 5.75m. The blocking back is calculated both during and after each assignment loop.

2.10 Model Calibration

The calibration of the Base Year (2006) traffic models was undertaken using an approach where the network was adjusted to ensure that the model realistically replicated routeing and vehicle speeds through the study area. Matrix estimation was then incorporated in the model calibration process in order to improve overall model validation.

2.11 Model Validation

Network validation was undertaken to establish that the network structure was accurate and that characteristics of the network are suitably represented in the model. A number of range and logic checks were undertaken, including routeing checks. Assignment validation was then undertaken for traffic flows (links and turns) and journey times. In most cases, the model compared extremely well with the observed situation, and met the DMRB validation criteria.

3 Traffic Data

3.1 Introduction

This section provides a summary of the observed data that has been used to develop the model and the analysis that has been undertaken. Greater detail on the traffic data is provided in the Traffic Survey Report (Mouchel, July 2011).

3.2 Overview of Data

This subsection provides a brief overview of the observed traffic data used to build the Greater Lincoln Transport Model. Further detail on this data is provided in Chapter 2 of the Traffic Survey Report.

3.2.1 Postcard Interview Surveys

Postcard Interview Surveys were carried out at 18 locations for a 12 hour period, between 7:00 and 19:00, on one weekday between Monday 2nd October 2006 and Wednesday 29th October 2006. At each site, postcards were distributed to drivers travelling in the inbound direction, with the exception of sites 13 and 14 in the city centre where postcards were distributed to drivers travelling in both directions.

The locations of the interview sites are shown in

Figure 3-1. In this plot, Interview sites 1-12 have been used to form a cordon around Lincoln. However, the cordon was not 'watertight' as a number of links cross the cordon were not included in the interview survey. The analysis of these non-interview sites is described in Chapter 5 of this report. Concurrent 12 hour Manual Classified Link Counts and 2-week, 24 hour ATC Counts were undertaken at each of these sites, with the exception of Site 6 where no ATC count is available.

Postcard questionnaires contain the following information:

- Where/ when the postcard is received
- Vehicle occupancy
- Vehicle type
- Purpose of travel
- Origin and destination of the trip
- Household Income

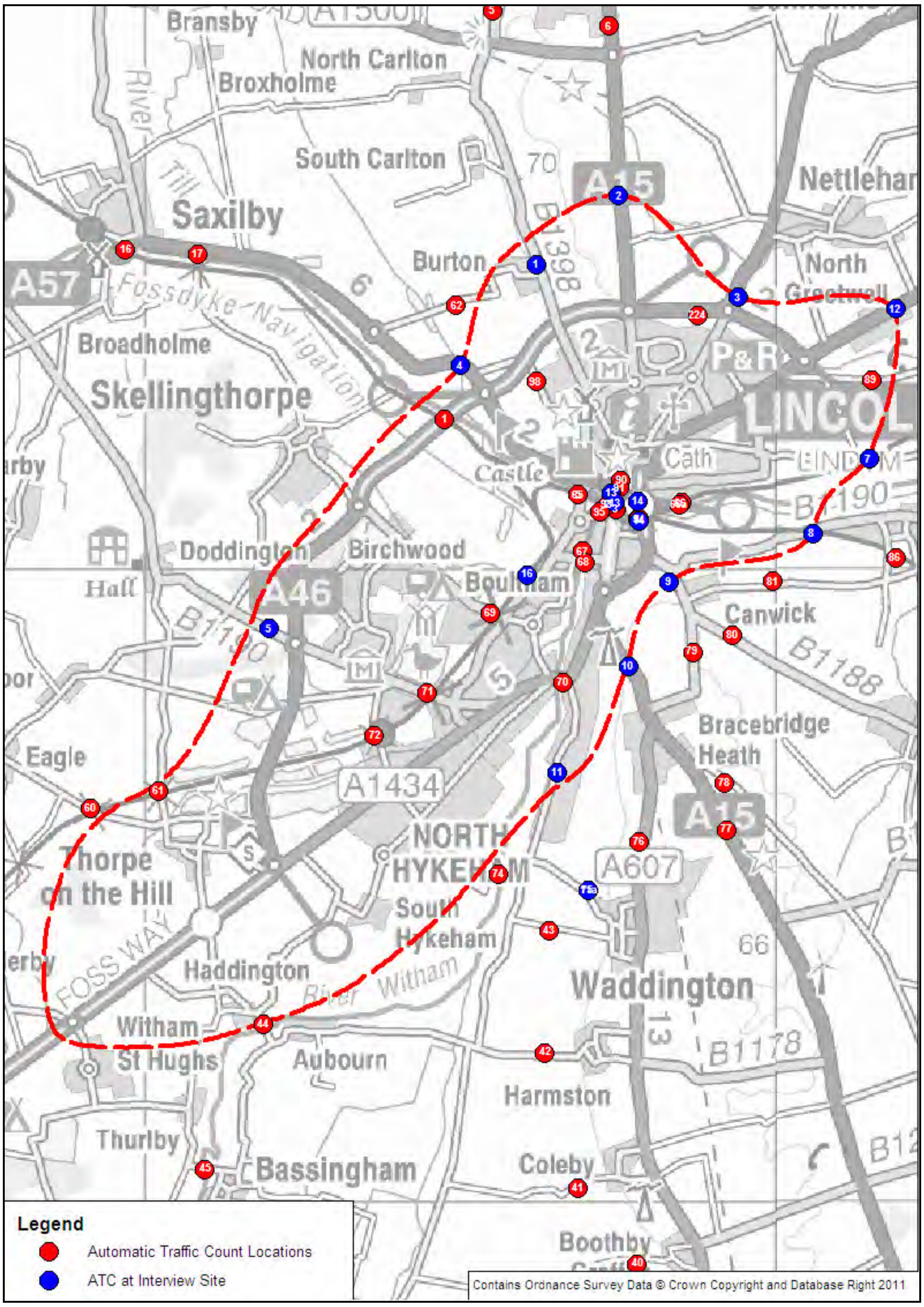
Figure 3-1 – Postcard Interview Sites

3.2.2 *Automatic Traffic Count Surveys*

Automatic Traffic Count (ATC) surveys were undertaken in September and October 2006 at 93 locations in the Greater Lincoln area, 17 of which were at Postcard

Interview sites. Each survey collected 24 hour data in both directions and lasted for a period of 14 days. The locations of the ATC surveys in the immediate vicinity of Lincoln are shown in Figure 3-2. This data has been supplemented by an additional six ATC sites in the centre of Lincoln, provided by Lincolnshire County Council, carried out between 07:00 and 19:00 on one weekday in October/November 2006.

Figure 3-2 – Automatic Traffic Count Surveys

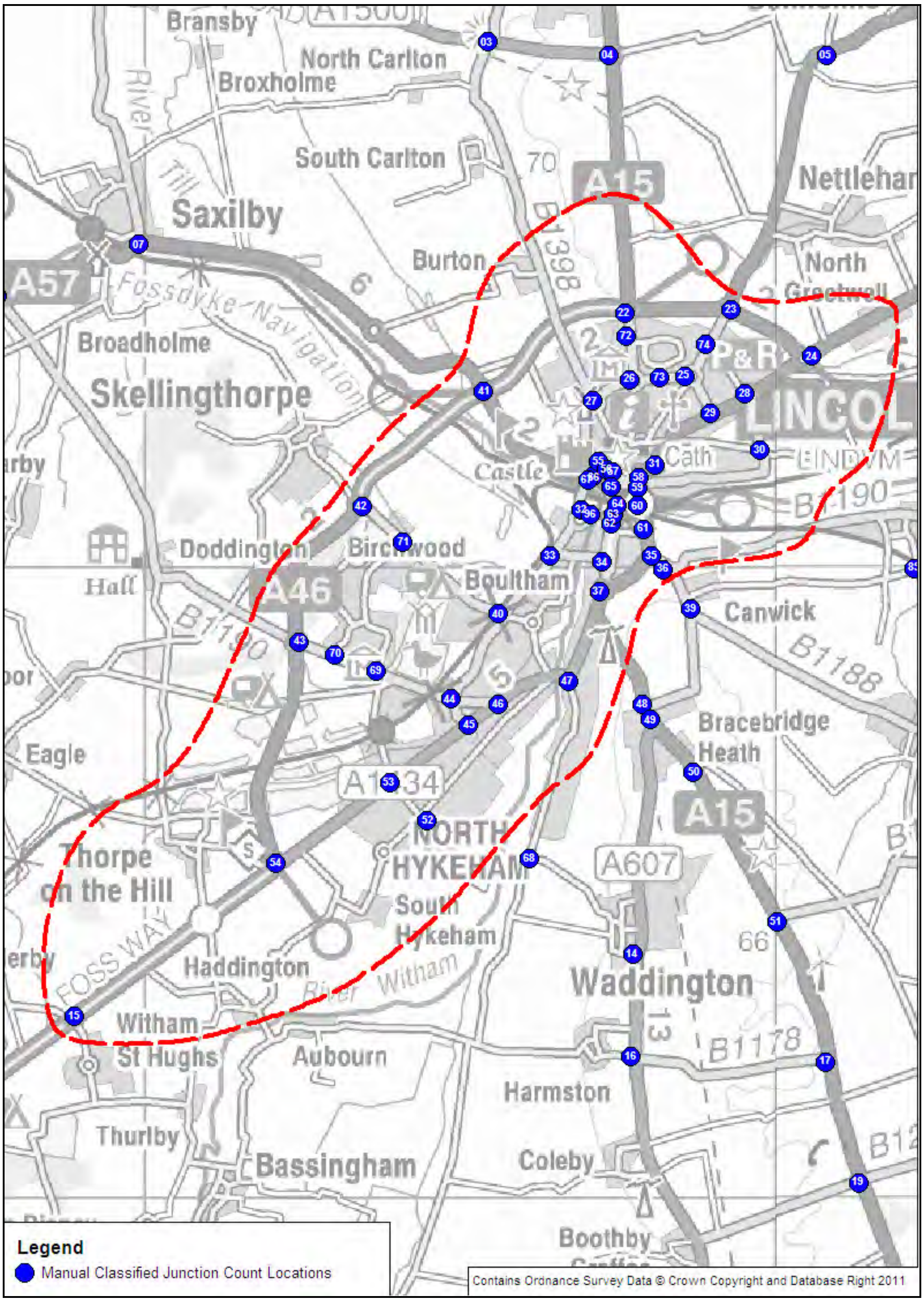


3.2.3 *Manual Classified Junction Count Surveys*

Manual Classified Junction Count (MCJC) surveys were undertaken at 76 junctions within the Greater Lincoln area.   Each survey was undertaken on one day in

September, October or November 2006, between 07:00-19:00. The locations of those surveys in the immediate vicinity of Lincoln are shown in Figure 3-3. This data has been supplemented by 13 MCJC surveys carried out in 2006, 2008 and 2011, which have been provided by Lincolnshire County Council.

Figure 3-3 – Manual Classified Junction Count Surveys

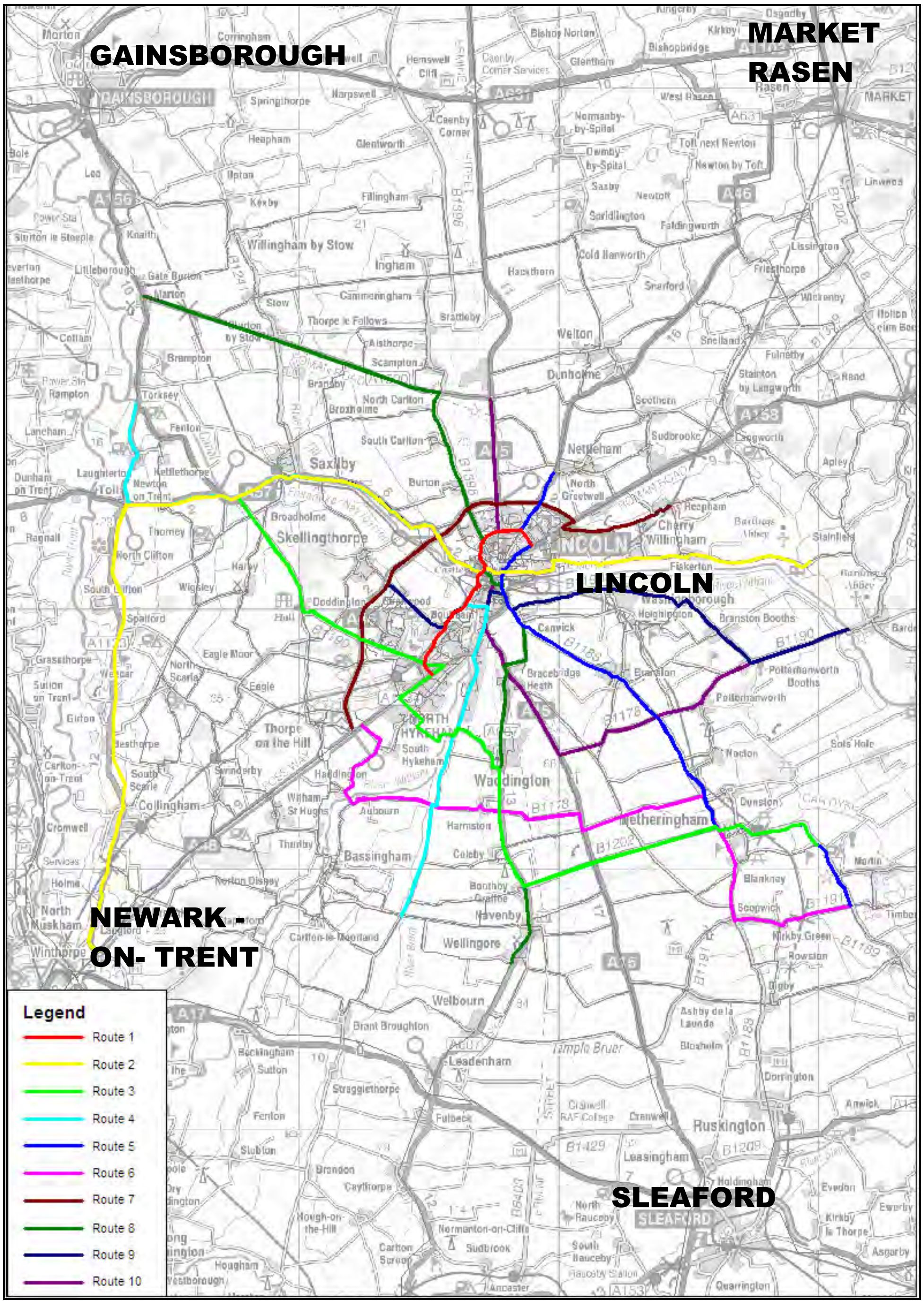


3.2.4 *Journey Time Surveys*

Journey Time Surveys were conducted on 10 routes in the Lincoln area, shown in Figure 3-4, across October and November 2006 with each route being surveyed a minimum of six times in each direction within the following time periods; 07:30-9:30, 10:00-15:00 and 16:30-18:30.

Given the relatively low sample, TrafficMaster journey time data for the year September 2009 to August 2010 was obtained and analysed to extract average journey times in both directions for certain routes within the Study Area.

Figure 3-4 – Journey Time Routes



3.3 Overview of Data Analysis

This subsection provides an overview of the processing and analysis of the observed traffic data. More detail on this is provided in Chapter 3 of the Traffic Survey Report.

The processing and analysis carried out is summarised as follows:

- All traffic count data has been standardised into five classifications; Cars, LGVs, OGVs, Light Vehicles and Total Vehicles, and each link and turning count has then been allocated to an Anode, Bnode and (where appropriate) Cnode to enable comparison with the model.
- All traffic count data has also been normalised, using a set of Day, Month and Year factors derived from TRADS data, to an "average weekday" in an "average month" in 2006.
- The accuracy of ATC data has been analysed in accordance with DMRB 12.2.1 and found to have an acceptable level of accuracy. (Further details of this analysis are provided in the Traffic Survey Report).
- ATC average weekday profiles have also been created, which confirm that the AM and PM Peak hours are 8:00-9:00 and 17:00-18:00 respectively.
- Analysis has also been undertaken to produce plots that illustrate traffic flows across screenlines and at junctions.
- The validity of Journey Time data has been checked and average travel times for each route in each direction have been calculated.

3.4 Rationalisation of Traffic Count Data

As part of the 2010 model review and in order to produce a set of traffic counts that could be used in the model building process, analysis of the count database was undertaken to identify and resolve inconsistencies between multiple traffic counts carried at similar locations.

The locations of each count were overlaid on the coded model network and a map base and the data compared at common sites. In total, 83 instances were identified where alternative sources of count data were available. An exercise was then undertaken to analyse the differences in flows and to determine how best to resolve these anomalies.

Adjustments included using average traffic flows across the common sites, using total traffic flows from one survey and classification/ turning proportions from another or selecting one survey over another because of its higher level of reliability. These actions were guided by the following general principles (in order of importance):

- Total traffic flows from ATC sites are more reliable than total traffic flows from MCC sites as they are an average over 8 days as opposed to 1 day.

- Vehicle type proportions from MCC sites are more reliable than those from ATC sites due to the limitations of pneumatic tubes.
- Counts from neutral months in 2006 are considered to be more reliable than counts from other months due to the need to apply larger normalisation factors in the latter cases.

In some instances, up to three data sources are available, for example three turning count surveys at junctions connected by two links. These added an additional layer of complexity to the calculation. In such situations, the reliability of the alternative data sources was afforded the highest rating.

Of the 83 instances of alternative counts data, 19 (~20%) were found to have differences in flow with GEH values greater than 5. However most of these 19 instances involved comparisons between single day surveys and it is therefore considered that, with daily fluctuations and potential survey errors, a degree of inconsistency is to be expected.

A list of the sites with alternative data sources is attached at Appendix A together with descriptions of how each has been resolved.

3.5 Calibration and Validation Counts

Table 3.1 below provides a summary of the allocation of the traffic count datasets to either model calibration or validation. Detailed tables are presented in Appendix B.

Figure 3.5 and Figure 3.6 show the locations of the calibration and validation counts respectively. It should be noted that a small number of turning counts have been used in both calibration and validation, with individual movements split between the two.

