Greater Lincoln Transport Model

Local Model Validation Report

Lincolnshire
COUNTY COUNCIL
HIGHWAYS ALLIANCE

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List of Abbreviations

Abbreviation	Name
ATC	Automatic Traffic Count
DfT	Department for Transport
GLHAM	Greater Lincoln Highway Assignment Model
GLTM	Greater Lincoln Transport Model
GPS	Global Positioning System
HGV	Heavy Goods Vehicle
ITN	Integrated Transport Network
LCC	Lincolnshire County Council
J2W	Journey to Work (census)
LEB	Lincoln Eastern Bypass
LGV	Light Goods Vehicle
LSB	Lincoln Southern Bypass
MCC	Manual Classified Count
MND	Mobile Network Data
MPOD	Mobile Phone Origin Destination
MSR	Model Specification Report
NTEM	National Trip End Model
NTS	National Travel Survey
OGV	Other Goods Vehicle
ONS	Office for National Statistics
ORR	Office for Rail and Road
OS	Ordnance Survey
P&R	Park and Ride
PCU	Passenger Car Unit
PPK	Pence Per Kilometre
PPM	Pence Per Minute
PSV	Passenger Service Vehicle
SATURN	Simulation and Assignment of Traffic in Urban Road Networks
TAG	Transport Analysis Guidance
TDCR	Traffic Data Collection Report
TMOD	Trafficmaster Origin Destination
TMJT	Trafficmaster Journey Time Data
VDM	Variable Demand Model
VOC	Vehicle Operating Costs
VOT	Value of Time

1 Introduction

1.1 Background to GLTM

Lincoln represents the centre of a dynamic urban region with approximately 100,000 people residing within the city proper. This increases to a population in excess of 130,000 when extended to the continuous urban area of Lincoln, including North Hykeham and Waddington, both nominally within North Kesteven district. The level of anticipated future year development growth and potential attendant transportation issues necessitate an appropriate tool to evaluate and appraise potential outcomes.

The previous Greater Lincoln Traffic Model (GLTM), owned by Lincolnshire County Council (LCC), was first developed in 2006. Whilst some updating, refinement and revalidation had been undertaken over the subsequent years, the fundamental data used to derive traffic patterns was collected in 2006.

It was therefore established that an updated Greater Lincoln Transport Model (also to be referred to as the GLTM) was needed to enable modelling and appraisal for new projects being developed by Lincolnshire County Council and its partners.

The transport model will provide a robust tool for analysis and appraisal towards four key objectives defined within the Model Specification Report (MSR):

- Development Management

  The Central Lincolnshire Local Plan was adopted on 24th April 2017 superseding the Local Plans of the City of Lincoln, West Lindsey and North Kesteven District Councils. The expansion targets within the Local Plan combined with speculative developer interest necessitate the ability for optimal traffic and transport engineering designs to be tested robustly to improve the efficiency and accessibility of new development, including the ability for mitigation areas which can be crucial in securing planning application. Model applications will include testing the trip generation and distribution of new developments, junction analysis and design and testing traffic management interventions.

- Strategic Business Case Evaluation

  A primary application of the model is expected to be the development of an Outline Business Case for Lincoln Southern Bypass (LSB), which is expected to increase in prominence with the construction of Lincoln Eastern Bypass (LEB) underway.

- High Level Policy Evaluation

  Two prominent areas of policy evaluation include parking policies and Park and Ride (P&R). Both of these areas straddle the area between assignment related issues (highway route choice) and demand related issues (propensity to travel) which would require special consideration within a model. This functionality is not contained within the previous GLTM but will be incorporated in the new demand model.

- Tactical Measures

  The model will be suitable for testing traffic impacts of day to day network management issues, which are the responsibility of Lincolnshire County Council, including noise and air quality assessments, maintenance, and event management.

1.2 Purpose of this Report

This report has been prepared to document the development and validation of the Highway Assignment Model for GLTM with reference to the Department for Transport's (DfT's) Transport Analysis Guidance (TAG) which defines the standards for traffic modelling, with particular reference to Unit M3.1 Highway Assignment Modelling.

The content of this report is structured as follows.