Table 3-1 – Calibration and Validation Counts

Type	Count Type	Number
Calibration Counts	Link count	368
	Turning counts	298
	Total Counts	**666 (69%)**
Independent Counts (Validation Counts)	Link count	34
	Turning counts	272
	Total Counts	**306 (31%)**
All Counts	**Total Counts**	**972**

Figure 3-5 – Calibration Counts

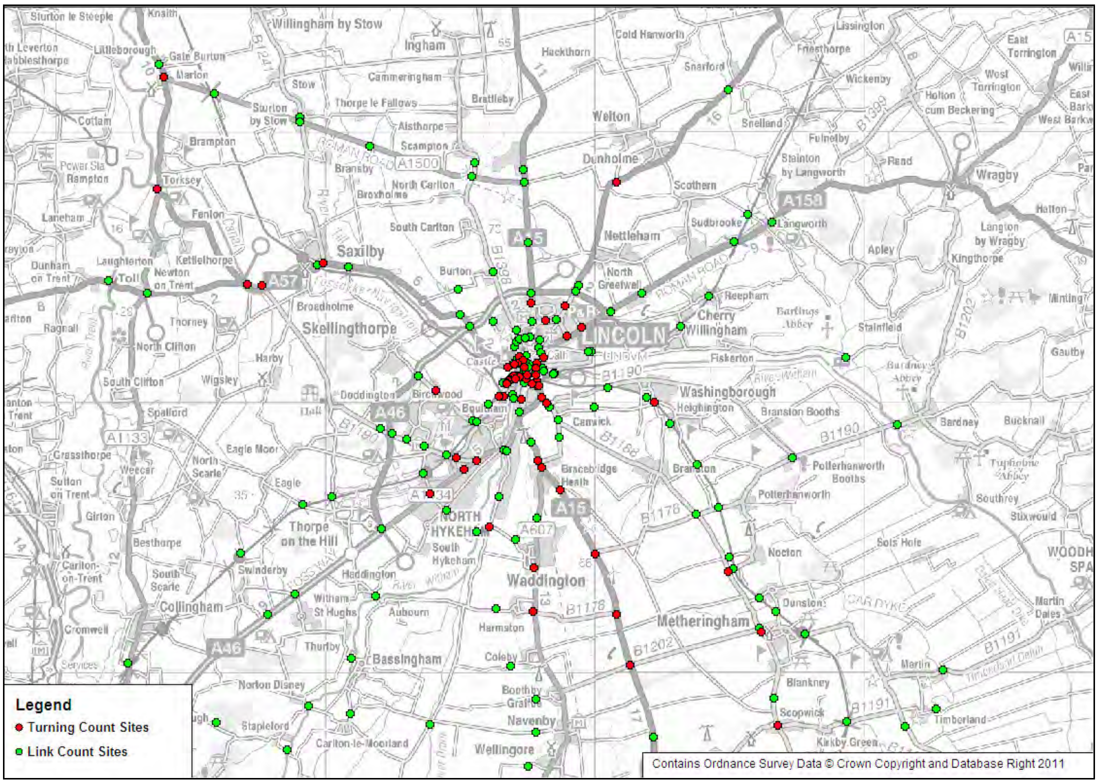
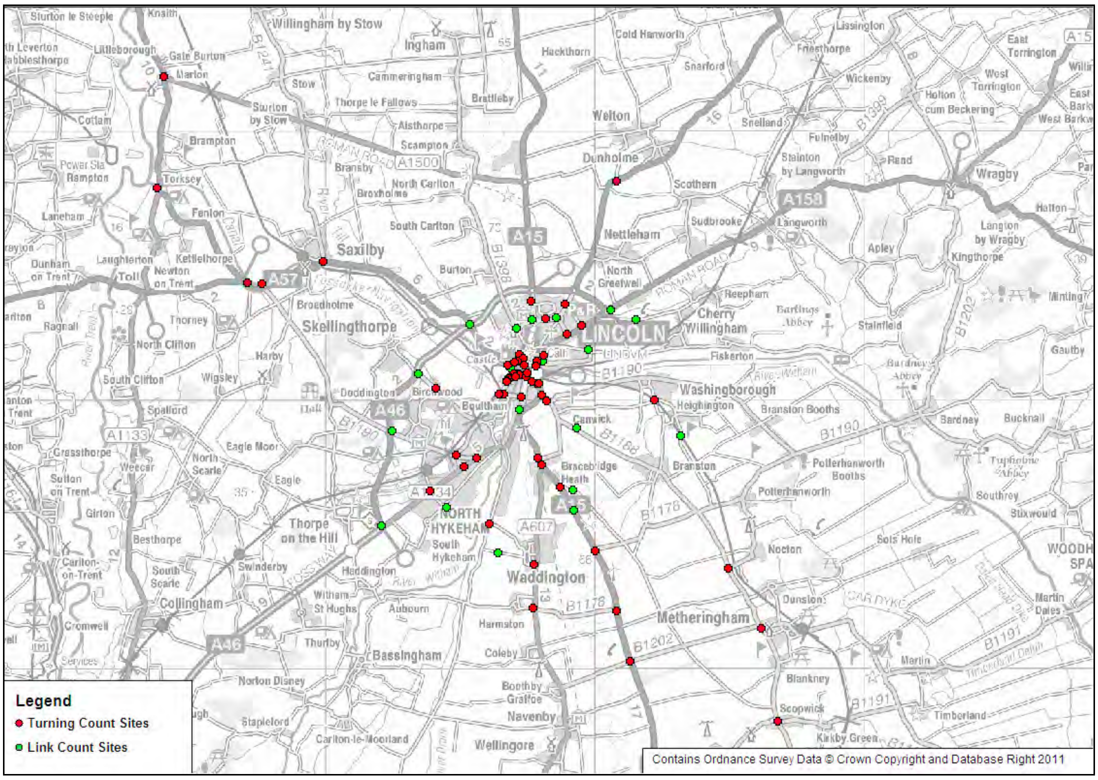


Figure 3-6 –Validation Counts – Lincoln



4 Network Development

4.1 Introduction

The road network represents the supply side of the modelling process, i.e. what the transport system offers to satisfy the movement needs of trip makers in the study area. The network is a system of nodes, representing junctions, which are connected by a number of links, which represent homogeneous stretches of road between junctions.

This section of the report describes the steps that have been taken to develop the highway network for the Greater Lincoln Transport Model.

4.2 Highway Network Definition

The modelled network provides an accurate representation of the existing highway network in Lincoln and its surrounding area.

Inside the study area it includes all 'A' and 'B' class roads and most of the minor roads within Lincoln. Residential roads that act as distributor routes have also been included. All junctions within the study area have been coded in detail in order to reproduce the effects of traffic queues and delays on vehicle routing patterns.

Outside the study area, a coarse network of buffer links has been defined to include all major 'A' roads; from the A1 in the west to the A153 in the east, and from the M180 in the north to the A52 in the south. This ensures that all long distance traffic is properly routed into and around the Lincoln area. The coverage of the Highway Network is shown in Figure 4.1 below.

4.3 Network Inventory

An inventory of the network was compiled from NAVTEQ, aerial photographs and site surveys. Information from these sources was then used to create links and junctions with exact details in VISUM. This included the junction layout, number of lanes and turn priority markers.

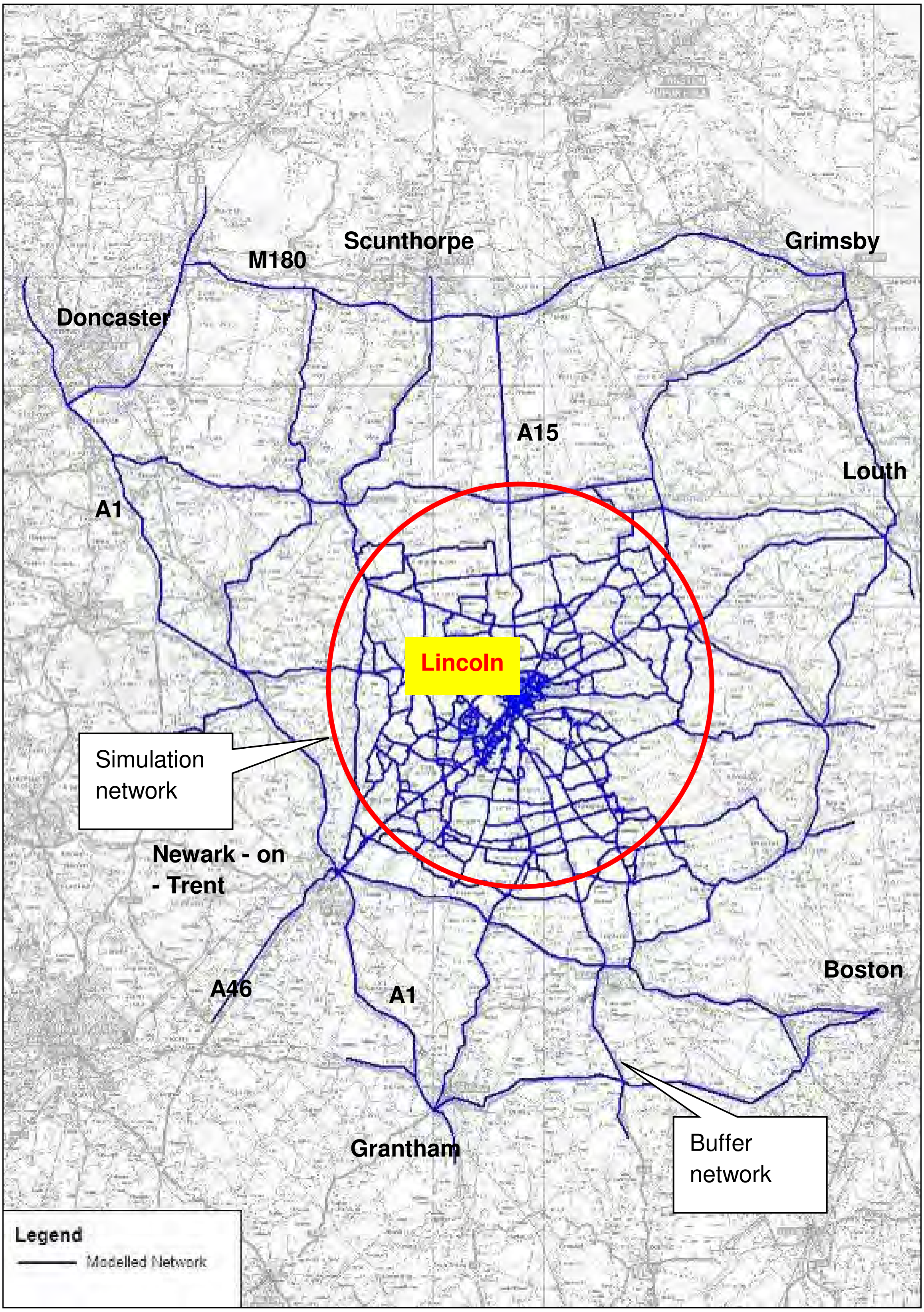
4.4 Node / Link Coding and Speed Flow Curves

All nodes were geo-coded using 1:10K raster maps. All link lengths for the model were checked from OS mapping with scale of 1:10K.

Roads are modelled as links in VISUM. All links were assigned correct distances. An appropriate speed-flow curve was also assigned for each link based on road type, number of lanes, speed limits, etc.

Information about all roads within the study area was gathered from the network inventory. This information included; type of road (urban, suburban, or rural, etc.), road classification (single, dual carriageway), speed limits and number of lanes of all the roads within the study area. The information was used to allocate the appropriate speed-flow curves to all the modelled links. A list of the speed-flow curves used for the Lincoln Eastern Bypass model is presented in Appendix C.

Figure 4-1 – Highway Network Coverage



The network coverage includes all the main roads to and from Lincoln. The wider network extends from Louth in the east to Retford in the west and from Boston and Grantham in the south to Grimsby and Doncaster in the north.

Major routes into Lincoln city centre include the A1434 Newark Rd and A15 Sleaford Rd to the south of Lincoln; A15 Riseholme Rd and A46 Lincoln Rd to the north; A57 Saxilby Rd to the west; and A158 Wragby Rd to the north east.

The network contains two main parts: simulation network in which junction/delay is modelled in detail and buffer network in which links are modelled only. Simulation network and buffer network are marked in Figure 4-1.

4.5 Junction Modelling

In order to represent the effects of traffic delays and queues at junctions, junctions have been modelled in detail to take into account traffic flows and conflicting movements. Each junction has been coded using detailed information from the highway network, which includes:

4.5.1 Priority Junction Modelling

A total of 437 priority junctions were modelled in the simulation network. The default saturation flows applied to the priority junctions in the study were as follows:

- Major Road Straight Ahead = 1950 pcu/hr/lane;
- Major Road Left Turn = 1850 pcu/hr/lane;
- Major Road Right Turn = 1750 pcu/hr/lane;
- Minor Road Left Turn = 745 pcu/hr/lane;
- Minor Road Right Turn = 627 pcu/hr/lane.

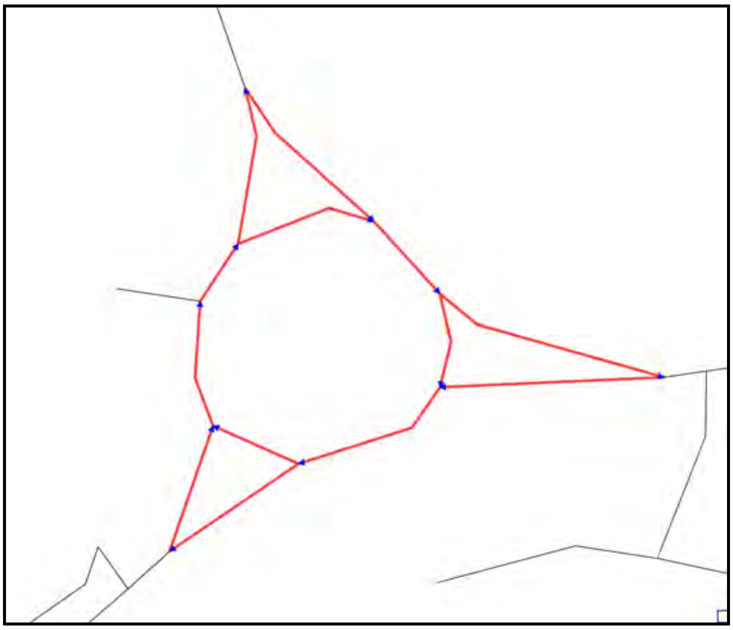
Saturation flows for junctions were further adjusted during the calibration/validation process taking into account the junction geometric layout such as lane width, number of lanes and lane marking of the junction

4.5.2 Roundabout Modelling

All roundabouts within the study area were modelled in detail. Capacities of roundabouts were calculated on the basis of the geometry of the roundabouts using the relationships derived from the TRL RR35 report. A spreadsheet was created based on formulae derived from the above report to calculate the maximum entry flow on each arm to the roundabout and the maximum circulating flow based on the measurements of the approach width, the entry width at the give way line, the length of the flare on the approach and the inscribed circle diameter of the roundabout.

An example of roundabout modelling is shown in Figure 4.2.

Figure 4-2 Example of a modelled roundabout junction



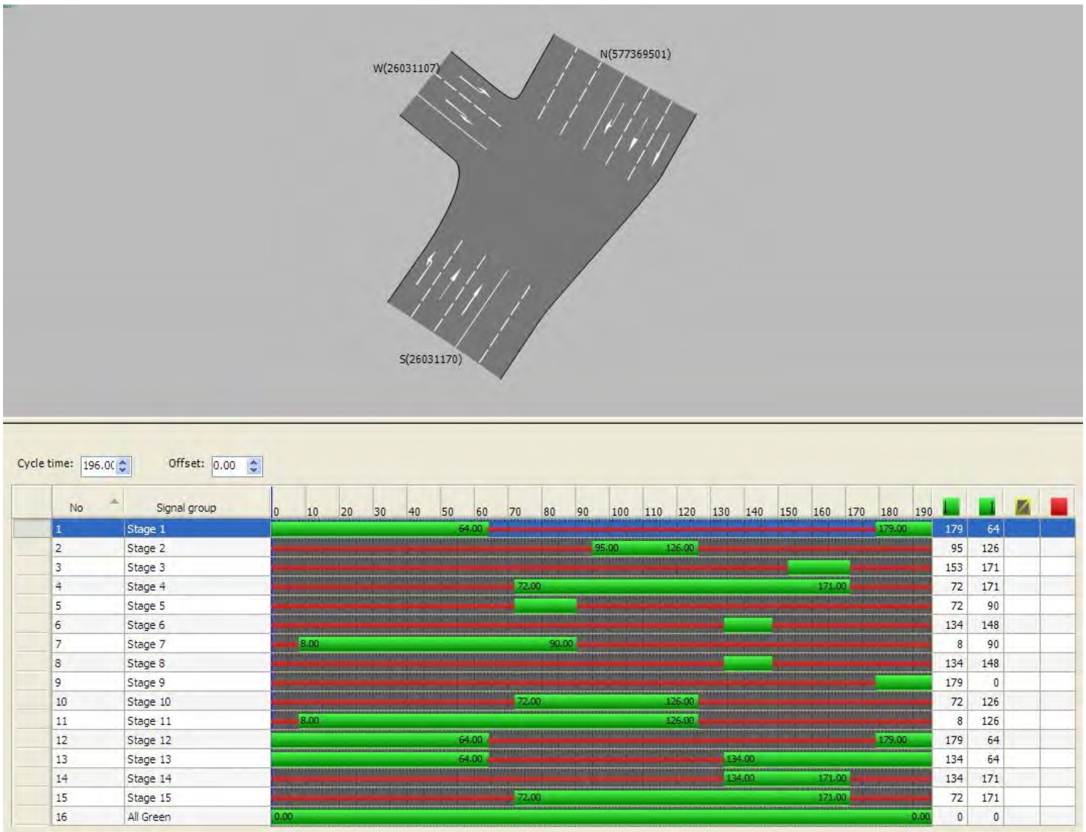
4.6 Signalised Junction Modelling

All signalised junctions inside the study area have been modelled in detail. Signal specifications, which contained details of phase, stages and intergreens, have been provided by Lincolnshire County Council and converted into the format required by VISUM for the three model time periods (AM, Inter Peak and PM).

In VISUM signal timings are entered using a number Signal Groups, which are created to represent the individual movements that occur at a junction. The starting and ending green time for each signal group must then be specified along with a total cycle time and offset should it be required. An example signalised junction is shown in

Figure 4-3.

Figure 4-3 – An example of signalised junction coded in VISUM



The locations of signalised junctions in Lincoln are shown in Figure 4-4.

Figure 4-4 – Signalised junction Locations in Lincoln

Lincoln City Centre operates on a SCOOT system and so starting and ending green times have been derived from LINSIG models for the various SCOOT regions. Outside the town centre all signalised junction are much further apart and so have been assumed to operate independently. Initial starting and ending green times and a cycle time have therefore been calculated for each junction under the assumption that phases run to their maximum allowed green times in the AM and PM Peak hours and to their average green times in the Inter Peak.

4.7 Zone (Centroid) Connectors

The loading of traffic onto the network from zones is achieved through centroid connectors at appropriate locations.

The loading points and types were reviewed carefully for each zone. The distance for the connector was calculated from plans/maps. The appropriate speed was then assigned based on the network characteristics of the zone.

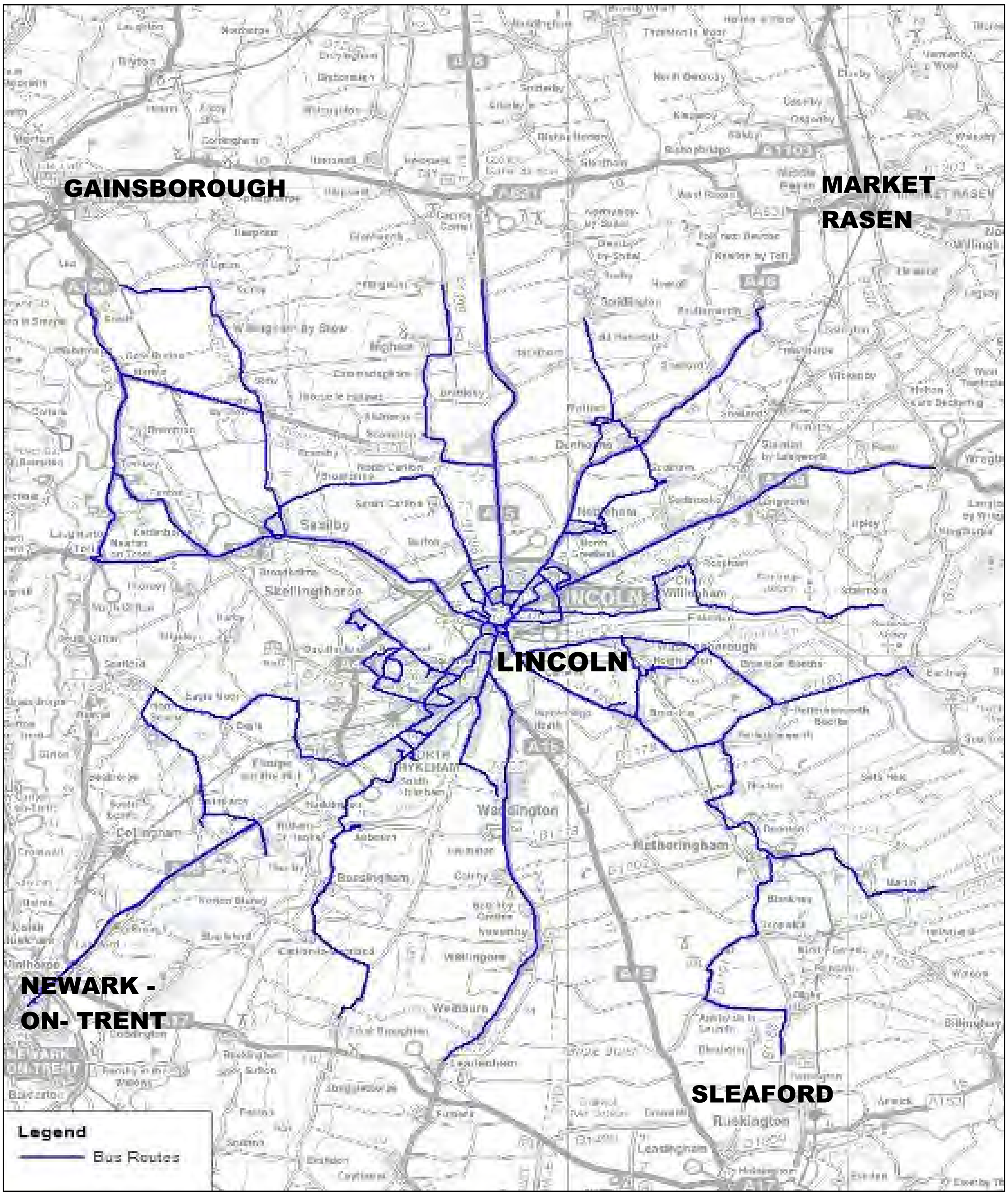
For external zones (outside the simulation area), loading points were attached to the appropriate locations at the edge of the buffer network. The distance and speed for these connectors have been estimated using GIS. Fuller details of the zoning system are provided in Appendix D.