- Chapter 2 introduces the **model structure** and **specification**;
- Chapter 3 outlines the **model standards** and **objectives**;
- Chapter 4 summarises the **data collection** undertaken for the model development;
- Chapter 5 covers the development and structure of the **highway network**;
- Chapter 6 describes the highway trip **matrix development**;
- Chapter 7 describes the **model calibration** process;
- Chapter 8 reports the **model validation** results; and
- Chapter 9 provides a **summary** and **conclusions** from the modelling.

The development of the demand model and public transport assignment is beyond the scope of this report and will be included in subsequent documentation.

2 Model Description and Specification

2.1 Introduction

There are four primary modelling components to GLTM:

- Greater Lincoln Highway Assignment Model (GLHAM)

  A highway assignment model developed within SATURN (Simulation and Assignment of Traffic in Urban Road Networks) to determine journeys travelling on the highway network including traffic flows, speed, delays, route choice and journey costs.

- Greater Lincoln Public Transport Model (GLPTM)

  A public transport assignment model developed within CUBE Voyager to predict journeys travelling on public transport routes including occupancy and journey costs.

- Greater Lincoln Trip End Model (GLTEM)

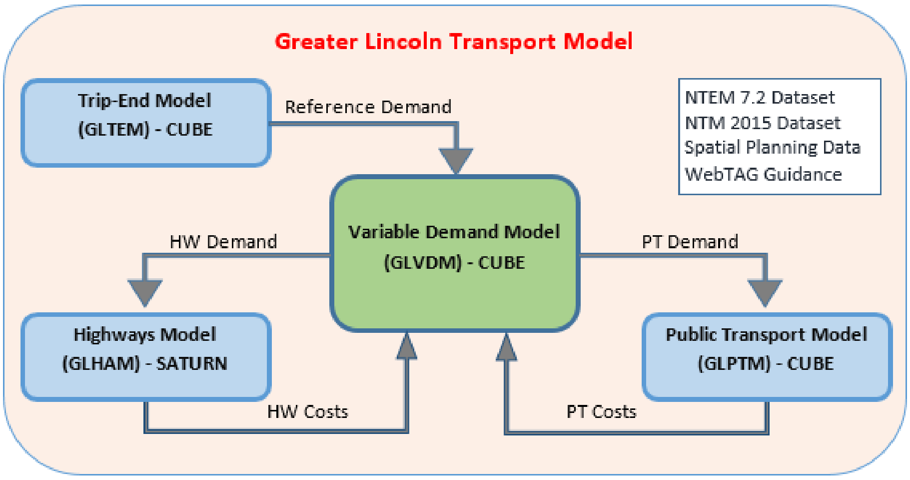
  A trip end model developed within CUBE Voyager to consider the trip generation impacts of land use changes or shifts in scale and pattern of economic activity.

- Greater Lincoln Variable Demand Model (GLVDM)

  A variable demand model (VDM) developed within CUBE Voyager to predict the future demand for private vehicle travel through consideration cost change impacts on trip distribution and mode split. GLVDM will facilitate mode choice between private highway and public transport assignments.

The interaction is summarised in Figure 2-1 below.

Figure 2-1 GLTM Model Structure



A detailed description of the public transport model development and demand model development will be included in the Public Transport Model Validation Report.

2.2 Model Software Platform

The GLTM family has been developed using a combination of two model platforms: SATURN and CUBE Voyager, as below.

The GLHAM has been developed in SATURN – Simulation and Assignment of Traffic in Urban Road Networks – which is static equilibrium highway assignment software. SATURN is considered as the market leader in this field due to its enhanced simulation routines for modelling congested assignment. Two key features include blocking back and flow meter propagation through the network. GLHAM has been developed using SATURN version 11.3.12.W.

The GLTEM, GLPTM and GLVDM have been developed using CUBE Voyager to avail of functionality covering public transport assignment and demand modelling. Scripting has been developed to link the SATURN highway models to the CUBE Voyager demand model in order to allow a seamless interaction between the highway model and the PT / Demand model to provide multimodal functionality.

2.3 Study Area

GLTM has been developed to provide detailed coverage of Lincoln and North Hykeham, with the simulation area boundary roughly defined by a cordon around the existing A46 bypass and the under-construction Eastern Bypass. The network and zoning detail is sufficiently detailed to facilitate the core uses of the model including:

- Land use development analysis;
- Strategic business case evaluation;
- High level policy evaluation; and
- Tactical measures for local intervention.