4.8 Bus Routes

Public bus services have been represented in the model so that the effect of buses on link and junction capacities can be taken into account. Bus routes and frequencies for each time period (AM, IP, PM) have been coded into the network using data from the Public Transport Information Section of the Lincolnshire County Council website. Buses were assigned as a fixed preload prior to the assignment of other vehicle matrices.

Figure 4-5 shows the coverage of bus routes. Detailed bus routes are shown in Appendix E.

Figure 4-5 – Bus Routes Coverage



4.9 Network Checks

In coding the network, a number of checks were carried out on the network in order to demonstrate its robustness in replicating the highway network. These checks included:

- Checking the routes through the network, produced by a standard path building algorithm by assigning a unity matrix;
- Checking the physical characteristics of the coded network (junction type, number of arms and lanes, lane usage);

- Checking of properties assigned to the network (distances, speeds, saturation flow for each turning movement, speed flow curves);
- Checking the loading points of every zone;
- Checking zone to zone distances;
- Checking that bus routes/ bus frequencies are coded properly;
- Comparing the observed and modelled distances of the journey time routes (see Appendix F);
- Range of network routeing forests (see Appendix G)

5 Matrix Development

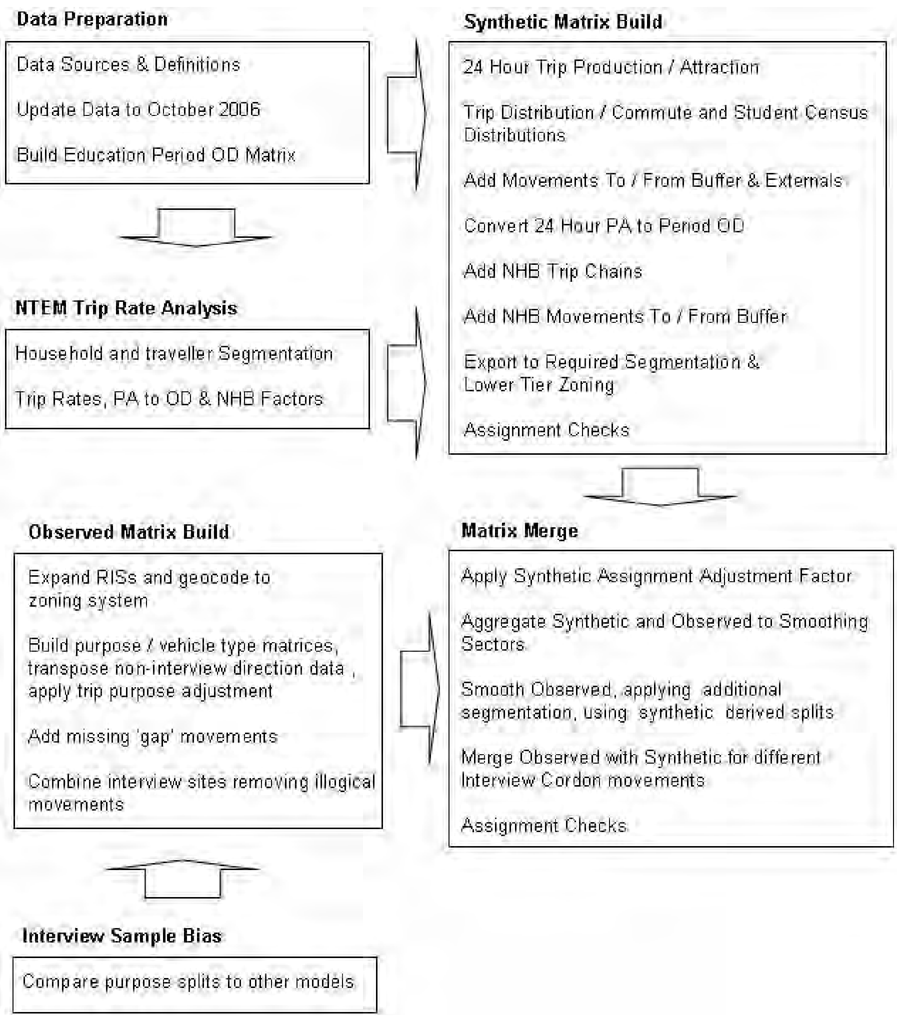
5.1 Introduction

The process of rebuilding the Base Year matrices is illustrated in Figure 5-1 and included the following principal stages:

- Data preparation and analysis
- Synthetic matrix build
- Observed matrix build; and
- Matrix merging.

This chapter discusses the matrix building steps briefly. Greater details of the matrix building process are provided in the GLTM Matrix Build Report, June 2011 provided as Annex A to this report.

Figure 5-1 - Matrix Build Process



5.2 Data Preparation and Analysis

Reusing existing model data and model zoning system has not only been considered important from a cost perspective to Lincolnshire County Council (LCC) but also with regards to meeting DfT programme targets. Furthermore, the synthetic build used established procedures and datasets.

Key to this process was the preparation of data to represent GLTM zoning. This included considering a number of key boundaries. For the synthetic matrices the Internal area used the Lincoln Policy Area (LPA) and included 139 zones. Within the Internal area detailed land use data was prepared. This area represented an area where productions and attractions were assumed largely self-contained with regards to general daily trip making and included ODs that may be significantly affected by the proposed Lincoln Eastern Bypass (LEB). The Internal area also contained the main highway network detail.

Within the Internal area the Interview Cordon represents the cordon around the Lincoln conurbation defined by the location of interview surveys. This is an important boundary for the merging of observed and synthetic matrices.

The Internal area was surrounded by a number of Buffer zones that had finite boundaries and contained areas that are expected to be influenced by the introduction of LEB. This Buffer area included only strategic highway network. Around the Buffer network are a number of External zones that represent the rest of the UK. These zones only connect to the strategic highway network and have no network of their own. They represent assumed strategic highway movement catchments, for example the A1 South to North.

The previous work included the data collection of all required interview records, traffic counts and journey time data. Interview records were subject to a rigorous checking and cleaning process. Also, all traffic counts were normalised to a neutral 2006 average weekday, checked for outliers where multiple observations were available, and checked for consistency with adjacent counts.

As well as 2001 Census data and data from the National Trip End Model (NTEM), reported through TEMPRO, new datasets were used in the matrix build, including:

- Census Area Statistics (CAS) household and population data;
- NTEM 6.2 trip rates;
- Pupil Level Annual Student Census (PLASC), college and university student data including home postcode and mode of travel;
- total employment and retail employment Annual Business Inquiry (ABI) data; and
- DfT freight annual tonnage data.

The majority of the effort in data cleaning has been associated with the interview data. This included the following tasks:

- interview data coded using Land Use Segmentation indexing;
- sample manual checks on interview records;
- missing postcodes derived from address or location details where possible;
- range checks on answer indexing;
- interview records converted to database format;
- trip origins and destinations converted from postcodes to OSGRs and plotted in MapInfo with illogical points checked and corrected or removed as required; and
- manual classified counts compared to ATCs and converted to database format.

All traffic count data has been normalised to a neutral 2006 month, assumed as November 2006 where necessary, and reformatted into a Microsoft (MS) Excel spreadsheet that contains the cordon / screenline / key junction reference, the Highway Assignment Model (HAM) node numbers, a location description and the Travel Segmentation model hour based vehicle flows. For ATC data the counts were reformatted to allow them to be imported into a MS Access database and averaged as necessary.

5.3 Observed Matrix Build

In order to model the trip patterns of vehicles entering the Lincoln Planning Area (LPA), postcard interview surveys were undertaken at several of the main routes into the study area, forming the basis of the interview cordon. This section describes the analysis that was involved in developing observed matrices from the postcard interview data. The cordon also includes minor road links for which postcard interviews were not conducted and their analysis is also described in this section.

The sites that formed the interview cordon are shown below in Figure 5-2 below.

Figure 5-2 – Postcard Interview Locations

5.3.1 *Postcard Interview Data – Cleaning Process*

The postcard interview data consisted of respondent's answers to the interview questions plus Ordinance Survey Grid References (OSGR) for the trip origin and destination locations. The OSGR data was used to append a set of zone numbers and analysis cordons to each postcard record. The initial stage in the interview analysis was to process and clean the interview and count data. This process began by importing the postcard interview data supplied by LCC to MS Access.

The initial process of cleaning the data involved removing any records that had blank origin or destination data. Any records where the origin and destination postcodes were identical were also discarded. Records with an illogical purpose were also discarded, e.g. where origin purpose and destination purpose were both stated as home.

Records with a vehicle type listed as pedal cycle or motorcycle were not to be included in the highway assignment model and so were discarded. Any records with a missing interview time or with an illogical journey direction (e.g. a HB trip with vehicle type equal to OGV) were also discarded.

Crow fly distances were calculated between origin point to destination point (O-D) and also between origin point to interview site point to destination point (O-I-D). It was considered that where the O-I-D distance was greater than three times the O-D distance, then this signified some illogical routing and records were discarded.

Zones within the GLTM have been aggregated to create analysis cordons. Analysis cordons 1 to 15 represent zones in the LPA, whilst analysis cordons 16 to 20 largely represent zones in the rest of Lincolnshire and analysis cordon 21 represents the rest of the UK. Any illogical cordon-to-cordon movements were identified and those records were removed from the data set. Table 5-1 shows the number of interview records discarded during each stage of the cleaning process.

Table 5-1 – Breakdown of Records Lost through Cleaning Process

Initial Interview Records	**9,055**
Interviews discarded due to missing origin details	278
Interviews discarded due to missing destination details	385
Interviews discarded due to identical origin and destination details	289
Interviews discarded due to error in purpose	25
Interviews discarded due to error in vehicle type	23
Interviews discarded due to error in time element	8
Interviews discarded due to error in distance factor	3
Interviews discarded due to record having distance factor >3	103
Interviews discarded due to Illogical movement relative to interview direction	718
Total Percentage of Interview Data Discarded	**20.2%**
Interview Records After Cleaning Process	**7,223**

5.3.2 *Expansion and Transposition of Postcard Interviews*

At each of the postcard interview sites, ATC data and MCLC data was collected in both directions. For each site, the ATC data consisted of at least two weeks of data, whilst for the MCLC data usually a single classified 12-hour count was available. All the counts were normalised to a neutral 2006 count, based on day and month.

The counts that were used in the expansion process adopted the vehicle proportions observed through MCLC data but the counts were ultimately controlled to the normalised ATC counts. In order to avoid using count data from faulty ATC equipment, any ATC counts that were more than two standard deviations from the mean were identified and excluded when calculating averages.

Due to a low rate of postcard return across all vehicle types, expansion of the postcode records was undertaken for the period from 0700 to 1000 hours for the AM peak, and from 1600 to 1900 hours for the PM peak.

Low return rates for LGVs and HGVs were especially prevalent at interview sites 6, 9 and 12 and so records from the full 12-hour interview period were used in the AM and PM peaks. All interview direction purpose splits were controlled back to the hour-specific purpose split.

Postcard interviews were distributed in the inbound (to the city centre) direction at the Lincoln cordon. To expand interview records to counts in the outbound direction, interview records were transposed by swapping origin and destination zones and adjusting time periods. Records collected in the AM period were assigned to the PM period for the non-interview direction and vice versa. Records collected in the inter-peak only had their origin and destination zones swapped.

The transposed interview data was adjusted so that the specific hour purpose splits were correct according to the interview direction splits. Table 5-2 presents a comparison between the observed purpose split across the cordon and the adjusted transposed purpose split.

Table 5-2 – Cordon Wide Purpose Split (Interview/Non-Interview Direction)

Modelled Hour	Purpose	Purpose Split Interview Direction	Purpose Split Non-Interview Direction
AM Peak Period			
1	HB Commute	0.495	0.471
2	HB Education	0.032	0.037
3	HB Shopping	0.094	0.090
4	HB Other	0.054	0.057
5	HB Emp Bus	0.058	0.063
6	NHB Emp Bus	0.055	0.051
7	NHB Other	0.071	0.072
8	LGV	0.103	0.110
9	OGV	0.034	0.044
	Period Total	**1.000**	**1.000**
Inter Peak Period			
1	HB Commute	0.106	0.108
2	HB Education	0.011	0.011
3	HB Shopping	0.230	0.227
4	HB Other	0.146	0.146
5	HB Emp Bus	0.056	0.057
6	NHB Emp Bus	0.091	0.091
7	NHB Other	0.121	0.121
8	LGV	0.144	0.144
9	OGV	0.091	0.092
	Period Total	**1.000**	**1.000**
PM Peak Period			
1	HB Commute	0.362	0.361
2	HB Education	0.012	0.008
3	HB Shopping	0.058	0.062
4	HB Other	0.166	0.189
5	HB Emp Bus	0.094	0.086
6	NHB Emp Bus	0.023	0.022
7	NHB Other	0.112	0.109
8	LGV	0.128	0.124
9	OGV	0.040	0.034
	Period Total	**1.000**	**1.000**

Table 5-3 below summarises the average expansion factors that were derived during each model period.

Table 5-3 – Average Expansion Factors derived for Interview Data

Time Period	Vehicle Type	Expansion Factor	
		Interview Direction	Non Interview Direction
AM Peak	Car	3.4	3.0
	LGV	7.0	9.4
	OGV	9.2	9.6
Inter Peak	Car	1.3	1.4
	LGV	6.2	6.5
	OGV	6.5	6.8
PM Peak	Car	3.8	3.4
	LGV	8.3	7.3
	OGV	7.8	5.7

5.3.3 *Non-Interview Sites*

The Lincoln cordon is made up of a total of 25 links, 12 of which were included in the postcard interview survey and the remainder were non-interview sites. Traffic count data was available for nine of these non-interview sites and further four minor roads were judged to carry insignificant levels of flow and were not therefore included in the original survey coverage. Vehicles on the non-interviewed links represent a relatively small proportion of trips crossing the cordon, as shown in Table 5-4 below.

Table 5-4 – Summary of Count Data on Interview Cordon

Site Type	AM Peak hour		Average Inter Peak hour		PM Peak hour	
	Flow	%	Flow	%	Flow	%
Interview Site	13,211	82%	9,858	86%	13,996	82%
Non-Interview Site	2,986	18%	1,570	14%	2,981	18%
Total	16,197		11,428		16,977	

For each non-interview site with count data available, trips were in-filled by creating all-vehicle select link analysis (SLA) matrices at each link and in both directions using the previous incarnation of the base model. These have then been cleaned in a similar fashion to the postcard interview data to discard any illogical movements. The matrices were then segmented by purpose by applying the observed cordon-wide purpose splits from the observed records. Segmented matrices were then controlled to the normalised count data and person trips were calculated by applying the average vehicle occupancy for each purpose.

Count data was unavailable for four of the sites shown as gaps in Figure 5-2. However, Lincolnshire CC confirmed the flows on these links was considered to be low (in the region of 600 vehicles per week) and so omitting them from the matrix building process would have an insignificant effect on trip patterns crossing the cordon.

5.3.4 *Merging of Expanded Postcard Records and SLA Matrices*

A factor was applied to each record that removed the potential for double counting. If a trip is fully observed and only crosses the cordon once, it maintains a factor of 1.0. Any trips that are partially observed or are likely to cross the cordon twice or three times were assigned a factor of 0.5 or 0.333 respectively. The analysis cordons and road layouts were used to assign factors to each analysis cordon to analysis cordon movement.

Once the postcards interview records and SLA matrices had been expanded they were merged to create one matrix of cordon crossing movements for each of the three modelled hour periods; 0800 to 0900, 1000 to 1600 average hour and 1700 to 1800. Table 5-5 shows the person trip and vehicle trip totals by modelled hour and direction.

Table 5-5 – Merged Vehicle & Person Trip Totals

Direction	Time Period	Vehicle Trips	Person Trips
Interview Direction	AM	7,321	9,355
	IP	4,226	6,299
	PM	4,593	6,298
Non-interview Direction	AM	4,118	5,709
	IP	4,334	6,438
	PM	7,080	9,608

5.3.5 *Assignment Check of Observed Matrices*

In order to check the accuracy of the observed matrices described in the sections above, these matrices were assigned to the highway model network. With only partially observed study area matrices, the network will be relatively uncongested and speeds unrealistically high. However, the assignment does provide an initial indication of how well the observed trips assign to the links on which they were recorded.

The results of these assignments are summarised in Tables 5-6 and 5-7 which compare modelled and observed flows in each modelled period and for inbound and outbound cordon flows. These show that the modelled flow crossing the cordon is lower than that observed. This is to be expected as some of the assigned traffic will not cross the cordon but seek alternative routes when the network is not fully unloaded.

Table 5-6 – Assignment Check of Observed Matrices (Inbound Direction)

Site Number	AM				IP				PM			
	Observed counts (veh)	Modelled counts (veh)	Diff	% Difference	Observed counts (veh)	Modelled counts (veh)	Diff	% Difference	Observed counts (veh)	Modelled counts (veh)	Diff	% Difference
RSI01	641	249	-392	-61.2	186	111	-75	-40.3	276	171	-105	-38.0
RSI02	758	626	-132	-17.4	392	188	-204	-52.0	502	302	-200	-39.8
RSI03	1036	1559	523	50.5	549	947	398	72.5	563	992	429	76.2
ATC62	110	39	-71	-64.5	41	6	-35	-85.4	110	10	-100	-90.9
NA	41	41	0	0.0	1	1	0	0.0	1	0	-1	-100.0
RSI07	561	484	-77	-13.7	169	280	111	65.7	120	172	52	43.3
RSI08	441	363	-78	-17.7	224	196	-28	-12.5	290	186	-104	-35.9
RSI09	1117	999	-118	-10.6	608	630	22	3.6	579	673	94	16.2
RSI10	454	756	302	66.5	432	445	13	3.0	446	612	166	37.2
RSI11	415	409	-6	-1.4	306	187	-119	-38.9	400	217	-183	-45.8
RSI11a	328	136	-192	-58.5	206	88	-118	-57.3	379	180	-199	-52.5
RSI12	607	583	-24	-4.0	513	211	-302	-58.9	511	291	-220	-43.1
near 12	491	91	-400	-81.5	490	37	-453	-92.4	54	54	0	0.0
ATC74	438	327	-111	-25.3	202	212	10	5.0	343	251	-92	-26.8
ATC44	413	382	-31	-7.5	128	160	32	25.0	216	241	25	11.6
ATC45	71	86	15	21.1	34	69	35	102.9	48	94	46	95.8
NA	1	0	-1	-100.0	1	0	-1	-100.0	1	0	-1	-100.0
RSI04	642	739	97	15.1	487	357	-130	-26.7	556	508	-48	-8.6
RSI05	326	395	69	21.2	192	255	63	32.8	261	354	93	35.6
RSI06	1290	811	-479	-37.1	815	557	-258	-31.7	1244	889	-355	-28.5
TC15	101	0	-101	-100.0	77	33	-44	-57.1	104	0	-104	-100.0
ATC60	37	35	-2	-5.4	32	31	-1	-3.1	42	43	1	2.4
ATC61	106	49	-57	-53.8	50	10	-40	-80.0	96	18	-78	-81.3
L115	154	22	-132	-85.7	1	3	2	200.0	91	16	-75	-82.4
TC42	422	420	-2	-0.5	214	253	39	18.2	274	260	-14	-5.1
	11001	**9601**	**-1400**	**-12.7**	**6350**	**5267**	**-1083**	**-17.1**	**7507**	**6534**	**-973**	**-13.0**

Table 5-7 – Assignment Check of Observed Matrices (Outbound Direction)

Site Number	AM				IP				PM			
	Observed counts (veh)	Modelled counts (veh)	Diff	% Difference	Observed counts (veh)	Modelled counts (veh)	Diff	% Difference	Observed counts (veh)	Modelled counts (veh)	Diff	% Difference
RSI01	166	98	-68	-41.0	180	112	-68	-37.8	573	268	-305	-53.2
RSI02	436	228	-208	-47.7	412	181	-231	-56.1	436	228	-208	-47.7
RSI03	652	959	307	47.1	525	929	404	77.0	652	959	307	47.1
ATC62	1036	1559	523	50.5	549	947	398	72.5	1036	1559	523	50.5
NA	1	0	-1	-100.0	1	1	0	0.0	1	0	-1	-100.0
RSI07	122	177	55	45.1	188	268	80	42.6	122	177	55	45.1
RSI08	123	185	62	50.4	166	198	32	19.3	123	185	62	50.4
RSI09	572	642	70	12.2	719	646	-73	-10.2	572	642	70	12.2
RSI10	310	427	117	37.7	404	499	95	23.5	310	427	117	37.7
RSI11	268	115	-153	-57.1	303	150	-153	-50.5	268	115	-153	-57.1
RSI11a	374	137	-237	-63.4	214	108	-106	-49.5	374	137	-237	-63.4
RSI12	471	223	-248	-52.7	530	224	-306	-57.7	471	223	-248	-52.7
near 12	247	55	-192	-77.7	576	53	-523	-90.8	247	55	-192	-77.7
ATC74	271	179	-92	-33.9	213	173	-40	-18.8	271	179	-92	-33.9
ATC44	196	242	46	23.5	123	141	18	14.6	196	242	46	23.5
ATC45	33	93	60	181.8	44	53	9	20.5	33	93	60	181.8
NA	1	0	-1	-100.0	1	0	-1	-100.0	1	0	-1	-100.0
RSI04	340	429	89	26.2	499	381	-118	-23.6	340	429	89	26.2
RSI05	228	382	154	67.5	210	245	35	16.7	228	382	154	67.5
RSI06	1235	800	-435	-35.2	849	583	-266	-31.3	1235	800	-435	-35.2
TC15	115	122	7	6.1	65	70	5	7.7	115	122	7	6.1
ATC60	46	45	-1	-2.2	30	29	-1	-3.3	46	45	-1	-2.2
ATC61	121	81	-40	-33.1	50	38	-12	-24.0	121	81	-40	-33.1
L115	68	5	-63	-92.6	1	0	-1	-100.0	68	5	-63	-92.6
TC42	212	199	-13	-6.1	229	251	22	9.6	212	199	-13	-6.1
	7644	**7382**	**-262**	**-3.4**	**7081**	**6280**	**-801**	**-11.3**	**8051**	**7552**	**-499**	**-6.2**

5.3.6 Interview Sample Bias

The potential for response bias was considered with the self-completion postcard interviews. Whilst there was concern over the personal details given by a number of respondents, the primary concern was the validity of the trip purpose descriptions.