The buffer area beyond the simulation coding is defined at two differing levels of detail. The regions immediately beyond the simulation area are defined with speed-flow curves to more represent the impact of rerouting in these localities. The resultant travel costs will be appropriately specified for use within the variable demand model. The remainder of the external area is coded with fixed speeds. This hierarchy is illustrated in Figure 2-2 below.

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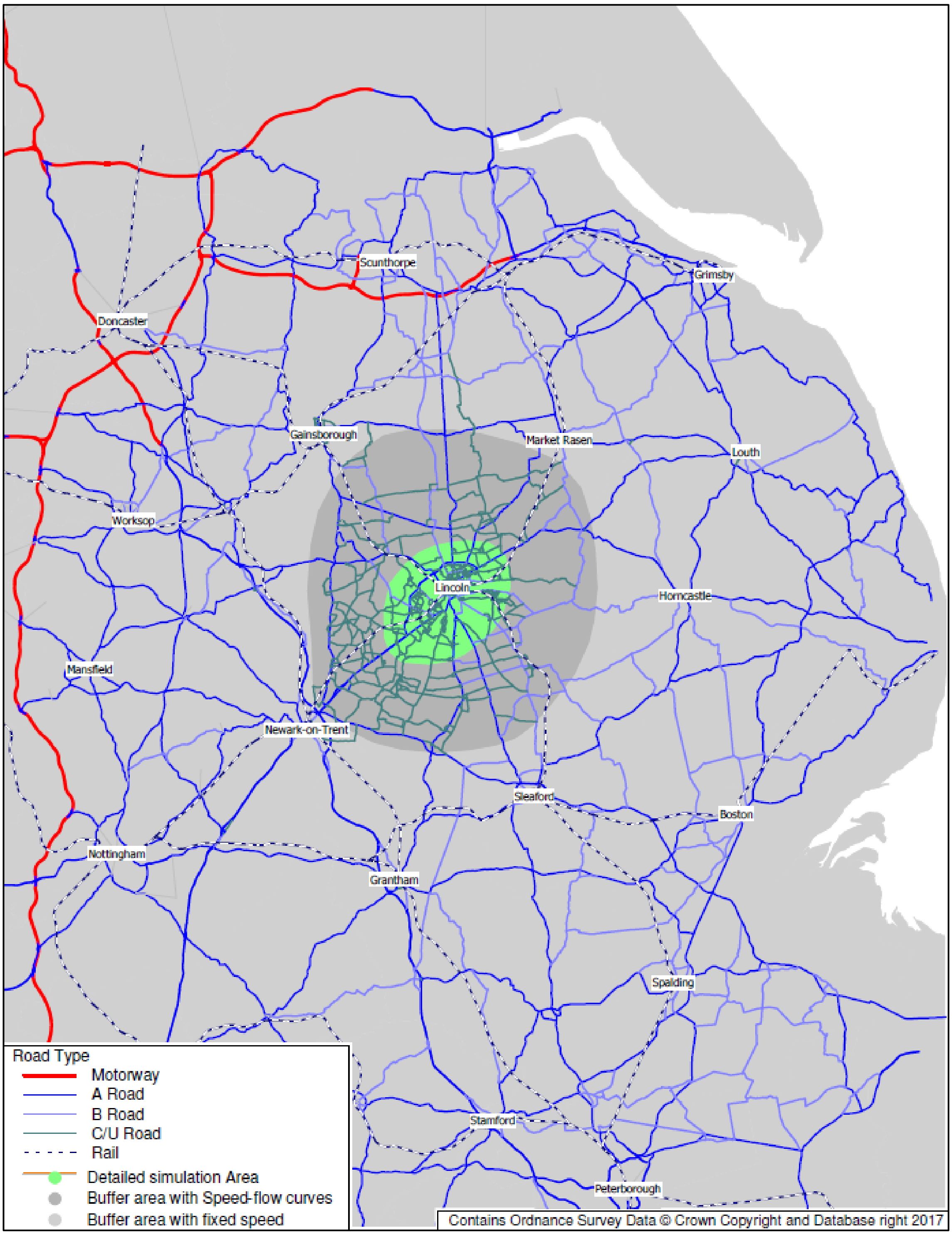
Figure 2-2 GLTM Model Coverage



2.4 Modelled Periods

Traffic patterns, purpose split, traffic volume and vehicle compositions and congestion vary by time of days and day of weeks. WebTAG M3.1 states that highway assignment models should therefore normally represent the morning and evening peak and the inter-peak period separately as a minimum.