Any bias with the interview returns could have the effect of misrepresenting business travel (EB) in particular as the type of person making such trips is less likely to have time available to return a completed questionnaire.

The interview questionnaires did not include data describing the respondent which might have been used to allow re-weighting the sample to the true make-up of the resident population. Hence the main focus on checking response bias was in checking the trip purpose splits. The trip purpose splits reported in the observed matrices are shown below in Table 5-8.

Table 5-8 – Observed Matrix Totals

Time Period	Journey Purpose	Person Matrix Total	% Split	Vehicle Matrix Total	% Split
AM	HB Commute	6,419	50.3%	5,719	50.3%
	HB Education	707	5.5%	414	5.5%
	HB Employers Business	679	5.3%	635	5.3%
	HB Other	2,721	21.3%	1,709	21.3%
	NHB Employers Business	728	5.7%	627	5.7%
	NHB Other	1,510	11.8%	835	11.8%
	Total	**12,763**	**100.0%**	**9,939**	**100.0%**
IP	HB Commute	1,038	10.9%	953	10.9%
	HB Education	137	1.4%	97	1.4%
	HB Employers Business	494	5.2%	444	5.2%
	HB Other	5,236	55.1%	3,283	55.1%
	NHB Employers Business	909	9.6%	802	9.6%
	NHB Other	1,685	17.7%	1,067	17.7%
	Total	**9,499**	**100.0%**	**6,646**	**100.0%**
PM	HB Commute	4,900	36.7%	4,381	36.7%
	HB Education	203	1.5%	134	1.5%
	HB Employers Business	1,040	7.8%	955	7.8%
	HB Other	4,540	34.0%	2,782	34.0%
	NHB Employers Business	332	2.5%	278	2.5%
	NHB Other	2,342	17.5%	1,350	17.5%
	Total	**13,357**	**100.0%**	**9,880**	**100.0%**
12 Hour	HB Commute	34,525	28.2%	30,965	28.2%
	HB Education	3,098	2.5%	1,952	2.5%
	HB Employers Business	7,258	5.9%	6,640	5.9%

Time Period	Journey Purpose	Person Matrix Total	% Split	Vehicle Matrix Total	% Split
	HB Other	49,569	40.5%	30,923	40.5%
	NHB Employers Business	8,105	6.6%	7,076	6.6%
	NHB Other	19,737	16.1%	11,864	16.1%
	Total	**122,292**	**100.0%**	**89,421**	**100.0%**
12 Hour	Commute	34,525	28.2%	30,965	28.2%
	Education	3,098	2.5%	1,952	2.5%
	Employers Business	15,363	12.6%	13,716	12.6%
	Other	69,306	56.7%	42,787	56.7%
	Total	**122,292**	**100.0%**	**89,421**	**100.0%**

5.3.7 *Bias checks*

The interview purpose splits provided have been checked against a number of different data sources as discussed below.

The first check was made against the National Trip End Model (NTEM) 6.2, as reported through TEMPRO and 2006 average weekday productions by purpose for the Lincoln urban area. Table 5-9 – Matrix Comparisons

shows the comparison of the NTEM data against the observed matrix totals from the Lincoln surveys.

It appears that the GLTM Commute and EB purpose proportions are overstated when compared to NTEM. The purpose HB Other also seems underrepresented compared to NTEM. This is believed to be a direct result of comparing the GLTM interview cordon data with NTEM productions, which are representative of the entire urban area - the interview cordon can be expect to include significantly longer distance commuting and EB and fewer local trips, for example education and shopping.

It was therefore decided to compare the interview cordon observed matrices with data from other projects where these involved face-to-face roadside interviews. The second check available was therefore against a study in Heysham, Lancashire, as shown in Table 5-9 – Matrix Comparisons

. This table shows a closer match to the interview data but the model has the Irish Sea to the West and is effectively a 'cul-de-sac' for trips.

The third check available was from a study in Shrewsbury that used roadside interviews. Shrewsbury is a free standing town of a similar size and nature to Lincoln. This again shows a much closer comparison to the GLTM purpose splits but surprisingly higher EB proportions. This may mean that the returns in Lincoln were low for this journey purpose but ultimately this is likely to 'undervalue' the scheme as this purpose tends to represents above average benefits.

When the observed total Commute and EB are compared to similar models with RIS observed matrices, the splits are similar to the GLTM splits. It has therefore been concluded that GLTM interviews do not show any obvious interview purpose bias.

Table 5-9 – Matrix Comparisons

Purpose	GLTM Trips	GLTM Splits	Shrews-bury	Shrews-bury %	Heysham	Heysham %	NTEM Productions	NTEM Splits
HB Commute	34,525	28.2%	12,216	24.2%	33,829	24.6%	24,927	17.9%
HB Employers Business	7,258	5.9%	7,115	14.1%	10,989	8.0%	3,836	2.8%
HB Other	52,667	43.1%	19,929	39.5%	62,981	45.8%	88,007	63.4%
NHB Employers Business	8,105	6.6%	6,073	12.0%	11,194	8.1%	4,208	3.0%
NHB Other	19,737	16.1%	5,130	10.2%	18,561	13.5%	17,907	12.9%
All Purpose Total	**122,292**	**100.0%**	**50,462**	**100.0%**	**137,553**	**100.0%**	**138,885**	**100.0%**
Commute + EB Total	49,888	40.8%	25,404	50.3%	56,012	40.7%	32,971	23.7%
All Other Total	79,662	59.2%	32,174	49.7%	92,531	59.3%	109,750	76.3%

5.4 Synthetic Matrix Build

Synthetic matrices are required for the full extent of the Internal area and for external trips with a potential to cross this area, and with full Land Use segmentation. The synthetic matrices are required for unobserved movements and to provide additional segmentation and spatial 'smoothing' not available from travel interview data.

The synthetic data is also likely to be the only source of information for bus, walk and cycle trips.

The trip production and attraction information required for the synthetic matrix build can only realistically be prepared for the Internal area, which in itself is a significant task. Therefore the main scope for the synthetic matrix build is the Internal area alone, and zones within this area are referred to as Internal zones.

5.4.1 Scope

If the large External zones were included in the attraction data, then the trip distributions using the 'gravity models' would be skewed towards these large zones. This is because the distribution function used is doubly constrained to ensure that the distribution replicates input production and attraction totals. It is therefore important that the productions and attractions are specified in a consistent manner for different geographical areas. For example if an attraction in Newark within the External area was fully specified, but the production excluded, the distribution model would have to satisfy the attraction from other productions, thus skewing the distribution to Newark, which had no production specified.

However, it is important that all relevant External to External movements that have the potential to cross the Internal area are also synthesised. Therefore, Commute and Employer's Business (EB) trip productions have been derived for England and Wales and then distributed directly from Journey to Work (J2W) census data, with External catchments being defined as passing through or not passing through the Internal area. This also includes trips using the strategic highway network around the Internal area, for example the A1, to ensure that there are realistic levels of traffic on these roads. This therefore provides an estimate of External to External strategic movements for the Commute and EB purposes. Other External area trip purposes are synthesised from the J2W data, as discussed below.

The synthetic matrix process operates at the twenty four hour level and full Land Use Segmentation for trip Production / Attraction (PA) analysis, and then the Land Use Segmentation aggregated by household composition and car ownership for the trip distribution analysis. Both these processes use a PA format. The later stages of the process convert from twenty four hour PA to period Origin / Destination (OD) formats and finally the Travel Segmentation. The synthetic process works independently for the following modes of travel:

- Car;
- Bus;
- Rail;
- Walk/Cycle;
- LGV; and
- OGV.

It also works independently of journey purpose for the following:

- Home Based (HB) Commute;
- HB Education;
- HB Shopping;
- HB Other;
- HB Employers Business (EB);
- Non Home Based (NHB) EB; and
- NHB Other.

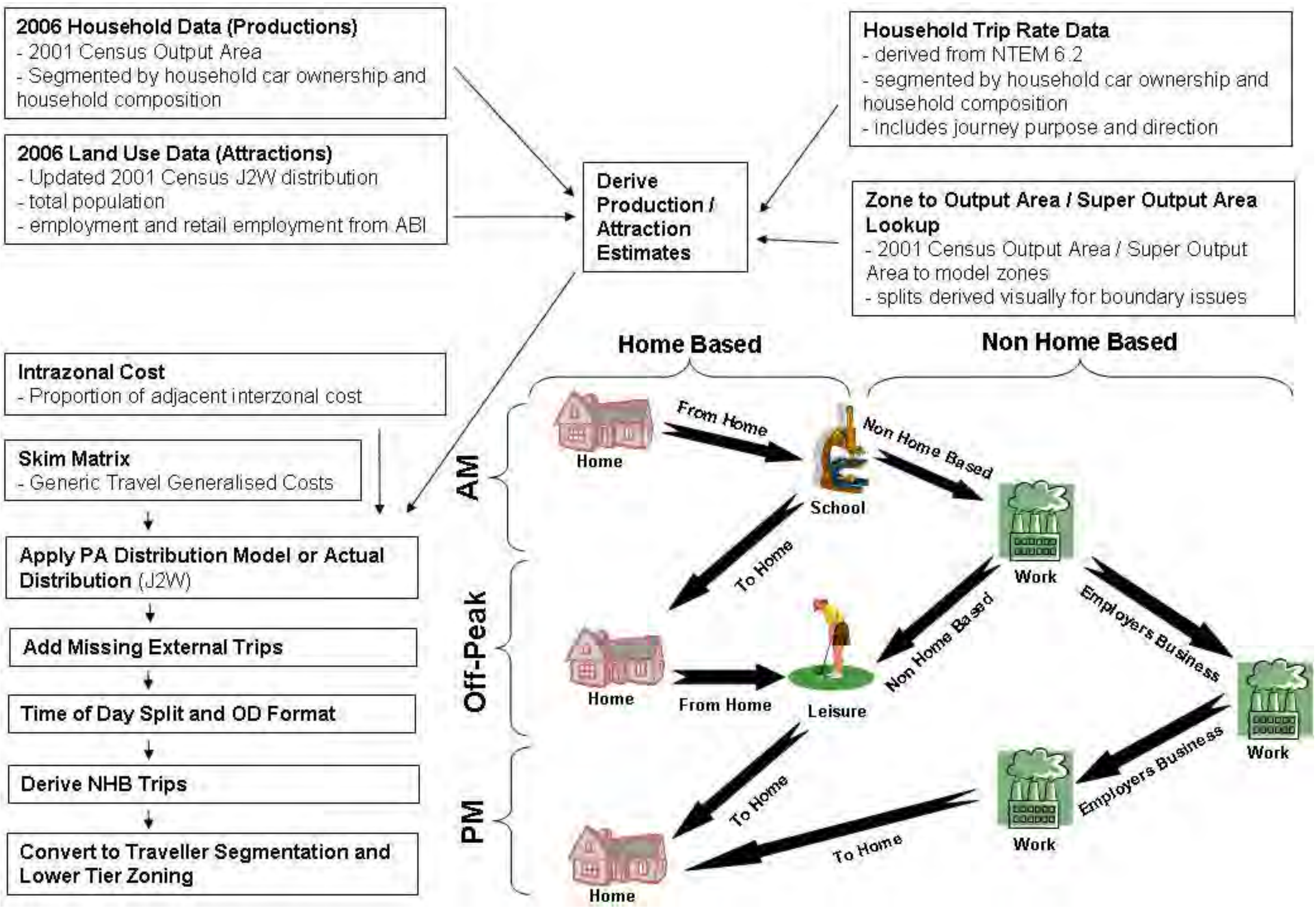
Whilst intrazonal movements are developed from the distribution process none are assigned within the assignment models and no cost information is Available from the assignment models. However, intrazonal movements are required for the Demand

Model and for forecasting. Intrazonal costs are therefore synthesised using proportions from adjacent interzonal movements.

5.4.2 *Method Overview*

The synthetic matrix build is focused on HB trip production / attraction and then trip distribution, all of which is undertaken separately by mode. Figure 5-3 provides an overview of the synthetic matrix build process, and includes an example 'cartoon' of typical daily trips represented.

Figure 5-3 – Synthetic Matrix Build



The overview shows the HB production analysis is based on the product of households and trip rates. The trip attractions are controlled by the totals implied by the trip productions and use a variety of data sources to indicate the attraction of zones for different journey purposes. Retail employment Annual Business Inquiry (ABI) data are used for Shopping attractions, and Other is based on total populations. No HB attractions are required for Commute and EB as the J2W distributions are used directly. Also, no attractions are required for Education as the distributions are taken directly from school PLASC, and college and university student data.

Figure 5-3 then shows the process post production / attraction calculations as consisting of the derivation of interzonal and intrazonal travel costs for input to the trip distribution process.

The output from the distribution process is twenty four hour PA matrices. These then have missing trips associated with External movements added in based on scaling and re-weighting the distribution of Commute trips. These include relevant External to External trips, and Internal to External and External to Internal movements. The PA matrices are then rescaled so that the attractions associated with each Internal zones are as originally calculated. This is followed by a similar process with the Internal productions, thus leaving the matrices with the correct Internal productions and small, but acceptable, discrepancies with the Internal attractions.

These PA matrices are then converted to an OD time period format. The time periods used at this stage represent 3 hour morning and evening periods, a 6 hour inter-peak period and a 12 hour off-peak / overnight period.

The process then derives estimates of NHB movements from the product of the destination totals of HB trips and NHB trip rates, derived from travel diary analysis.

No reliable method was available for constructing LGV and OGV freight movements. Therefore the LGV and OGV freight matrices are simply built from the total employment as a production and attraction, and then Furnessed with a unitary matrix. In addition the OGV matrices are then attracted to district level and controlled to the DfT trip movements, derived from annual tonnages. It should be noted that freight movements are longer distance movements and are expected to be mostly observed following Phase C when RIS data is combined with the synthetic matrices.

Initial assignments of the synthetic matrices are used for checking and to prepare a global factor Car, LGV and OGV matrix adjustment factor derived from the total of observed counts / modelled flows for these three vehicle types. These factors are applied directly to the LGV and OGV synthetic matrices to produce the final version. However, Car Adjustment is applied to the trip rates and the synthetic matrices rebuilt. This is necessary as the trip rates can be expected to require a certain amount of local adjustment and they could be useful for future forecasts, although not used in the LEB model application. This factoring is important as when merging the synthetic matrices with the observed RIS matrices the synthetic needs to have reasonably similar volumes to the observed, which is controlled to counts at each interview site. A summary of the trip totals for the synthetic HAM matrices is shown in

Table 5-10.

Table 5-10 – Synthetic Matrix Trip Totals by Vehicle Type

Flow Group	Time Period		
	AM	IP	PM
Commute	99,901	14,077	66,286
Other	58,941	68,679	62,779
EB	19,435	8,651	13,344
GV	4,421	2,537	3,116
OGV	2,464	1,812	1,304

5.5 Observed and Synthetic Matrix Merge

The two different private vehicle matrix builds of synthetic and observed needed to be merged together. This not only allows missing observed movements to be added but also allows the observed matrices to be 'smoothed', additional segmentation to be added and improves the connection of observed matrices to land use data. The final matrices are held at the entire Lower Tier zoning system, and provide the level of detail necessary for Variable Demand Modelling (VDM). Public transport, Walk and Cycle matrices only exist as synthetic.

5.5.1 Smoothing and Additional Segmentation

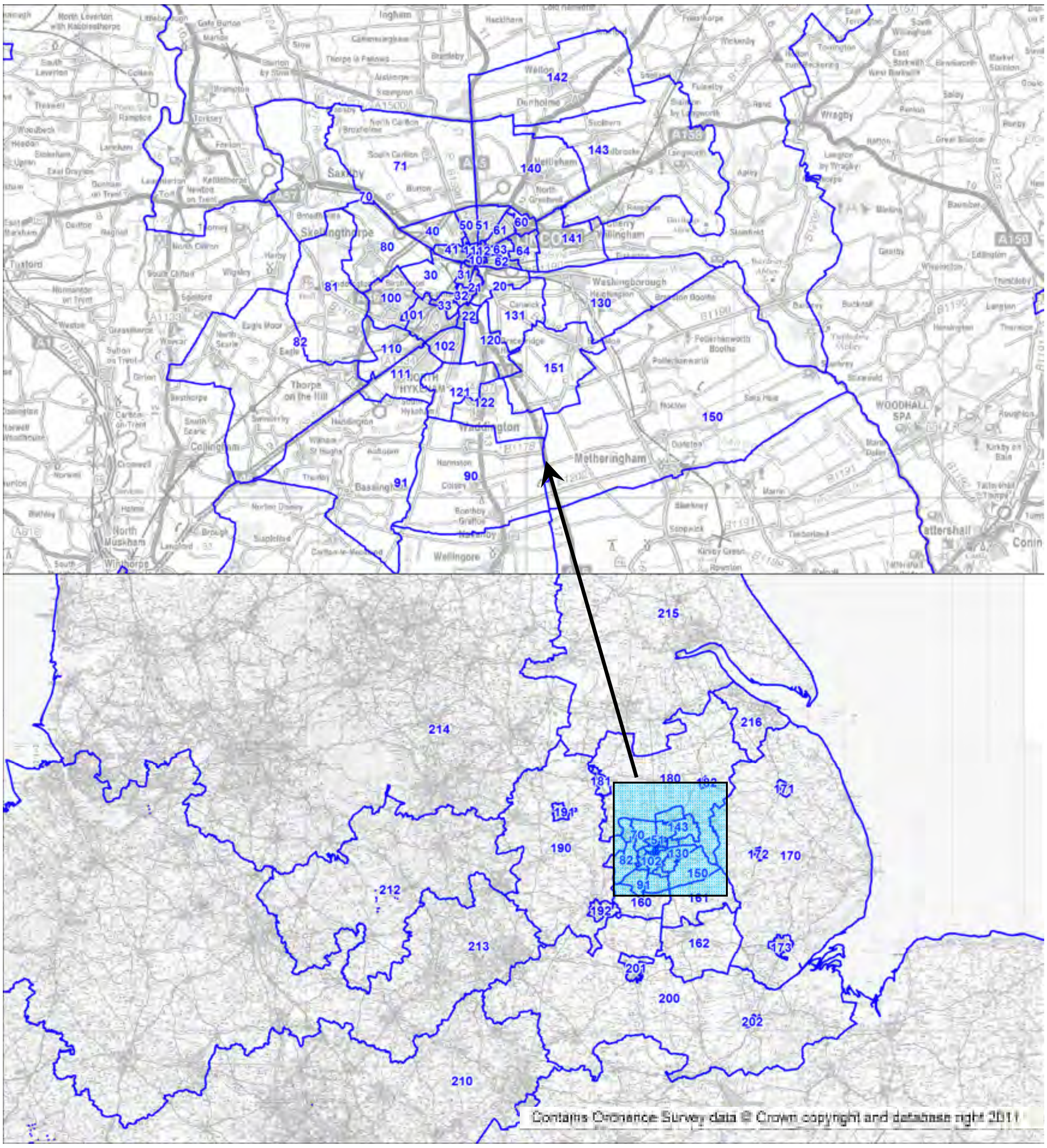
Smoothing was only applied to the Car matrices as the synthetic freight was not considered sufficiently reliable plus segmentation of freight matrices is not necessary.