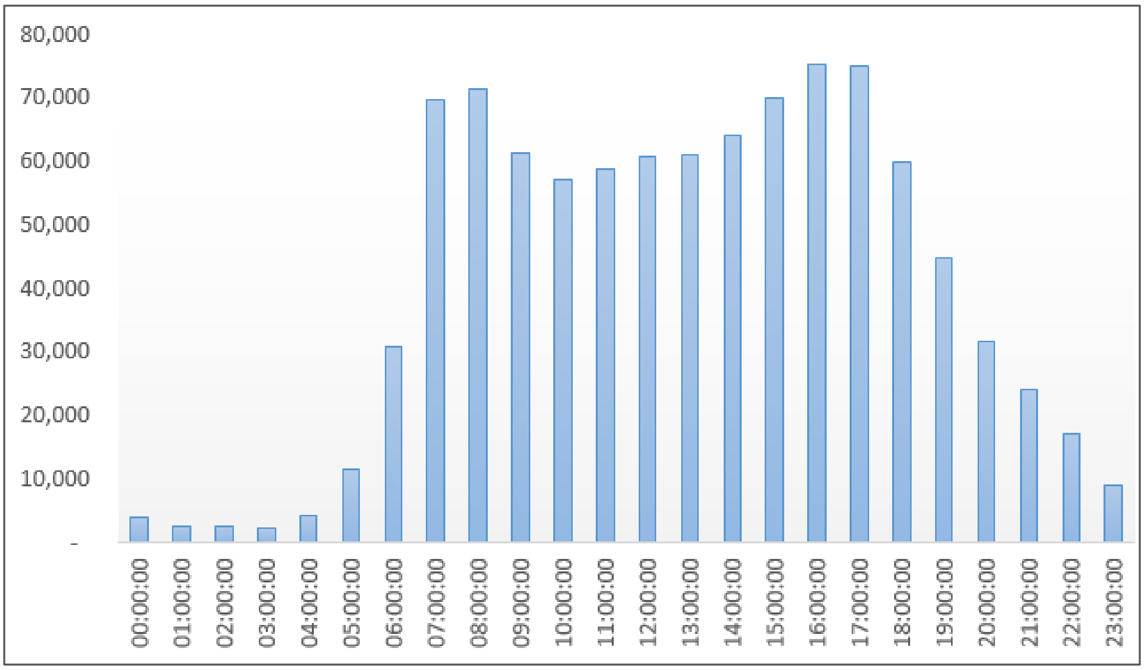
The base year of GLTM has been defined as an average weekday (Monday to Friday) in an average neutral month, as agreed with LCC. The inclusion of Friday is supported with reference to flow profiles and accords with the specification of the mobile phone demand data defined in Section 4.2.

Time periods modelled are defined below

- AM peak hour (08:00-09:00);
- Inter peak average hour (10:00-16:00); and
- PM peak hour (17:00-18:00).

The peak hours are consistent with those from the previous GLTM, evidenced by analysis of the flow profile from the commissioned automatic traffic count (ATC) surveys conducted in November 2016 presented in Figure 2-3.

Figure 2-3 Average Weekday Flow Profile (ATC Nov. 2016)



2.5 Assignment User Classes

As stated in section 2.6 of the WebTAG M3.1, operating costs vary by vehicle types and values of time vary by the purpose of the trip being made. This means that different combination of vehicle and trip purposes have varying distance coefficients and should be modelled separately as they are likely to choose different routes through the network.

Travel demand is segmented into user classes to reflect the impact of varying parameters for value of time and vehicle operating costs on route choice for different trip purposes. Five user classes are modelled within GLTM, in accordance with the WebTAG M3.1, as below:

- User Class 1: Employers Business (herein referred to as Business);
- User Class 2: Commute;
- User Class 3: Other;
- User Class 4: Light Goods Vehicles (LGVs); and
- User Class 5: Heavy Goods Vehicles (HGVs).

Demand segments produced during the development of the highway demand matrices (described in Chapter 6) were aggregated into these five user classes prior to conducting highway assignment.

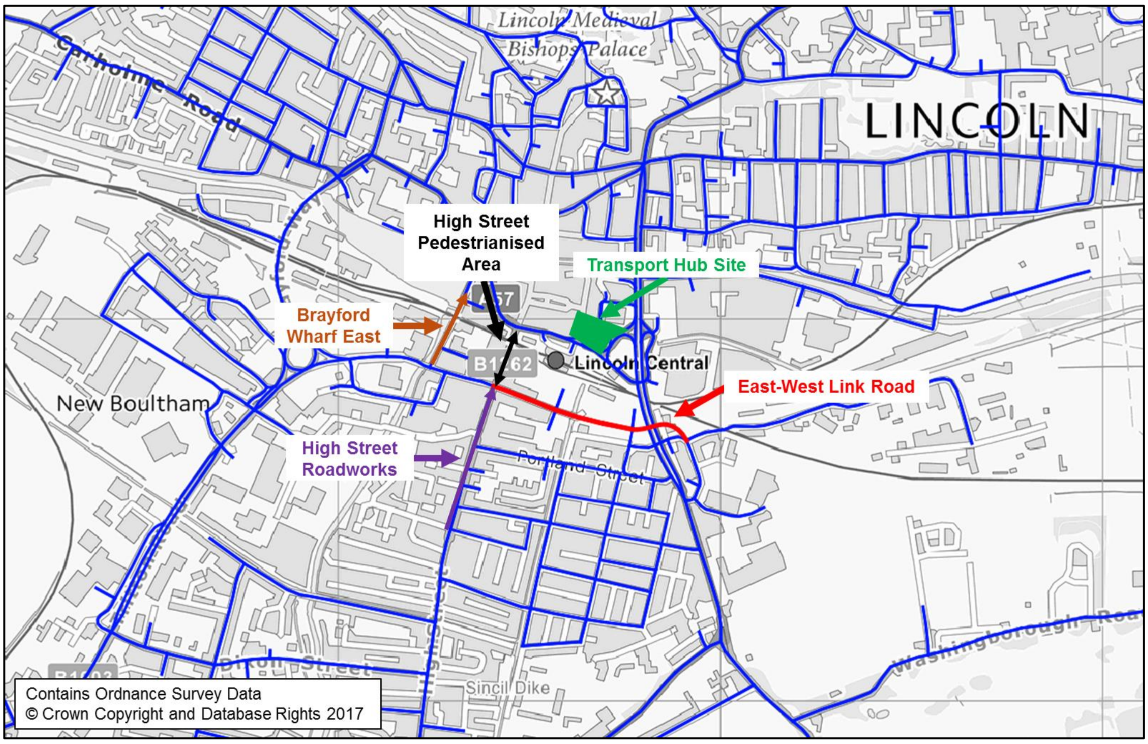
2.6 Representation of Ongoing Roadworks

There were various major roadwork schemes ongoing within Lincoln at different stages of the model development, including the data collection phases.

- Lincoln East-West Link Road opened on 17th November 2016, connecting the High Street to Pelham Bridge and Canwick Road with a direct link thus allowing traffic to bypass the city centre level crossings.
  - Lincoln Transport Hub began construction in August 2016, with number of roads either being closed or constrained operation to traffic at the following locations:
    - The gyratory section on Oxford Street/Norman Street was closed down during the construction of the Hub. However, Oxford Street was open with restriction in order for traffic to gain access to the car park on St Mary's street from the A15 Canwick road;
  - Pedestrianisation of High Street between St Mary's Street and Tentercroft Street;
  - The section of High Street south of Tentercroft Street in the northbound direction was one lane in operation;
- Brayford Wharf E southbound, section between Pope Walk and Brayford Street, was closed for vehicular traffic (i.e. north bound only).
- Lincoln Eastern Bypass began construction in early 2017with an expected opening of late 2019. This will be a new link outside Lincoln city centre and most of the construction works is being carried out off-line therefore it is assumed to not impact on the base networks and distribution.

The presence of on-going roadworks (excluding Lincoln Eastern Bypass) was reflected in the base year network development. The locations of the central schemes are illustrated in Figure 2-4.