The process to smooth and further segment the observed matrix required a set of smoothing sectors to be prepared. A key point of smoothing the observed matrices is to remove any sampling issues that may exist in the interview data. It is likely that respondents will correctly state the broad area to which they have travelled from and are travelling to. Therefore the smoothing sectors split the analysis cordons into conurbation areas, built by aggregating Lower Tier zones.

Another important function of the smoothing is to ensure a better connection with land use data. One issue can be where interview postcode coordinate accuracy could allocate an origin or destination to the wrong zone. This is likely to be more prevalent with specific locations for example schools or shopping areas. By arranging the smoothing sectors to wholly encompass such areas the smoothing process better realigns the trips to the underlying land uses. The additional segmentation of Household Income and Car Availability has also been added by smoothing sector.

Figure 5-4 shows the smoothing sectors and there index, which is built from the constituent analysis cordon * 10. The smoothing sectors are smaller within the interview cordon and adjacent to it as that represents a concentration of observed movements. Further from the interview cordon the observations are more parse and therefore the smoothing sectors become larger. As the GLTM zones are relatively large outside of the LPA area the smoothing sectors are mostly a copy of the Lower Tier zones.

Figure 5-4 – Smoothing Sectors



The vast majority of the 31,705 observed car vehicle trips were smoothed at the first attempt using smoothing sector to smoothing sector synthetic data. This process aggregated to the observed matrices at the trip level by smoothing sector origin and smoothing sector destination. To achieve this the synthetic matrices were aggregated to the same level and a set of splitting factors were then derived to disaggregate the observed sector movements to Lower Tier origin and destination, and Household Income and Car Availability.

From this initial process 28,800 observed vehicle trips were smoothed. To cater for the unsmoothed trips splitting factors were derived for all synthetic trips associated with each origin sector and associated with each destination sector. The unsmoothed observed sector to sector movements were then smoothed by applying these splitting factors to the observed origin and the observed destination. This increase the total smoothed trips to 30,356 vehicles.

After this second process there were still observed vehicle trips that had not been smoothed. These were added by smoothing using the synthetic aggregated to the Report Cordons (see model specification for details). Household Income and Car Availability splitting factors were derived from cordon to cordon synthetic movements and applied to the missing observed movements. This increase the total adjusted trips to 31,607 vehicles.

Dealing with the final missing observed trips involved again retaining the original observed origin and destination and applying global Household Income and Car Availability splits. This increase the total adjusted trips to the complete 31,697 vehicles.

A small number of additional illogical movements were also removed from the smoothed observed matrices but these only reduced the total trips to 31,705 vehicles.

The smoothing process adds substantially more segmentation. The original 11,458 observed records were increased to 113,211 records with the inclusion of select link matrices for interview cordon gaps. When smoothed this increases to 984,571 records which include the additional Household Income and Car Availability segmentation. This level of segmentation is important to allow VDM. When the matrices are converted to a format for use in the HAM most of the detailed segmentation is aggregated and the HAM matrices contain more feasible numbers for use in the assignment process.

As a wide area synthetic matrix construction was developed an allowance was made for trips which were not expected to impact the Lincoln network, and to reflect the skeletal nature of routes beyond the immediate area of influence of Lincoln. These external to external flows were reduced to allow a balance between synthetic demand (operating with relatively low confidence) and network supply. These external adjustments did not impact the internal flow volumes derived from surveyed data.

5.5.2 *Merging process*

The smoothing process disaggregates the observed matrices to the same level of segmentation available in the synthetic matrices. The two sets of data can therefore be combined directly. However, the substantial buffer model network that surrounds the interview cordon means that many interview cordon movements will be partial.

To assist in understanding partial interview cordon movements ODs were categorised using the interview cordon, and local routing knowledge and judgement, into the following movement indices:

1. Fully Observed Interviews;

2. Internal To Interview Cordon;
3. External To Interview Cordon;
4. Irrelevant;
5. Partially Observed Interviews - Short Distance;
6. Partially Observed Interviews - Medium Distance; and
7. Partially Observed Interviews - Long Distance.

Movements categorised as 1 included trips with an origin or destination within the interview cordon. These observed trips were combined directly with synthetic movements wholly within the interview cordon (category 2).

Movements categorised as 3 were not expected to travel through the interview cordon and therefore have been added directly. Also, the volume correction added to improve the synthetic flow to count comparison was removed if the trip was without an origin or destination within the LPA, as discussed previously.

Movements categorised as 4 were removed from the matrices.

Movements categorised as 5, 6 and 7 were dealt with in two stages: firstly for the movements with an observed record; and secondly for potentially unobserved movements. The definition of movements categorised as 5, 6 and 7 had been prepared through local routing knowledge. As such it was possible that some of the OD pairs may have been miscoded and may not have potential to travel through the interview cordon. Furthermore, an assumed proportion of an OD movement that had been observed travelling through the interview cordon was used to calibrate the merged matrices. This proportion was specified for three different OD distance categories of:

1. Short (< 31 km) = 100%;
2. Medium (< 51 km) = 70%; and
3. Long (< 110 km) = 10%.

These proportions assume that the further away from the interview cordon the more likely that OD movements will route around the cordon, thus a lower proportion can be expected to pass through the cordon.

The first stage in dealing with these partial cordon movements was to merge all observed movements categorised as 5, 6 and 7, and divide them by the percentages listed above. However, this clearly is not applicable for movements that have not been sampled. Therefore, for any missing analysis cordon aggregated movements categorised as 5, 6 and 7 the synthetic OD movement was used, with the volume correction removed if without an origin or destination within the LPA, as discussed previously.

Table 5-11 below shows a breakdown of the trips as they were merged for the different types of movements. The fully observed totals only include trips with an origin or destination within the interview cordon and as such they don't match the smoothed observed trip totals. These trips do account for some 85% of observed car movements, with the remaining 15% representing through trips some of which are assumed to be partial. These 15% are factored by around 1.89 to account for the missing trips that are expected to divert around the interview cordon.

Table 5-11 – Matrix Merge Report – Assignment Hours

Merged Data	AM Peak			IP Peak			PM Peak			Total
	Car	LGV	OGV	Car	LGV	OGV	Car	LGV	OGV	
1: Fully Observed Car	10,511	0	0	6,567	0	0	9,963	0	0	27,041
Plus 1: Fully Observed Freight	10,511	1,162	313	6,567	1,166	589	9,963	1,511	355	32,137
Plus 2: Internal Synthetic Car	22,837	1,162	313	12,852	1,166	589	19,313	1,511	355	60,098
Plus 2: Internal Synthetic Freight	22,837	4,227	2,021	12,852	2,924	1,845	19,313	3,672	1,259	70,950
Plus 3: External Synthetic Car	46,578	4,227	2,021	42,314	2,924	1,845	45,424	3,672	1,259	150,265
Plus 3: External Synthetic Freight	46,578	7,675	2,727	42,314	7,165	3,837	45,424	6,994	1,789	164,504
Plus 5/6/7. Partially Observed Car	48,751	7,675	2,727	43,815	7,165	3,837	48,046	6,994	1,789	170,800
Plus 5/6/7. Partially Observed Freight	48,751	7,946	2,940	43,815	7,379	3,999	48,046	7,430	2,000	172,307
Plus 5/6/7. Partially Observed Synthetic Car	49,089	7,946	2,940	43,923	7,379	3,999	48,282	7,430	2,000	172,989
Plus 5/6/7. Partially Observed Synthetic Freight	49,089	7,975	2,946	43,923	7,404	4,013	48,282	7,455	2,005	173,093
Final Merged	**49,088**	**7,975**	**2,946**	**43,923**	**7,404**	**4,013**	**48,282**	**7,455**	**2,005**	**173,092**

6 Model Calibration

6.1 Introduction

The calibration process is defined in WebTAG Unit M3 as the estimation of the parameters of a chosen model by fitting to observations. The most critical parameters during the development of the model relate to the link properties, junction coding and assignment routeing parameters.

6.2 Calibration Process

The calibration of the model was undertaken whereby the network was adjusted to ensure that the model realistically replicated routeing and vehicle speeds through the study area. Matrix estimation was incorporated in the model calibration process in order to obtain matrices based on the routeing patterns to which the network was calibrated.

The calibration process involved a number of tasks, as follows:

- Checks on the basic structure of the network, including link lengths, junction configuration and banned turns;
- Checks on speed-flow curves to ensure that they reflect the existing situation;
- Checks to ensure that link speeds and journey times are reasonable;
- Checks to ensure that vehicle routeings are realistic and appropriate; and
- Use of matrix estimation procedures to adjust and ‘fit’ the prior trip matrices to observed traffic flows.

Any observed traffic flows used in the calibration process, for matrix estimation, cannot be considered as independent for validation purposes. Under these circumstances, DMRB advises that some count data should be retained and used only at the validation stage. Therefore, a number of traffic counts from different parts of the network were retained as independent counts and were not used in the matrix estimation.

Successful calibration entails matching the observed traffic counts (used in matrix estimation) with modelled flows. The matching is monitored using statistical procedures as recommended in DMRB. The recommended statistic is the GEH statistic, a form of chi-squared statistic, and is defined as:

$$GEH=\sqrt{\frac{(M-C)^2}{0.5(C+M)}}$$

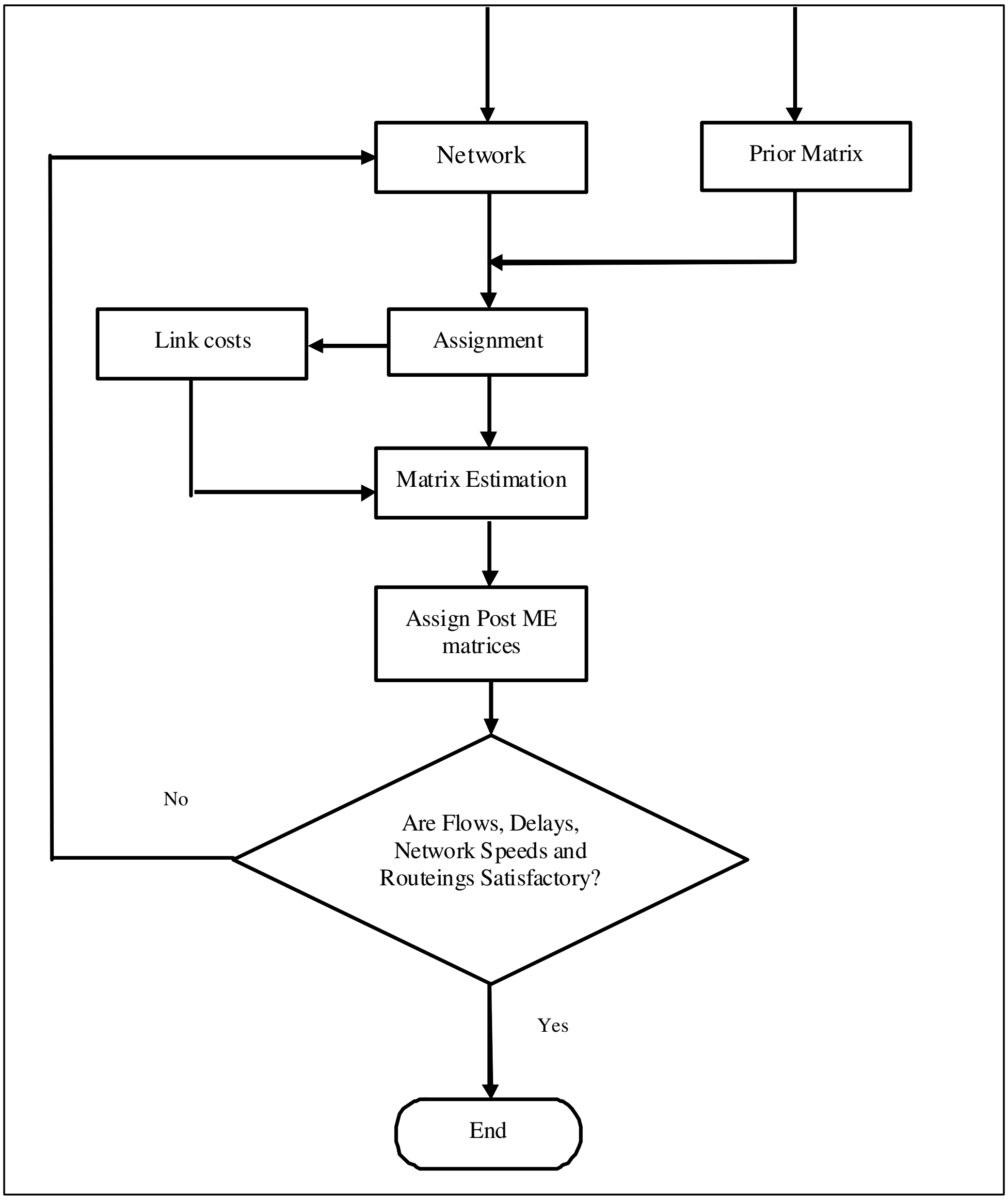
Where: M = modelled flow; and

C = observed flow (count)

Based on DMRB guidance, a GEH value of less than 5, which indicates a satisfactory fit between modelled flows and independent observed data, (whatever the level of flow) should be achieved on 85% of individual links. For screenlines, or other combinations of links, a GEH value of less than 4 is required in all, or nearly all, cases. The acceptability guidelines set out for validation in DMRB were adopted as criteria against which to gauge the results of the model calibration process.

Figure 6-1 provides a schematic representation of the main steps involved in the model calibration process. It can be seen that it is an iterative process where network and junction properties are adjusted until a point is reached where network speeds, flows, delays and routeings are deemed to be representative of the observed conditions.

Figure 6-1 – Model Calibration Process



6.3 Acceptability Guidelines

The acceptability guidelines set out for validation in DMRB were adopted as criteria against which to gauge the results of the model calibration process. These are shown in Table 6-1.

Table 6-1 – DMRB Acceptability Guidelines for Assignment Validation

Criteria and Measure	Acceptability Guidelines	
1. Assigned Model Hourly Flows compared with Observed Flows		
i. Observed Flows < 700 vph	Modelled flow within ± 100	> 85% of links
ii. Observed Flows between 700 – 2,700 vph	Modelled flow within ± 15%	> 85% of links
iii. Observed Flows > 2,700 vph	Modelled flow within ± 400	> 85% of links
iv. Screenline Flow Totals (normally > 5 links)	Modelled flow within ± 5%	All (or nearly all) screenlines
2. GEH Statistic		
i. Screenline flow totals (normally > 5 links)	Modelled flow within ± 5%	All (or nearly all) screenlines

6.4 Assignment Parameters

Assignment of the O/D matrices to the Lincoln road network was undertaken using the ICA Equilibrium iterative assignment procedure in VISUM. This combines elements of both standard Equilibrium (Wardrop) and 'all-or-nothing' assignment methodologies. The procedure models the "learning process" of users on the network over a number of iterations, where information gained on the previous trip is used for the next route search.

For each O/D pair, the least impeded route is initially calculated via the Intersection Capacity Analysis (ICA) module and traffic assigned to it in an all-or-nothing approach. Impedance is then recalculated and factored into the cost of the route for the next iteration which subsequently loads a proportion of traffic onto the next least impeded route. With successive iterations the most cost-effective route per O/D pair is optimised. The process ends when the shift of vehicles between routes is minimal. The model can then be said to have reached a converged solution.

6.5 Generalised Cost Parameters

The cost of travel is expressed in terms of generalised cost minutes, which can be related to the value of time and out of pocket costs. A multiple user class assignment method was used that allows Cars, LGV's and HGV's to be assigned simultaneously to the same network but using different generalised cost functions.

The components of the generalised cost function used in the traffic model were based on the Transport Economics Note (TEN 2007) with assumptions provided from WebTAG 3.5.6 (2007). WebTAG calculates the costs of travel based on the assumptions of the value of money which a traveller is willing to pay to compensate for the time spent driving on the road.

For modelling purposes, generalised costs were calculated based on the assumptions of average travel speed on the road, vehicle fuel consumption, values of time, and average vehicle occupancies of each trip purpose. Non-fuel vehicle operating costs, such as maintenance or insurance etc., were not taken into account as drivers generally only perceive the fuel and time elements of their journey in making route choices.

The average travel speed on the network was obtained from the observed journey time surveys which were carried out in the study area in 2006. The average travel speeds derived from these surveys were 52.6kph in the AM Peak, 56kph in the Inter Peak, and 52.1kph in the PM Peak.

Based on the above and the WebTAG guidance, values of pence per kilometre (PPK) and pence per minute (PPM) for three vehicle classes (Car, LGV, HGV) by purpose type (Work, Commute, Other) were calculated for all three time periods. Monetary time (PPM) and distance (PPK) costs were then converted into generalised costs and used in VISUM. They are shown in Table 6-2. They accord with a localised calculation of trip length banding from DfT publication *Understanding and valuing impacts of transport investment – Values of travel time savings*" (DfT, October 2015). It is understood these Values of Time are to be released in November 2016. This application to the modelling is consistent with the LEB Value of Time Note issued to DfT in January 2016, where the latest distance banding has been averaged for trips within the LEB model.

Table 6-2 – Generalised Cost Parameters

User Class	Time Period	Monetary Values		Generalised Cost	
		Time (pence per minute)	Distance (pence per kilometre)	Time	Distance
Car Commute	AM IP PM	19.70	6.82	1.00	0.35
Car Other	AM IP PM	14.10	6.82	1.00	0.48
Car Employed Business	AM IP PM	29.64	13.29	1.00	0.45
LGV	AM IP PM	20.52	13.84	1.00	0.67
HGV	AM IP PM	20.80	41.94	1.00	2.02

6.6 Matrix Estimation

Following the development of the peak period matrices the matrix estimation (ME) process was an integral part of the development of the base year model matrices for AM, average IP and PM hours, designed to provide greater local detail to the local traffic model and enhance the precision of the matrices.

The matrix estimation process employed within the calibration was designed to adjust the travel pattern to the observed traffic counts. This process adjusted trips using available observed traffic counts to give the best-fit matrix. This process is dependent on several factors including the quality of the prior matrix, traffic routeing and the order and consistency of the observed traffic counts. Thus it is essential that the process is monitored closely to ensure the following:

- The trip matrix is converging to a stable solution;
- Travel patterns at a sector level are reasonable;
- Trip length distributions are reasonable.

The matrix estimation was undertaken within VISUM, using the TFlowFuzzy element of the suite. Trips were adjusted in the matrix to produce estimated matrices consistent with the observed traffic counts.

The equation used in the matrix estimation procedure may be written as:

$$T_{ij} = t_{ij} \prod_a X_a^{Pija}$$

where:

T_{ij} is the output post matrix of OD 'ij-pairs';

t_{ij} is the input prior matrix of OD 'ij-pairs';

$\prod_a$ is the product over all counted links a;

X_a is the balancing factor associated with counted link a;

^{Pija} is the fraction of trips from i to j using link a.

The process starts with the assignment of the prior trip matrices. Trip movements using the target links (for which counts are available) are then identified and factored to match the target flows, as closely as possible given that several movements may go through any one site and individual movements may go through several sites. The resultant post-ME2 matrices may then be reassigned to start a subsequent iteration of the matrix estimation process, to further fine tune the prior trip matrices. There are no specific convergence criteria for matrix estimation, but the aim of the procedure is to improve the goodness of fit between modelled flows and counts.

For the Lincoln Eastern bypass Traffic Model, the procedure achieved a satisfactory level of fit between modelled and observed flows in 4 to 6 iterations.

Comparisons between traffic counts and modelled flows used in the matrix estimation process were undertaken for each iteration of the process. The calibration procedure was monitored by reviewing the changes to the trip matrices resulting from matrix estimation and the comparison of observed traffic counts and modelled traffic flows.

The changes in travel patterns were also monitored at a sector level during the calibration process

6.7 Effects of Matrix Estimation on Prior Matrices

The effects of matrix estimation on the trip matrices were monitored by comparing movement totals at sector level. The study area was compressed into 10 sectors as shown in Figure 6-2, defined as follows:

- Internal sector (Main Lincoln, inside RSI cordon),
- LPA sectors (sector 2, 3 and 4, surrounding RSI cordon)
- External sectors (5, 6, 7, 8, 9 and 10).