Figure 2-4 Location of Ongoing Roadworks



Following consultation with LCC, it was agreed that congestion within Lincoln is not at such an extent that the existing roadworks would cause any significant time period shift for trip making. This is supported by the comparison presented in the TDCR which showed the daily flow profile from the November 2016 ATCs and representative of the GLTM base network conditions (also reported in Figure 2-3) against the similar profile reported from the previous LEB study. There was a strong similarity between the peak profiles providing support to this assumption.

This is not surprising since the roadworks are within the city centre and the impact is only likely to be affecting the start and end of journeys. Were the roadworks to be over a significant stretch of one of the strategic radial or bypass routes then then drivers may have allocated more time to navigate congested routes.

It has been assumed that the impact of the two schemes in the city centre would be on route choice rather than total number of trips or linkage between areas. Since the base models have been developed for an average neutral month, this excludes the seasonal variation from tourism trips without local knowledge of existing roadworks and alternative routes.

The construction of the East-West Link Road and the Transport Hub are confined to a specific locality and it is assumed that this has not impacted on strategic routeing. However, there is an impact on route choice in that area which impacted on comparison of traffic counts from different survey periods within that area.

The impact of the existing network conditions are discussed further:

- In Section 4.3 relating to the reconciliation of traffic counts;
- In Section 5.3 detailing the base year supply for these areas; and
- In Section 6.3.6 describing the base year demand for these areas.

2.7 Model Version

This report relates to the validated base year GLHAM with version file reference:

- Network/Model: GLTM_b16_net_v020_{am,ip,pm}.ufs
- Prior matrix: GLTM_b16_mat_v012d_prior_*{am,ip,pm}.ufm*
- Calibrated matrix: GLTM_b16_mat_v012d_prior_*{am,ip,pm}_i6.ufm*

3 Model Standards and Objectives

3.1 Introduction

GLHAM has been developed in accordance with the guidance set out in TAG Unit M3.1 *Highway Assignment Modelling* to ensure that the base year model achieves expected standards and is suitable for all types of modelling and appraisal in future.

This section describes the methodologies and standards which have been adopted for GLHAM including those reproduced from TAG M3.1 relating to comparisons in three key areas including:

- Assigned flows and observed counts across screenlines and cordons as a check on the quality of the trip matrices;
- Assigned flows and observed counts on individual links and turning movements at junctions as check on the quality of the network and the assignment; and
- Modelled journey times and observed journey times along routes as a check on the quality of the assignment.

3.2 Assignment Methodology

Assignment models split trips according to the routes they take through the network, and then calculate the costs of travelling via each route. The assignment procedure adopted for the highway model is based on an equilibrium assignment with multiple demand segments for three modelled time periods.

Model assignment of trips to the highway network were undertaken using a standard approach that is based on a 'Wardrop User Equilibrium', which seeks to minimise travel costs for each vehicle type in the network. The Wardrop User Equilibrium is based on the following propositions:

"Traffic arranges itself on congested network such that the cost of travel on all routes used between each origin-destination pair is equal to the minimum cost of travel and used routes have equal or greater costs".

The Wardrop User Equilibrium as implemented in SATURN is based on the 'Frank-Wolfe Algorithm', which is employed as an iterative process. The process is based on successive 'All or Nothing' iterations, which is then combined to minimise an 'Objective function'. Travel costs are then recalculated after each iteration and compared to those from the previous iteration. The process is terminated once successive iteration costs do not change significantly. This process enables multi-routeing between any origin-destination pair.

In addition to that, SATURN offers two other features, which differentiates it from other software platforms, which is 'flow metering' and 'blocking back'.

'Flow metering' refers to the phenomenon, whereby if a flow V enters a link with capacity C where V>C (so that the link is a 'bottleneck'), then the exit flow must equal

C which will be less than the total demand flow V. And equally, all further links downstream along those Origin-destination paths used by the flows caught in the bottleneck will experience metered flows.

'Blocking back', in contrast to the 'flow metering', describes the impact of traffic queues forming on links which are longer than available stacking capacity. In these cases the queue will propagate upstream and 'block' onto subsequent links. This can result in wider area impacts on delays route choices.

3.3 Convergence Criteria and Standards

As described in the previous section, an assignment model is deemed converged if no significant change in travel costs across all the routes between successive iterations. WebTAG M3.1 recommends number of criteria to be applied for all the model assignments in order to achieve a final solution (i.e. route choice, flows and delays produced from the model are deemed stable).

WebTAG recommends that the model should continue until, for at least 98% of cases the percentage of link flow or cost differences change by no more than 1% on four successive iterations.

This corresponds to setting the following SATURN parameters:

```
RSTOP: 98%        PCNEAR: 1%        NISTOP: 4
```

That is, the assignment should continue until at least **RSTOP** of links have a flow or cost change of at most **PCNEAR** percent for **NISTOP** successive iterations.

Within SATURN, the percentage flows report how stable the assignment is. The proximity between the assignment and simulation loop is given by %GAP in the reporting tables, i.e. how close the assignment is to Wardop's equilibrium.

Table 3-1 Convergence Criteria

Criteria	Base Model Acceptance Values
Delta and %GAP	Less than 0.1%
Percentage of links with flow change (P)<1%	Four consecutive iterations > 98%
Percentage of links with cost change (P2)<1%	Four consecutive iterations > 98%
Percentage change in total user costs (V)	Four consecutive iterations > 0.1%

3.4 Count Data Verification Standards

Count data has been obtained from various sources for use within the model build including newly commissioned surveys in November 2016 and March 2017 plus data which had been collected for other studies currently being undertaken by LCC within the area of interest.

The data collection and verification process followed the guidance set out in TAG Unit M2.1 *Data Sources and Surveys* documented in Chapter 4 and in the Traffic Data Collection Report (TDCR).

3.5 Network Calibration Standards

A set of network verification tests were undertaken prior to the commencement of the calibration/validation.

- Test 1 – Completeness Check: ensures that the network produced is complete according to the Model Specification Report (MSR).
- Test 2 – SATURN Compilation Check: ensures that all the errors/warnings produced by SATNET have been reviewed and checked.
- Test 3 – Inspection of Key Junctions: ensures that all the key junctions within Lincoln and areas of interest in network are coded correctly
- Test 4 – Network Routeing: ensures that routeing on the network appear realistic;
- Test 5 – Link Consistency Tests: ensures that link type, distance, speed limit, etc. are consistent between directions and up/downstream; and
- Test 6 – Flat Matrix Assignment Test: ensures that model assignment with a flat matrix produces plausible routeing and also to investigate whether or not locations with excessively high delays are as a result of significant flows or due to coding error.

For test four, the following equation taken from TAG Unit M3.1 defines the number of OD pairs that should be examined:

$$Number\ of\ OD\ Pairs = (Number\ of\ Zones)^{0.25} \times Number\ of\ User\ Classes$$

These checks are designed to provide reassurance that:

- The network building is complete to the agreed specification;
- The network and inputs have been appropriately checked, the SATURN warnings have been reviewed and formal testing has been carried out against a list of potential errors; and
- The network coding is satisfactory, as far as can be determined, before commencement of the calibration/validation stage.

The network will be validated against the journey time criteria set out in Table 3-4 and the link flow criteria set out in Table 3-5.

3.6 Matrix Calibration Standards

The developed trip matrices have been assigned for each modelled period and the modelled flows compared at a full screenline level against the observed counts. A matrix estimation (ME) process was undertaken to refine the trip matrices by vehicle type.

The changes brought about by ME are reported against the significance checks as set out in TAG Unit M3.1, reproduced in Table 3-2 below. Any exceedance of these criteria would be examined and assessed for their importance to the accuracy around the simulation area.

Table 3-2 Significance of Matrix Estimation Criteria

Measure	Significance Criteria
Matrix zonal cell values	Slope within 0.98 and 1.02; intercept near zero; R^2> 0.95
Matrix zonal trip ends	Slope within 0.99 and 1.01; intercept near zero; R^2> 0.98
Trip length distributions	Means within 5%; standard deviations within 5%
Sector to sector level matrices	Differences within 5%

3.7 Validation Criteria and Acceptability Guidelines

The model has been validated against the guidelines set out in TAG Unit M3.1. This states that comparisons should be carried out in three areas:

- Assigned flows and counts totalled for each screenline or cordon as a check on the quality of the trip matrices;
- Modelled and observed journey times along routes as a check on the quality of the assignment; and
- Assigned flows and counts on individual links and turning movements at junctions as a check on the quality of the network and the assignment.