In total, the all-vehicle trip matrices changed in size between the prior and post-estimation stages as follows:

- AM Peak hour: 0.1%;
- Inter Peak hour: -0.8%;
- PM Peak hour: +0.6%.

These changes are shown at individual sector level and by time period in Table 6-3 to

Table 6-5. Key changes at a more aggregate level are summarised schematically in Figures 6-3 to 6-5. In general, the differences between prior and post matrices were relatively small (less than 4%). However, for some movements, where trips are relatively low, or were not observed directly, there are some relatively large differences.

Figure 6-2 – Sector Map

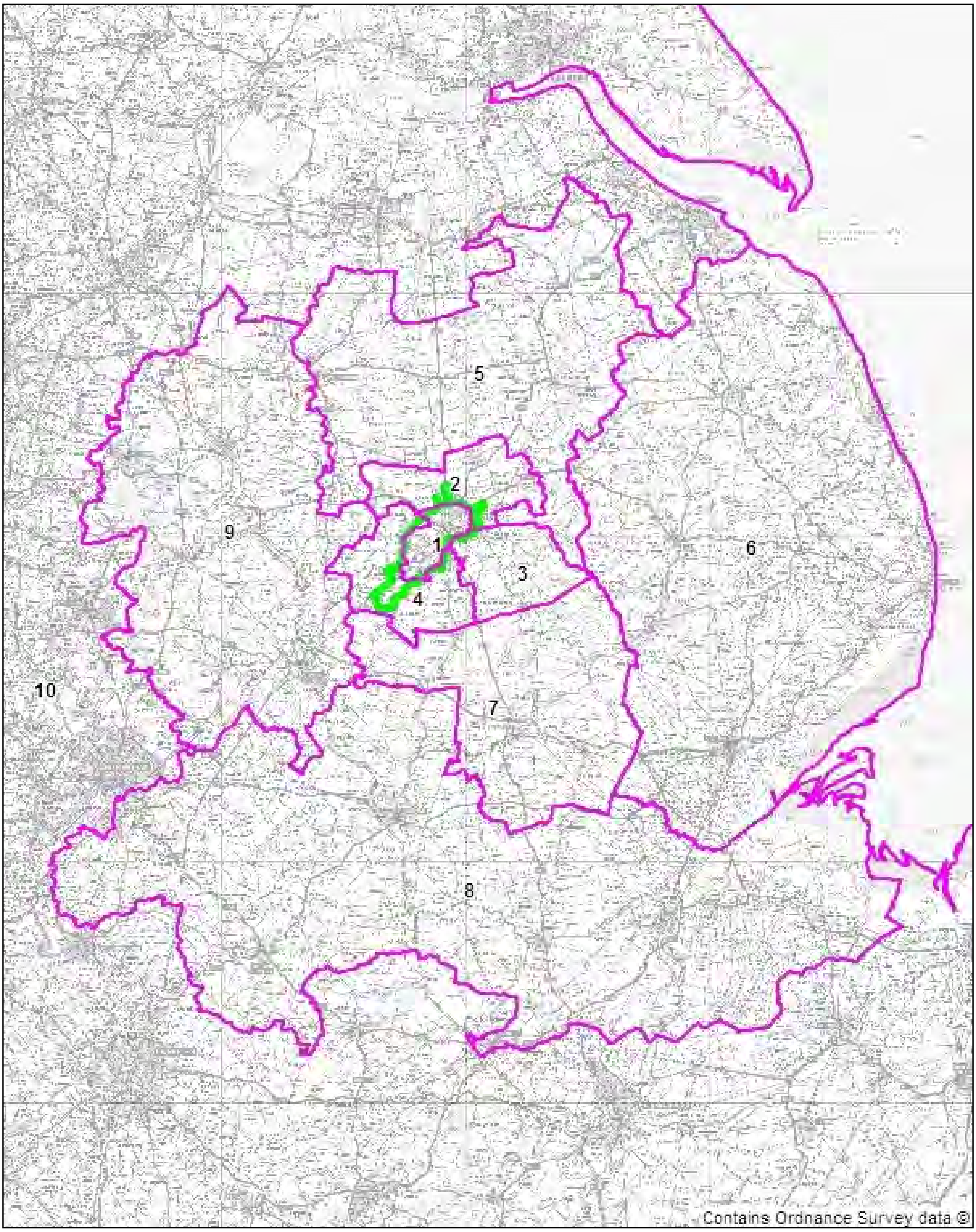


Table 6-3 – Effects of Matrix Estimation on Prior Matrix – AM Peak (updated)

Origin Sector	Matrix	Destination Sector										
		1	2	3	4	5	6	7	8	9	10	Total
1	Prior	10,460	651	301	2,480	320	261	153	131	523	543	15,822
	Post	10,553	620	283	2,419	347	240	147	122	531	522	15,783
	%Diff	-1%	5%	6%	2%	-8%	8%	4%	7%	-2%	4%	0%
2	Prior	1,606	1,504	30	204	419	97	33	23	119	554	4,589
	Post	1,587	1,512	22	186	448	96	25	15	124	503	4,518
	%Diff	1%	0%	25%	9%	-7%	2%	23%	36%	-5%	9%	2%
3	Prior	799	22	1,004	437	17	83	263	54	64	111	2,854
	Post	768	20	1,004	453	15	83	263	54	59	104	2,823
	%Diff	4%	8%	0%	-4%	11%	0%	0%	0%	8%	6%	1%
4	Prior	2,877	148	156	2,780	140	94	393	196	232	194	7,212
	Post	2,885	157	176	2,834	144	117	379	192	236	183	7,302
	%Diff	0%	-6%	-12%	-2%	-3%	-24%	4%	2%	-1%	6%	-1%
5	Prior	893	488	22	142	474	26	1	4	2	97	2,150
	Post	959	517	18	116	476	27	6	3	4	112	2,241
	%Diff	-7%	-6%	17%	18%	0%	-5%	-432%	17%	-163%	-16%	-4%
6	Prior	403	102	37	109	26	2,269	32	106	4	188	3,277
	Post	318	101	37	106	28	2,269	32	106	4	188	3,190
	%Diff	21%	1%	0%	3%	-8%	0%	0%	0%	0%	0%	3%
7	Prior	337	48	136	393	2	49	450	69	20	18	1,520
	Post	349	48	136	409	2	49	450	69	20	19	1,549
	%Diff	-4%	0%	0%	-4%	-42%	0%	0%	0%	0%	-1%	-2%
8	Prior	298	33	18	258	1	65	46	3,261	63	576	4,618
	Post	318	34	18	268	1	65	46	3,261	63	576	4,650
	%Diff	-7%	-5%	-1%	-4%	-53%	0%	0%	0%	0%	0%	-1%
9	Prior	713	76	28	323	2	76	12	79	1,591	301	3,201
	Post	674	83	25	305	2	77	12	79	1,591	301	3,149
	%Diff	5%	-9%	10%	6%	-1%	-1%	0%	0%	0%	0%	2%
10	Prior	615	108	8	316	248	389	64	1,586	1,002	10,430	14,765
	Post	649	109	8	296	231	388	63	1,584	1,001	10,427	14,757
	%Diff	-6%	-1%	1%	6%	7%	0%	1%	0%	0%	0%	0%
Total	Prior	19,001	3,179	1,741	7,442	1,648	3,409	1,448	5,510	3,619	13,013	60,009
	Post	19,060	3,199	1,728	7,393	1,694	3,411	1,424	5,485	3,633	12,935	59,963
	%Diff	0%	-1%	1%	1%	-3%	0%	2%	0%	0%	1%	0%

Notes:

(i) Trips are in vehicles
(ii) Sectors are shown in Figure 6.3, and defined below

- **Sector 1 - Interview Cordon (including all Lincoln District and part North Kesteven District)**

- **Sector 2 – Lincoln Planning Area North (within West Lindsey District)**
- **Sector 3 – Lincoln Planning Area South East (within North Kesteven District)**
- **Sector 4 – Lincoln Planning Area South West (within North Kesteven District)**
- **Sector 5 – West Lindsey District**
- **Sector 6 – East Lindsey and Boston Districts**
- **Sector 7 – North Kesteven District**
- **Sector 8 – Rushcliffe, Melton, South Kesteven and South Holland Districts**
- **Sector 9 – Bassetlaw and Newark & Sherwood Districts**
- **Sector 10 – Rest of England, Wales and Scotland**

Table 6-4 – Effects of Matrix Estimation on Prior Matrix – Inter Peak (updated)

Origin Sector	Matrix	Destination Sector										
		1	2	3	4	5	6	7	8	9	10	Total
1	Prior	7,981	833	375	1,791	430	333	225	116	245	456	12,785
	Post	8,001	793	347	1,781	444	292	191	90	232	420	12,592
	%Diff	0%	5%	7%	1%	-3%	12%	15%	22%	5%	8%	2%
2	Prior	756	717	20	132	239	32	33	21	23	206	2,178
	Post	760	721	20	126	239	31	28	15	24	189	2,153
	%Diff	0%	-1%	-3%	5%	0%	1%	16%	29%	-2%	8%	1%
3	Prior	356	14	417	173	7	17	92	14	10	89	1,191
	Post	345	12	417	184	6	17	92	14	10	77	1,175
	%Diff	3%	14%	0%	-7%	21%	0%	0%	1%	-3%	14%	1%
4	Prior	1,580	125	139	1,660	123	70	198	156	179	289	4,517
	Post	1,588	118	138	1,695	112	65	189	156	187	282	4,529
	%Diff	-1%	5%	1%	-2%	9%	7%	5%	0%	-5%	2%	0%
5	Prior	402	212	9	72	1,170	34	6	18	6	196	2,126
	Post	413	216	8	63	1,130	32	7	16	5	190	2,078
	%Diff	-3%	-2%	17%	12%	3%	6%	-19%	12%	21%	3%	2%
6	Prior	298	24	18	81	32	5,276	50	145	22	391	6,337
	Post	272	23	18	73	31	5,276	50	145	21	389	6,297
	%Diff	9%	2%	0%	11%	4%	0%	0%	0%	6%	0%	1%
7	Prior	248	25	93	160	5	51	1,114	81	62	57	1,895
	Post	227	20	93	156	5	51	1,114	81	62	55	1,864
	%Diff	9%	20%	0%	2%	-11%	0%	0%	0%	0%	3%	2%
8	Prior	113	18	16	115	6	143	76	8,035	112	1,568	10,201
	Post	97	12	16	113	4	143	76	8,035	112	1,566	10,174
	%Diff	15%	32%	0%	2%	29%	0%	0%	0%	0%	0%	0%
9	Prior	205	23	8	251	6	18	43	118	4,398	909	5,977
	Post	202	24	8	251	4	17	43	118	4,398	908	5,973
	%Diff	1%	-4%	0%	0%	22%	5%	0%	0%	0%	0%	0%
10	Prior	417	226	97	300	177	355	59	1,506	887	4,110	8,134
	Post	407	212	86	291	174	353	58	1,505	886	4,095	8,068
	%Diff	2%	6%	11%	3%	2%	1%	1%	0%	0%	0%	1%
Total	Prior	12,356	2,217	1,192	4,734	2,195	6,328	1,896	10,211	5,943	8,269	55,341
	Post	12,312	2,152	1,151	4,732	2,150	6,277	1,847	10,176	5,937	8,170	54,904
	%Diff	0%	3%	3%	0%	2%	1%	3%	0%	0%	1%	1%

Notes: (i) Trips are in vehicles

(ii) Sectors are shown in Figure 6.4, and defined below

- **Sector 1 - Interview Cordon (including all Lincoln District and part North Kesteven District)**

- **Sector 2 – Lincoln Planning Area North (within West Lindsey District)**
- **Sector 3 – Lincoln Planning Area South East (within North Kesteven District)**
- **Sector 4 – Lincoln Planning Area South West (within North Kesteven District)**
- **Sector 5 – West Lindsey District**
- **Sector 6 – East Lindsey and Boston Districts**
- **Sector 7 – North Kesteven District**
- **Sector 8 – Rushcliffe, Melton, South Kesteven and South Holland Districts**
- **Sector 9 – Bassetlaw and Newark & Sherwood Districts**
- **Sector 10 – Rest of England, Wales and Scotland**

Table 6-5 – Effects of Matrix Estimation on Prior Matrix – PM Peak (updated)

Origin Sector	Matrix	Destination Sector										
		1	2	3	4	5	6	7	8	9	10	Total
	Prior	8,065	1,602	709	2,785	694	349	383	182	584	540	15,893
1	Post	8,042	1,528	752	3,006	660	354	423	195	616	550	16,127
	%Diff	0%	5%	-6%	-8%	5%	-1%	-10%	-7%	-5%	-2%	-1%
	Prior	521	873	59	189	285	68	40	26	55	244	2,359
2	Post	515	872	66	206	263	68	42	28	55	248	2,362
	%Diff	1%	0%	-11%	-9%	8%	0%	-4%	-7%	0%	-2%	0%
	Prior	397	30	548	237	14	27	105	16	25	6	1,404
3	Post	385	25	548	237	12	27	105	16	23	6	1,383
	%Diff	3%	15%	0%	0%	17%	0%	0%	0%	10%	1%	2%
	Prior	2,154	264	295	2,129	210	100	370	215	232	248	6,218
4	Post	2,193	269	300	2,179	217	104	370	235	240	255	6,363
	%Diff	-2%	-2%	-1%	-2%	-3%	-4%	0%	-9%	-4%	-3%	-2%
	Prior	429	279	24	91	456	22	1	6	1	266	1,576
5	Post	422	282	19	104	438	24	2	6	1	255	1,554
	%Diff	2%	-1%	19%	-14%	4%	-8%	-58%	6%	-1%	4%	1%
	Prior	326	56	53	129	20	2,175	42	65	91	452	3,408
6	Post	320	56	53	132	19	2,175	42	65	91	452	3,404
	%Diff	2%	1%	0%	-3%	3%	0%	0%	0%	1%	0%	0%
	Prior	279	44	192	220	1	31	427	40	18	68	1,318
	Post	272	39	192	220	2	31	427	40	18	68	1,307
7	***%Diff***	3%	11%	0%	0%	-136%	0%	0%	0%	0%	0%	1%
	Prior	141	32	39	200	3	92	58	3,280	70	1,915	5,829
	Post	138	27	39	201	2	92	58	3,280	70	1,914	5,820
8	***%Diff***	2%	18%	0%	-1%	19%	0%	0%	0%	0%	0%	0%
	Prior	620	106	69	205	2	4	21	63	1,972	1,203	4,265
	Post	651	107	65	204	2	4	21	63	1,972	1,203	4,293
9	***%Diff***	-5%	-2%	5%	1%	-10%	-1%	0%	0%	0%	0%	-1%
	Prior	655	669	226	341	99	181	21	644	341	12,295	15,472
10	Post	664	666	188	340	161	181	20	644	341	12,291	15,496
	%Diff	-1%	1%	17%	0%	-63%	0%	1%	0%	0%	0%	0%
	Prior	13,587	3,956	2,214	6,525	1,784	3,048	1,467	4,538	3,389	17,235	57,743
Total	Post	13,602	3,872	2,221	6,829	1,777	3,059	1,510	4,571	3,426	17,241	58,108
	%Diff	0%	2%	0%	-5%	0%	0%	-3%	-1%	-1%	0%	-1%

Notes:* *(i) Trips are in vehicles

(ii) Sectors are shown in Figure 6.5, and defined below

- **Sector 1 - Interview Cordon (including all Lincoln District and part North Kesteven District)**
- **Sector 2 – Lincoln Planning Area North (within West Lindsey District)**
- **Sector 3 – Lincoln Planning Area South East (within North Kesteven District)**
- **Sector 4 – Lincoln Planning Area South West (within North Kesteven District)**
- **Sector 5 – West Lindsey District**
- **Sector 6 – East Lindsey and Boston Districts**
- **Sector 7 – North Kesteven District**
- **Sector 8 – Rushcliffe, Melton, South Kesteven and South Holland Districts**
- **Sector 9 – Bassetlaw and Newark & Sherwood Districts**
- **Sector 10 – Rest of England, Wales and Scotland**

Table 6-6 – Aggregated Sector movements changes AM Peak

Origin Sector	Matrix	Destination Sectors			
		1	2 to 4	5 to 10	Total
1	Prior	10,460	3,432	1,930	15,822
	Post	10,553	3,322	1,909	15,783
	%Diff	**-1%**	**3%**	**1%**	**0%**
2 to 4	Prior	5,282	6,286	3,087	14,655
	Post	5,240	6,365	3,039	14,644
	%Diff	**1%**	**-1%**	**2%**	**0%**
5 to 10	Prior	3,260	2,643	23,629	29,532
	Post	3,268	2,634	23,635	29,536
	%Diff	**0%**	**0%**	**0%**	**0%**
Total	Prior	19,001	12,362	28,646	60,009
	Post	19,060	12,320	28,582	59,963
	%Diff	**0%**	**0%**	**0%**	**0%**

The important movements are between sector 1 and LPA sectors 2-4. In AM peak, matrix estimation changed these movements by less than 3%.

Table 6-7 – Aggregated Sector movements changes inter peak

Origin Sector	Matrix	Destination Sectors			
		1	2 to 4	5 to 10	Total
1	Prior	7,981	3,000	1,804	12,785
	Post	8,001	2,922	1,670	12,592
	%Diff	**0%**	**3%**	**7%**	**2%**
2 to 4	Prior	2,692	3,396	1,798	7,886
	Post	2,693	3,432	1,733	7,857
	%Diff	**0%**	**-1%**	**4%**	**0%**
5 to 10	Prior	1,683	1,748	31,239	34,670
	Post	1,618	1,682	31,154	34,454
	%Diff	**4%**	**4%**	**0%**	**1%**
Total	Prior	12,356	8,143	34,841	55,341
	Post	12,312	8,035	34,557	54,904
	%Diff	**0%**	**1%**	**1%**	**1%**

The important movements are between sector 1 and LPA sectors 2-4. In the interpeak, matrix estimation changed these movements by less than 4%.

Table 6-8 – Aggregated Sector movements changes PM Peak

Origin Sector	Matrix	Destination Sectors			
		1	2 to 4	5 to 10	Total
1	Prior	8,065	5,096	2,733	15,893
	Post	8,042	5,286	2,799	16,127
	%Diff	**0%**	**-4%**	**-2%**	**-1%**
2 to 4	Prior	3,072	4,624	2,286	9,981
	Post	3,093	4,701	2,313	10,108
	%Diff	**-1%**	**-2%**	**-1%**	**-1%**
5 to 10	Prior	2,450	2,975	26,442	31,868
	Post	2,467	2,935	26,472	31,874
	%Diff	**-1%**	**1%**	**0%**	**0%**
Total	Prior	13,587	12,694	31,461	57,743
	Post	13,602	12,922	31,584	58,108
	%Diff	**0%**	**-2%**	**0%**	**-1%**

The important movements are between sector 1 and LPA sectors 2-4. In the PM peak, matrix estimation changed these movements by less than 4%.

6.8 Effects of Matrix Estimation on Cell Values and Trip Ends

Comparisons of prior and post matrix estimation matrices in terms of origin and destination trip ends totals are presented in Appendix M and in Tables 6.9 to 6.12 below.

Table 6-9: Regression statistics – Matrix zonal cell values

User Class	AM			IP			PM		
	Slope	Intercept	R^2	Slope	Intercept	R^2	Slope	Intercept	R^2
UC1	1.00	0.00	0.99	1.00	0.00	1.00	1.00	0.00	1.00
UC2	1.00	0.00	0.99	1.00	-0.01	1.00	1.00	0.00	1.00
UC3	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
LGV	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
HGV	0.99	0.00	0.99	1.00	0.00	1.00	1.00	0.00	1.00

Table 6-10: Regression statistics – Zonal Trip Ends - AM

User Class	AM Origin Trip ends			AM Destination Trip ends		
	Slope	Intercept	R^2	Slope	Intercept	R^2
UC1	1.01	-0.27	0.99	0.99	2.16	1.00
UC2	1.01	0.12	0.99	1.00	0.64	0.99
UC3	1.00	-0.06	1.00	0.98	0.57	1.00
LGV	1.00	-0.53	1.00	0.99	0.10	1.00
HGV	0.95	-0.21	0.99	0.93	0.09	0.99

Table 6-11: Regression statistics – Zonal Trip Ends - IP

User Class	IP Origin Trip ends			IP Destination Trip ends		
	Slope	Intercept	R^2	Slope	Intercept	R^2
UC1	1.00	-0.19	1.00	0.98	0.13	1.00
UC2	0.99	-0.29	1.00	0.99	0.17	1.00
UC3	0.98	-0.05	1.00	0.97	0.16	1.00
LGV	0.99	-0.19	1.00	0.99	-0.04	1.00
HGV	0.99	-0.21	1.00	0.99	-0.09	1.00

Table 6-12: Regression statistics – Zonal Trip Ends - PM

User Class	PM Origin Trip ends			PM Destination Trip ends		
	Slope	Intercept	R^2	Slope	Intercept	R^2
UC1	1.01	0.19	1.00	1.00	0.71	1.00
UC2	0.99	1.33	1.00	1.00	0.59	1.00
UC3	1.00	0.23	1.00	1.00	0.10	1.00
LGV	1.00	0.41	1.00	1.00	0.29	1.00
HGV	0.99	0.03	1.00	0.99	0.04	1.00

It can be seen that, in most cases, differences in trip-end totals between prior and post matrices are small. However, in a few cases, there are slightly larger differences, mostly for sector 1 and sector 10. These have been the main areas of adjustment for matrix estimation. Plots of cell value changes resultant from the matrix estimation are indicated in Appendix M.

6.9 Trip Length Distribution

Comparisons of the prior and post matrix trip length distributions have been undertaken for the AM, PM and Inter Peak models.

Figure 6-3 to

Figure 6-5 present the trip length distributions for the prior and post matrix estimation trip matrices as altered by the matrix estimation process.

It can be observed that only the number of short distance trips has increased significantly while the number of longer distance trips has remained relatively unchanged.

Average trip lengths are shown in Table 6.13. SD are shown in Table 6.14. Data shows a mix of local and longer trips, including A46, A1 and other strategic routes.

Table 6-13: Average Trip Length km

	AM		IP		PM	
Class	Prior	PME	Prior	PME	Prior	PME
UC1	42.9	42.1	39.8	39.5	46.2	45.8
UC2	31.9	31	42.6	42.1	51	50.6
UC3	81.6	80.9	62.1	61.5	100.3	100.4
LGV	86.7	87.9	72.6	72.7	84.5	83.9
HGV	61.1	64.3	76.1	76.3	68	68.2

Table 6-14: Average Trip Length Standard Deviation

	AM		IP		PM	
Class	Prior	PME	Prior	PME	Prior	PME
UC1	38.1	37.7	36.9	36.8	39.4	39.3
UC2	34.9	34.7	37.9	37.7	41.9	43.9
UC3	64.5	63.9	49.2	48.7	80.8	44
LGV	68.8	69.9	57.2	57.2	66.9	66.4
HGV	48.1	50.5	59.9	60.1	53.4	53.5

Figure 6-3 – Trip Length Distribution – AM Peak

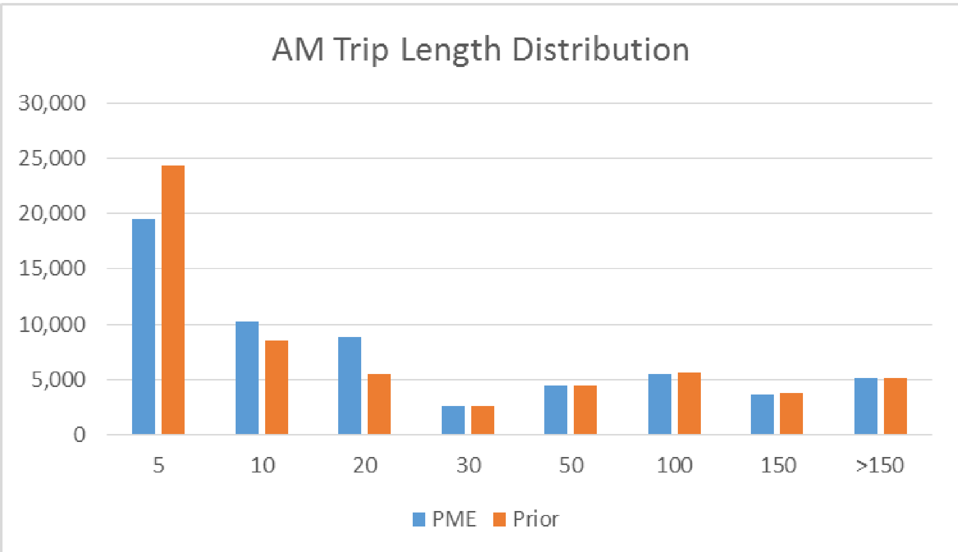


Figure 6-4 – Trip Length Distribution – Inter Peak

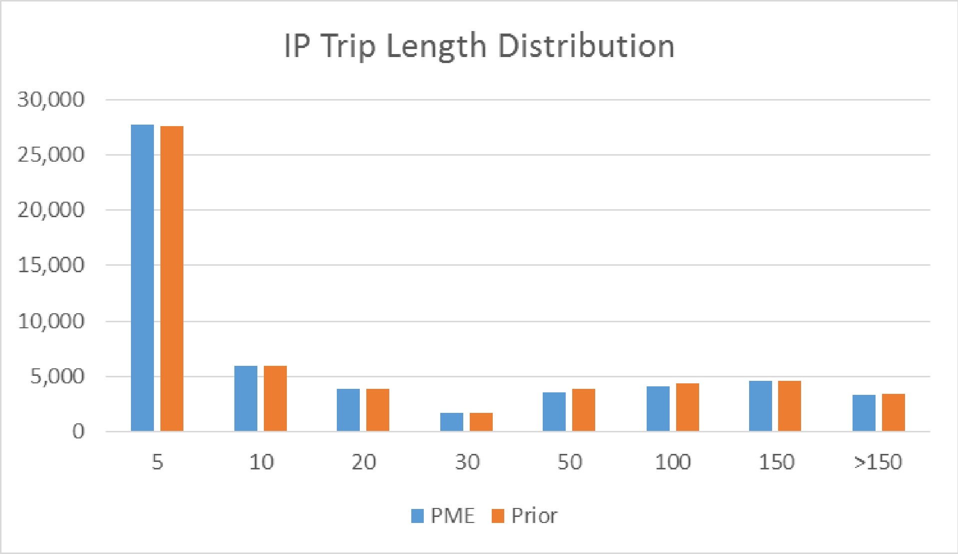
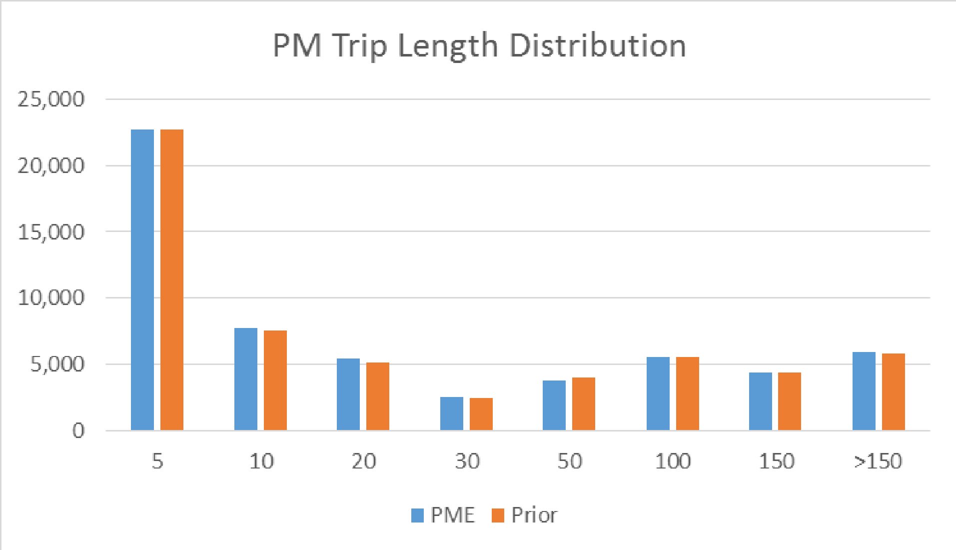


Figure 6-5 – Trip Length Distribution – PM Peak



6.10 Model Convergence

Convergence is the measure used to determine model stability during the assignment process (see Section 5.2). A suitably converged model can be expected to produce consistent outputs with minimal model noise. A total of 50 iterations were run to gain a statistically significant sample of convergence data.

The following convergence criteria are recommended in DMRB:

- Duality Gap less than 1% - this expresses the difference between the current estimates of the costs associated with trips through the modelled network against the theoretical costs if all traffic were to use the minimum cost route associated with their journey. It measures how far modelled flows differ from the desired equilibrium.
- Average absolute difference less than 1 – this is the number of routes that deviate from each other based on the impedances of the assignment.
- Relative average absolute difference less than 5% - this is the percentage of routes that deviate from each other based on the impedances of the assignment.

Tables 6.15 through 6.17 demonstrate the convergence statistics for the model. The assignment process employed for distributing the trips onto the available routes is known as Intersection Capacity Analysis (ICA). It is one of the distribution methods available in VISUM. This method of assignment is particularly suitable for urban areas where delays are mainly caused by junctions. This method allows for the effect of traffic 'Blocking back' from junctions to be accounted for in the assignment process. This is illustrated in the Figure 6.6 below.

As it can be observed the ICA is employed to determine capacity and delay at junctions. This information is then passed onto a subordinate assignment process which distributes the traffic onto the available routes. This is done through an iterative process and ends when the shift of traffic between routes in minimal. A set of criteria need to defined so that the process can terminated once these are satisfied (i.e. the model has reached convergence). In the case of the ICA assignment the convergence criteria relate to the change in turning and link flows between successive iterations as well as the GAP statistic. The GAP statistic is defined as the ratio of the difference between vehicle impedance and theoretical impedance divided by the theoretical vehicle impedance. A small value of GAP implies that the routes chosen are very close to the minimum cost routes. Further criteria relate to the change in link and turning flows between successive iterations. The change in volume is defined by the GEH statistic.

Table 6-15: AM Peak Convergence

Iteration	GAP (%)	Percentage of turns with GEH<1 between assignments	Percentage of links with GEH<1 between assignments
19	0.0002%	1.00	1.00
20	0.0002%	0.99	0.99
21	0.0003%	1.00	1.00
22	0.0005%	0.99	0.99
23	0.0003%	0.99	0.99
24	0.0004%	1.00	1.00
25	0.0002%	1.00	0.99
26	0.0003%	1.00	1.00
27	0.0001%	1.00	1.00
28	0.0001%	1.00	1.00

Table 6-16: Inter Peak Convergence

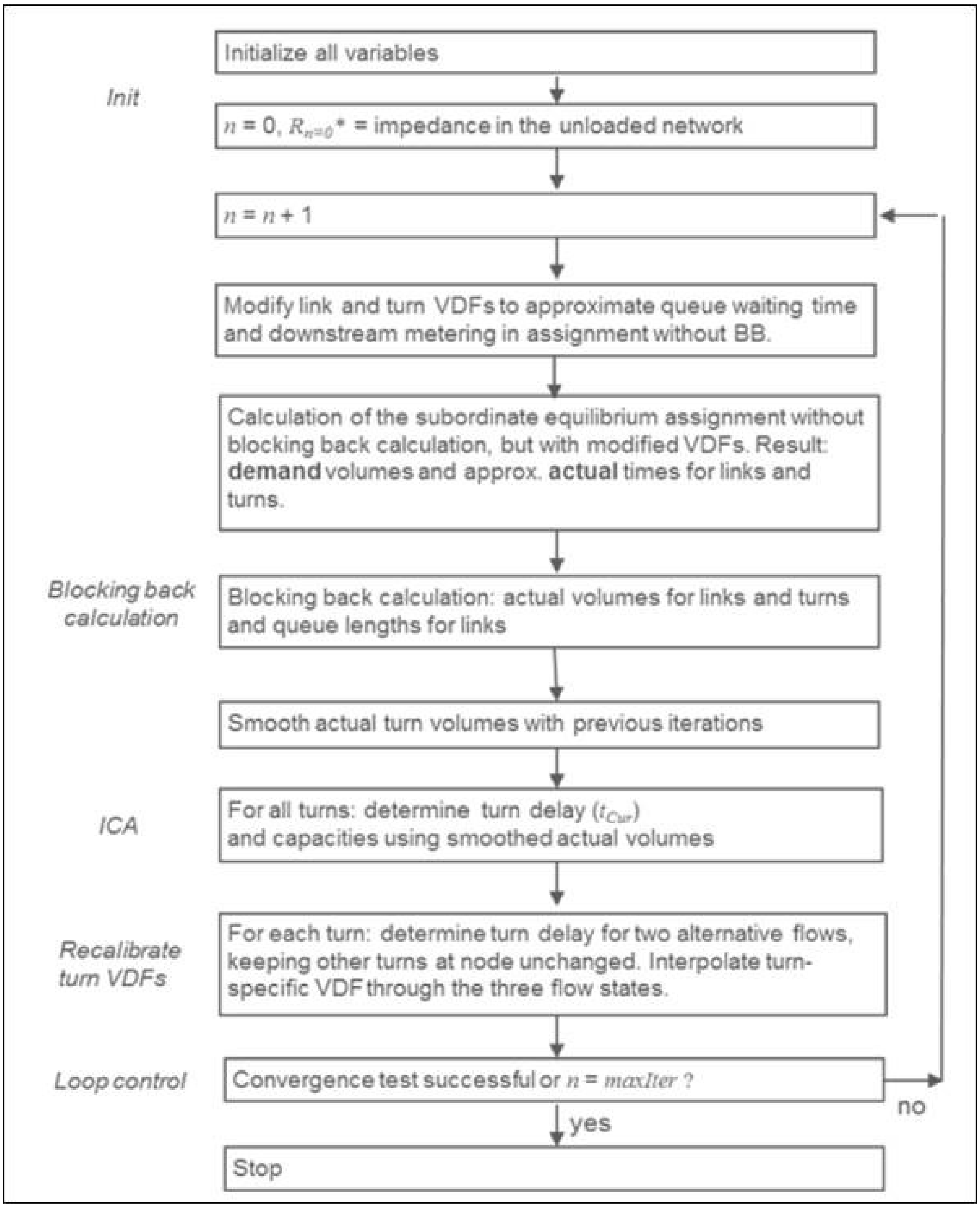
Iteration	GAP (%)	Percentage of turns with GEH<1 between assignments	Percentage of links with GEH<1 between assignments
10	0.0005%	0.99	0.99
11	0.0004%	0.98	0.99
12	0.0005%	0.94	0.95
13	0.0003%	0.99	1.00

14	0.0003%	1.00	1.00
15	0.0001%	1.00	1.00
16	0.0006%	0.99	1.00
17	0.0002%	0.99	1.00
18	0.0001%	1.00	1.00
19	0.0001%	1.00	1.00

Table 6-17: PM Peak Convergence

Iteration	GAP (%)	Percentage of turns with GEH<1 between assignments	Percentage of links with GEH<1 between assignments
27	0.0004%	0.98	0.99
28	0.0003%	0.99	0.99
29	0.0002%	0.99	1.00
30	0.0005%	1.00	1.00
31	0.0005%	0.99	0.99
32	0.0002%	1.00	1.00
33	0.0002%	1.00	1.00
34	0.0002%	1.00	0.99
35	0.0001%	1.00	1.00
36	0.0001%	1.00	1.00

Figure 6-6 – VISUM Assignment and Convergence Tests.



7 Model Validation

7.1 Introduction

Model Validation is undertaken to check that a transport model accurately represents the transport network that it has been based upon. The main aims of this process, as stated in DMRB (Volume 12, Section 1), 'Traffic Appraisal in Urban Areas', are:

- To demonstrate that the model accurately reproduces an existing and independently observed situation
- To summarise the accuracy of the base from which future forecasts are to be prepared.

7.2 Screenline Flow Validation

Seven screenlines (as shown in Figure 7-1) controlling major movements in the study area are used in validation. Comparisons of modelled and observed flows were undertaken for these screenlines (by direction) as shown below in Tables 7-1 to 7-4.

Table 7-1 –Validation Summary – Screenlines

Pass/Fail	AM	Inter Peak	PM
	Flow	Flow	Flow
Screenline 1 – NB	×	✓	×
Screenline 1 – SB	✓	✓	✓
Screenline 2 – EB	✓	✓	✓
Screenline 2 – WB	✓	✓	✓
Screenline 3 – NB	✓	✓	✓
Screenline 3 – SB	✓	✓	✓
Screenline 4 – EB	✓	✓	✓
Screenline 4 – WB	✓	✓	✓
Screenline 5 – NB	×	✓	✓
Screenline 5 – SB	✓	✓	✓
Screenline 6 – EB	✓	✓	✓
Screenline 6 – WB	✓	×	✓
Screenline 7 – EB	✓	✓	×
Screenline 7 – WB	✓	✓	×
Total Passing DMRB Criteria	**12 / 14**	**13 / 14**	**11 / 14**
% Passing DMRB Criteria	**86%**	**93%**	**79%**

Figure 7-1 – Flow Validation Screenlines

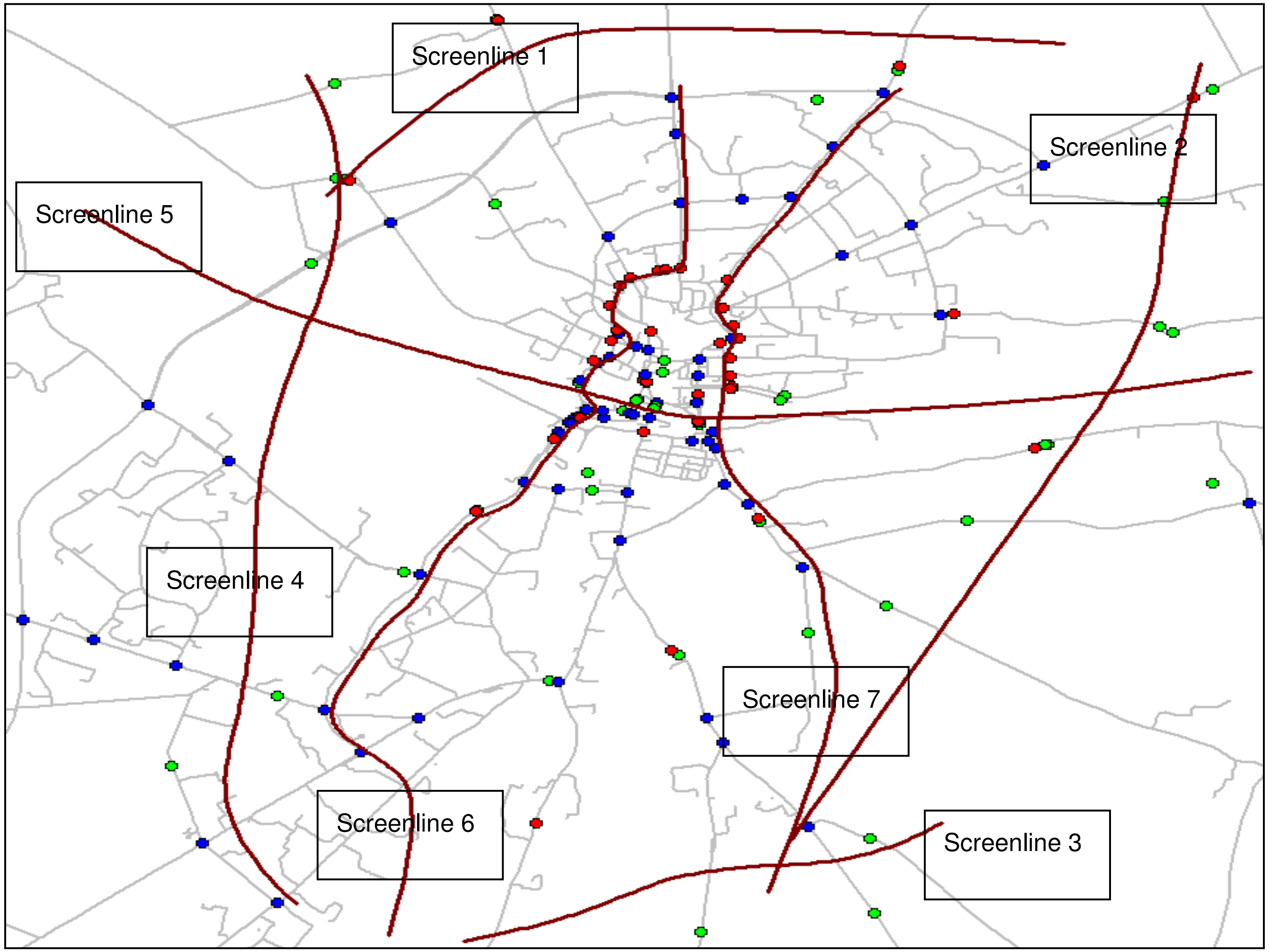


Table 7-2 – Validation Screenline Summary – AM Peak

Screenline	Direction	Observed (vehicle)	Modelled (vehicle)	Obs - Mod (vehicle)	% Diff	WebTAG Criteria
Screenline1	NB	1,666	1,548	118	7.08	×
	SB	3,211	3,162	49	1.53	✓
Screenline2	EB	1,752	1,678	74	4.22	✓
	WB	3,314	3,456	-142	-4.28	✓
Screenline3	NB	1,352	1,335	17	1.26	✓
	SB	1,486	1,493	-7	-0.47	✓
Screenline4	EB	4,520	4,413	107	2.37	✓
	WB	3,614	3,713	-99	-2.74	✓
Screenline5	NB	5,418	5,870	-452	-8.34	×
	SB	4,190	4,101	89	2.12	✓
Screenline6	EB	7,067	7,245	-178	-2.52	✓
	WB	6,023	6,244	-221	-3.67	✓
Screenline7	EB	4,744	4,566	178	3.75	✓
	WB	4,836	4,975	-139	-2.87	✓
Number of Screenlines passing DMRB Criteria						**12/14**
Percentage of Screenlines passing DMRB Criteria						**86%**

Table 7-3 – Validation Screenline Summary – Inter Peak

Screenline	Direction	Observed (vehicle)	Modelled (vehicle)	Obs - Mod (vehicle)	% Diff	WebTAG Criteria
Screenline1	NB	1,684	1,709	-25	-1.48	✓
	SB	1,705	1,714	-9	-0.53	✓
Screenline2	EB	1,849	1,820	29	1.57	✓
	WB	1,768	1,809	-41	-2.32	✓
Screenline3	NB	812	827	-15	-1.85	✓
	SB	990	943	47	4.75	✓
Screenline4	EB	2,805	2,918	-113	-4.03	✓
	WB	2,896	2,967	-71	-2.45	✓
Screenline5	NB	3,727	3,899	-172	-4.61	✓
	SB	3,720	3,888	-168	-4.52	✓
Screenline6	EB	5,245	5,111	134	2.55	✓
	WB	5,460	5,121	339	6.21	×
Screenline7	EB	4,110	3,956	154	3.75	✓
	WB	4,586	4,556	30	0.65	✓
Number of Screenlines passing DMRB Criteria						**13 / 14**
Percentage of Screenlines passing DMRB Criteria						**93%**

Table 7-4 – Validation Screenline Summary – PM Peak

Screenline	Direction	Observed (vehicle)	Modelled (vehicle)	Obs - Mod (vehicle)	% Diff	WebTAG Criteria
Screenline1	NB	2,843	2,640	203	7.1	×
	SB	2,059	2,069	-10	-0.5	✓
Screenline2	EB	3,385	3,395	-10	-0.3	✓
	WB	1,874	1,927	-53	-2.8	✓
Screenline3	NB	1,396	1,428	-32	-2.3	✓
	SB	1,492	1,495	-3	-0.2	✓
Screenline4	EB	3,981	4,150	-169	-4.2	✓
	WB	4,099	3,908	191	4.7	✓
Screenline5	NB	4,559	4,538	21	0.5	✓
	SB	5,204	5,103	101	1.9	✓
Screenline6	EB	6,298	6,225	73	1.2	✓
	WB	6,445	6,180	265	4.1	✓
Screenline7	EB	5,040	4,484	556	11.0	×
	WB	5,563	5,096	467	8.4	×
Number of Screenlines passing DMRB Criteria						**11 / 14**
Percentage of Screenlines passing DMRB Criteria						**79%**

It can be seen that of the 14 screenlines (by direction) 12 pass in the AM Peak, 13 pass in the Inter Peak and 11 pass the DMRB 5% Flow difference validation criteria in the PM Peak. The DMRB target criteria suggest that all or nearly all of screenlines should pass the criteria.

The model has been recalibrated as the adherence to guidance was originally based on targets relevant in 2006, which included screenline based GEH criteria. As this required revisiting the opportunity was also taken to introduce updated values of time and a software enhancement to a recent, more stable version of VISUM.

As the ability to add to and critically review the 2006 travel dataset is somewhat limited by time the decision was made to limit the adjustments made to the 2006 model to avoid excessive distortion of the original data.

The most important movement for LEB is Screenline 5. For this the AM northbound movement narrowly misses out on achieving the 5% target. All other time periods and directions are within targets.

Of the dataset the worst performing location is Screenline 7 in the PM peak which is on average around 9% short of traffic. This comprises traffic heading into and out of Lincoln Centre from the East.

Appendix J provides a link based assessment of the Validation. A summation of WebTAG criteria is included. None of the time periods match the 85% target. The model reaches 71%, 82% and 63% in the AM, IP and PM peak respectively.

Whilst this is not an ideal outcome it is evidenced that the traffic on strategic corridors performs well providing confidence that strategic movements to, from and around Lincoln are well represented. The age of the data and the difficulty of investigating a model constructed a significant length of time ago precludes investigation of performance beyond that presented. Any issues with performance would need to be investigated at Present Year Validation stage, or as forecast sensitivities. This will be addressed in the relevant reporting

7.3 Journey Time Validation

It is important that journey times are properly validated to ensure that speeds on links and delays at junctions are accurately represented by the model. This will give confidence in the model's ability to correctly forecast the likely impacts of changing traffic demand and network improvements on route choice and changes in travel costs.

The journey time validation is based on comparisons of observed and modelled journey times along 10 (bi-directional) routes (shown in Figure 3-4). .

Table 7-5, Table 7-6, and Table 7-7 provide a summary of the journey time validation results for each of the three modelled time periods. They show that, for all three time periods, the difference between modelled and observed journey times is within 15%

or 1 minute for 16 out of 20 routes (80%) for AM Peak, 17 out of 20 routes (85%) for the Inter-Peak and 16 out of 20 routes (85%) for the PM Peak. This validation narrowly misses the DfT target criteria (as described in Table 6-1).

Detailed journey time validation results for all routes are presented in Appendix K, which includes figures showing comparison of observed and modelled journey times over the length of each route.

Table 7-5 – Journey Time Validation Summary – AM Peak

Route	Description	Direction	Modelled Distance (km)	Journey Times (mm:ss)				
				Observed	Modelled	Difference	% Diff	Pass DMRB
Route 1	B1182 Ruskin Ave/A15 Wragby Rd and A1434 Newark Rd/B1003 Tritton Rd	SB	8.478	1231	1243	12	1%	✓
		NB	8.434	1115	1245	130	12%	✓
Route 2	Ferry Rd/Short Ferry Rd and A1133/A46	WB	46.77	3435	4552	1,117	33%	×
		EB	46.85	3381	3254	-127	-4%	✓
Route 3	B1189 Moor Ln and A57 Gainsborough Rd/B1190 Tom Otters Ln	NB	36.38	2727	3361	634	23%	×
		SB	36.42	2947	2998	51	2%	✓
Route 4	Hopyard Ln/Navenby Ln and A1133 Newark Rd/A156	NB	34.32	2511	2598	87	3%	✓
		SB	34.42	2978	2633	-345	-12%	✓
Route 5	B1189/B1191 Main St/Station Rd and A46 Lincoln Rd/Washdyke Ln	NB	25.88	2044	2305	261	13%	✓
		SB	26.14	1957	2057	100	5%	✓
Route 6	B1191 Main St/B1189/Station Rd and A1434 Newark Rd/Boundary Ln	WB	28.74	1678	1844	166	10%	✓
		EB	28.74	1724	1645	-79	-5%	✓
Route 7	A46/A1434 Newark Rd and Moor Ln/Fiskerton Rd	EB	19.52	1263	1217	-46	-4%	✓
		WB	19.5	1369	1341	-28	-2%	✓
Route 8	A607 Cliff Rd/Skinnand Ln and A1500 Stow Park Rd/High St	NB	36.52	2688	2845	157	6%	✓
		SB	36.66	2824	2886	62	2%	✓
Route 9	B1190 Branston Causeway at river and B1378 Skellingthorpe Rd/Lincoln Rd	WB	21.34	1793	2156	363	20%	×
		EB	21.48	2049	2086	37	2%	✓
Route 10	B1190 Branston Causeway at river and A1500 Horncastle Ln/A15	NB	23.72	2218	2670	452	20%	×
		SB	23.7	2181	1998	-183	-8%	✓
Number of routes passing DMRB criteria								**16 / 20**
Percentage of routes passing DMRB criteria								**80%**

Table 7-6 – Journey Time Validation Summary – Inter Peak

Route	Description	Direction	Modelled Distance (km)	Journey Times (mm:ss)				
				Observed	Modelled	Difference	% Diff	Pass DMRB
Route 1	B1182 Ruskin Ave/A15 Wragby Rd and A1434 Newark Rd/B1003 Tritton Rd	SB	8.478	1151	1044	-107	-9%	✓
		NB	8.434	1073	946.2	-127	-12%	✓
Route 2	Ferry Rd/Short Ferry Rd and A1133/A46	WB	46.92	3030	2970	-60	-2%	✓
		EB	46.86	3002	2809	-193	-6%	✓
Route 3	B1189 Moor Ln and A57 Gainsborough Rd/B1190 Tom Otters Ln	NB	36.38	2514	2471	-43	-2%	✓
		SB	36.42	2736	2554	-182	-7%	✓
Route 4	Hopyard Ln/Navenby Ln and A1133 Newark Rd/A156	NB	34.32	2444	2475	31	1%	✓
		SB	34.42	2654	2355	-299	-11%	✓
Route 5	B1189/B1191 Main St/Station Rd and A46 Lincoln Rd/Washdyke Ln	NB	25.88	1866	1777	-89	-5%	✓
		SB	26.14	1825	1926	101	6%	✓
Route 6	B1191 Main St/B1189/Station Rd and A1434 Newark Rd/Boundary Ln	WB	28.74	1640	1467	-173	-11%	✓
		EB	28.74	1664	1463	-201	-12%	✓
Route 7	A46/A1434 Newark Rd and Moor Ln/Fiskerton Rd	EB	19.52	1118	928	-190	-17%	×
		WB	19.5	1169	959.4	-210	-18%	×
Route 8	A607 Cliff Rd/Skinnand Ln and A1500 Stow Park Rd/High St	NB	36.52	2488	2487	-1	0%	✓
		SB	36.66	2608	2645	37	1%	✓
Route 9	B1190 Branston Causeway at river and B1378 Skellingthorpe Rd/Lincoln Rd	WB	21.34	1777	1717	-60	-3%	✓
		EB	21.48	1872	1679	-193	-10%	✓
Route 10	B1190 Branston Causeway at river and A1500 Horncastle Ln/A15	NB	23.72	2221	1883	-338	-15%	×
		SB	23.7	2036	1879	-157	-8%	✓
Number of routes passing DMRB criteria								**17 / 20**
Percentage of routes passing DMRB criteria								**85%**

Table 7-7 – Journey Time Validation Summary – PM Peak

Route	Description	Direction	Modelled Distance (km)	Journey Times (mm:ss)				
				Observed	Modelled	Difference	% Diff	Pass DMRB
Route 1	B1182 Ruskin Ave/A15 Wragby Rd and A1434 Newark Rd/B1003 Tritton Rd	SB	8.478	1320	1364	44	3%	✓
		NB	8.434	1174	1179	5	0%	✓
Route 2	Ferry Rd/Short Ferry Rd and A1133/A46	WB	47.03	3315	3401	86	3%	✓
		EB	46.96	2904	3108	204	7%	✓
Route 3	B1189 Moor Ln and A57 Gainsborough Rd/B1190 Tom Otters Ln	NB	36.38	2863	3114	251	9%	✓
		SB	36.42	2912	3224	312	11%	✓
Route 4	Hopyard Ln/Navenby Ln and A1133 Newark Rd/A156	NB	34.32	2651	3148	497	19%	×
		SB	34.42	2746	3231	485	18%	×
Route 5	B1189/B1191 Main St/Station Rd and A46 Lincoln Rd/Washdyke Ln	NB	25.88	2064	2158	94	5%	✓
		SB	26.14	2025	2343	318	16%	×
Route 6	B1191 Main St/B1189/Station Rd and A1434 Newark Rd/Boundary Ln	WB	28.74	1656	1859	203	12%	✓
		EB	28.74	1668	1787	119	7%	✓
Route 7	A46/A1434 Newark Rd and Moor Ln/Fiskerton Rd	EB	19.52	1274	1425	151	12%	✓
		WB	19.5	1338	1047	-291	-22%	×
Route 8	A607 Cliff Rd/Skinnand Ln and A1500 Stow Park Rd/High St	NB	36.52	2782	2842	60	2%	✓
		SB	36.66	2836	3048	212	7%	✓
Route 9	B1190 Branston Causeway at river and B1378 Skellingthorpe Rd/Lincoln Rd	WB	21.34	2158	2177	19	1%	✓
		EB	21.53	1968	1830	-138	-7%	✓
Route 10	B1190 Branston Causeway at river and A1500 Horncastle Ln/A15	NB	23.72	2374	2611	237	10%	✓
		SB	23.7	2247	2290	43	2%	✓
Number of routes passing DMRB criteria								**16 / 20**
Percentage of routes passing DMRB criteria								**80%**

7.4 Checking

Further checks were undertaken (Shortest path and select link analyses) on all major routes in the network to ensure that the routes used between origin and destination pairs were realistic.

Individual junction delays were also checked for each of the model periods to assess the scale of delay reported. These were found to be proportionate and reasonable.

Flow diagrams and Volume/ Capacity diagrams for AM, IP and PM are presented in Appendix L. The diagams present a sensible, intuitive and recognisable representation of traffic assigned across the Lincoln network.

8 Summary and Conclusions

8.1 Summary and Conclusions

The “Greater Lincoln Transport Model" (GLTM) was developed to support, amongst other things, the Major Scheme Business Case (MSBC) funding bid for the Lincoln Eastern Bypass. The original model was reconstructed in 2010 by Mouchel to provide an updated funding application for this scheme resulting in the BaFB and related materials submitted to the DfT in 2011.

This Local Model Validation Report (LMVR) describes the development of the modelled networks and trip matrices and the subsequent model revalidation process to take account of updates and commentary post 2011. Hence the work also includes refinements made as part of the Public Inquiries. The work-stream follows the principles agreed with the DfT after a meeting held in 2015 and is designed to provide a proportionate update given the age of the data involved.

8.2 Model overview

The model reconstruction (2011) and revalidation (2016) has retained the original structure, in particular the approach to demand forecasting, but involved a thorough review and reworking of the available traffic data. Hence the principle stages reported here include network validation, matrix development (combining observed and synthetic elements), model calibration and model validation.

The model itself represents typical weekday (Tuesday-Thursday) conditions in October and November 2006. Separate models were developed for the AM Peak hour (08:00-09:00), PM peak hour (17:00-18:00) and an average inter-peak hour (10:00-16:00). The model has used data primarily from a comprehensive set of highway traffic surveys undertaken during the last quarter of 2006.

The model covers the urban area of Lincoln City and surrounding countryside, and broadly aligns with the Lincoln Planning Area (LPA).

The highway network model was capacity restrained, incorporating junction delay simulation within the Lincoln urban area. The model reconstruction included extensive correction to network coding and subsequent checking.

The travel demands were derived from trips observed at a cordon around Lincoln combined with synthetic estimates of internal and wholly external trips. Checks included the assignment of the observed matrix cells and comparison with traffic flow data at the study area cordon. Subsequently, the observed and synthetic matrices were merged prior to the calibration of the overall demand matrices using matrix estimation techniques.

8.3 Traffic Data

The available traffic data used in the model was thoroughly checked, including the postcard returns from roadside surveys at the study area cordon.

The database of traffic counts was also reviewed and conflicting or inconsistent counts removed. The count data was also allocated to either the model calibration or validation stages.

Whilst the original 2006 journey time data was largely retained, the relatively low sample size was enhanced using observations from the TrafficMaster database.

8.4 Network Development

A comprehensive review of the highway network model was undertaken as part of the updating process and a substantial number of corrections or adjustments made for application of the model to the Eastern Bypass assessment.

External 'buffer' network links were either extended or added to the model and the detailed coding of simulation nodes revised within the detailed study area. The latter included the derivation of signal timings to represent the SCOOT control system in Lincoln city centre. Bus services were also updated and coded into the highway model.

Network validation checks included link attributes, junction type coding, link distances and assignment routing checks.

8.5 Matrix Development

The matrix development process retained the original study methodology in combining observed and synthetic matrix elements, although all steps in this process were updated and data sources revisited.

The observed matrix elements were derived from the roadside surveys undertaken at the study area cordon. Where (the less busy) roads crossing the cordon were not included in the original survey, estimated movement patterns were derived from analyses using the existing model.

Possible bias in the self-completion survey, in particular journey purpose descriptions, was tested against comparable databases from other studies. This did not reveal any significant bias judged to have affected the quality of the data.

Following construction of the observed matrices, the partial matrices were assigned to the network for each modelled period and by direction as a preliminary validation check. This indicated a shortfall in all periods, indicating the routing of some (external- external) trips away from the cordon, not unexpectedly given the partially loaded (and hence uncongested) state of the network in this test.

The synthetic matrix process included the derivation of internal and external trips, for all vehicle purposes including freight transport. The demand was scaled to that impacting the study area. In merging the observed and synthetic matrices, smoothing was undertaken to reduce the effects of variable sample sizes within the model data.

8.6 Model Calibration

Model calibration involved the iterative adjustment of the network models, including junction and speed/ flow coding, and matrix estimation to derive model outputs which were measured against count and journey time data, adopting DMRB validation guidelines. Assignment parameters were derived from latest WebB

The effects of matrix estimation were monitored at sector level to gauge the extent of adjustment within the model. This was judged to be acceptable within the various sectors, including those where observed data was incorporated within the model.

Other aspects of the performance of the model were also monitored and reported here; including origin/ destination trip ends, trip length distribution and model convergence.

8.7 Model Validation

The process of model validation again followed the guidance given in DMRB in terms of comparisons between observed and modelled traffic flows and journey times.

Data was formed for a series of 7 two-way screenlines at which observed and modelled traffic flows were compared. In all cases, these comparisons exceeded the DMRB guidelines for flow and GEH statistics, as shown in Table 8-2.

Table 8-1 – Validation Summary – Screenlines

Pass/Fail	AM	Inter Peak	PM
	Flow	Flow	Flow
Screenline 1 – NB	×	✓	×
Screenline 1 – SB	✓	✓	✓
Screenline 2 – EB	✓	✓	✓
Screenline 2 – WB	✓	✓	✓
Screenline 3 – NB	✓	✓	✓
Screenline 3 – SB	✓	✓	✓
Screenline 4 – EB	✓	✓	✓
Screenline 4 – WB	✓	✓	✓
Screenline 5 – NB	×	✓	✓
Screenline 5 – SB	✓	✓	✓
Screenline 6 – EB	✓	✓	✓
Screenline 6 – WB	✓	×	✓
Screenline 7 – EB	✓	✓	×
Screenline 7 - WB	✓	✓	×

Pass/Fail	AM	Inter Peak	PM
	Flow	Flow	Flow
Total Passing DMRB Criteria	**12 / 14**	**13 / 14**	**11 / 14**
% Passing DMRB Criteria	**86%**	**93%**	**79%**

Journey time validation showed that, for each of the three time periods, the difference between modelled and observed journey times was within 15% or 1 minute, if higher, for all routes, and therefore 90% or more of routes pass the DMRB journey time validation criteria. A summary of the journey time validation is provided in Table 8-2 below.

Table 8-2 – Summary of Journey Time Validation

Time Period	Percentage of Routes Passing DMRB Validation Criteria
AM Peak	80%
Inter Peak	85%
PM Peak	80%

The model replicates the observed 2006 situation reasonably well, although a number of aspects fail to adhere to DMRB validation criteria across the city as a whole. It is suggested that the model performs acceptably well in those areas which are expected to be impacted most significantly by LEB. On this basis, it has been demonstrated that the base year traffic model, for each of the three modelled time periods, provides a plausible representation of the 2006 traffic demands in the wider Lincoln area.

Given the age of the survey data being used a Present Year Validation comparison of the model and appropriate forecast year sensitivity testing will be undertaken to ensure that the LEB is adequately assessed to the satisfaction of DfT. The purpose of the model is to evaluate the impact of recent changes and updates in the local transportation landscape since the BaFB on the viability of the Lincoln Eastern Bypass. On this basis the model is considered to be fit for the intended purpose.

Any future evaluation of strategic schemes in Lincoln is proposed to use an updated model, currently under development..

9 Appendices

Separate volume provided.

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We have used our reasonable endeavours to provide information that is correct and accurate and have discussed above the reasonable conclusions that can be reached on the basis of the information available. Having issued the range of conclusions it is for the client to decide how to proceed with this project.