3.7.1 Trip Matrix Validation Criteria

The trip matrices have been validated against the criteria set out in Table 3-3 that is reproduced from TAG Unit M3.1.

Presentation of the outputs is based around the TAG reporting guidelines as follows:

- Screenlines should be made up of 5 links or more;
- The comparisons for screenlines containing high flow routes such as motorways should be presented both including and excluding such routes; and
- The comparisons should be presented by vehicle type, by modelled time period and separately for screenlines used as constraints in the ME process and screenlines used for independent validation.

Table 3-3 Trip Matrix Validation Criteria

Criteria	Acceptability Guideline
Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines

3.7.2 *Journey Time Validation Criteria*

Journey time routes have been validated against the criteria set out in Table 3-4 that is reproduced from TAG Unit M3.1.

Presentation of the output is based on the TAG reporting guidelines as follows:

- Comparisons should be presented separately where distinct speed/flow relationships and/or link speeds have been used for light and other vehicles; otherwise they should be presented together; and
- Comparisons should be presented separately by modelled period and also by user class if a sufficient sample to a level of accuracy has been obtained for each to allow a meaningful validation.

Table 3-4 Journey Time Routes Validation Criteria

Criteria	Acceptability Guideline
Modelled times along routes should within 15% of surveyed times (or 1 minute if higher than 15%)	> 85% of routes

3.7.3 *Link Flow Validation Criteria*

The measures used for link flow validation are:

- The absolute and percentage differences between modelled flows and counts; and
- The GEH statistic which is a hybrid of the Chi-squared statistic to incorporate both relative and absolute errors. It is defined by

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

where M is the modelled flow and C is the observed flow.

Both measures are considered broadly consistent and meeting either is considered satisfactory by TAG Unit M3.1. The following, taken from TAG, should be noted:

- The above criteria should be applied to both link flow and turning movements however it is accepted that it may be more difficult to achieve for the latter;

- The comparisons should be presented separately for each modelled time period and separately for cars and all vehicles but not for goods vehicles unless sufficiently accurately link counts have been obtained; and
- It is recommended that comparisons against both measures are reported.

The acceptability criteria are given in Table 3-5 reproduced from TAG Unit M3.1.

Table 3-5 Link Flow and Turning Movement Validation Criteria

Criteria	Description	Acceptability Guideline
1	Individual flows within 100 veh/hr of counts for flows less than 700 veh/hr	> 85% of cases
	Individual flows within 15% of counts for flows from 700 veh/hr to 2,700 veh/hr	> 85% of cases
	Individual flows within 400 veh/hr of counts for flows more than 2,700 veh/hr	> 85% of cases
2	GEH < 5 for individual flows	> 85% of cases

4 Summary of Data Collection

4.1 Introduction

It is stated in WebTAG Unit M1.1 that *"data collection is necessary in order to inform the parameters that represent the model responses (calibration) and to provide a source of information against which the model can be compared to assure its quality (validation)."*

To develop GLHAM to a robust level which is compliant with WebTAG a variety of data types were required either through existing sources or the commission of new surveys including:

- Counts of vehicles on links or at junctions;
- Journey times on links throughout the detailed area of modelling; and
- Observed person travel demand data.

The TDCR contains a detailed description of the sources of data collected and their verification for use in the model build. This chapter summarises the application within the modelling process for the data sources specified in that report.

4.2 Travel Demand Data

4.2.1 Mobile Phone Origin-Destination Data (MPOD)

Building a transport model necessitates the development of base year travel demand matrices for assignment, as described in Chapter 6. This construction process required an understanding of the trip making behaviour for Lincoln including trip rates, trip length distributions and travel purpose.

The suitability of different demand data sources was considered as part of the model scoping exercise and mobile phone origin-destination (MPOD) data was chosen as the primary travel data source. Citilogik were commissioned to derive MPOD matrices from mobile network data (MND) supplied by Vodafone. The data was collected over a four week period split into two segments, to avoid a school half-term week, from 03/10/2016 to 16/10/2016 and from 14/11/2016 to 20/11/2016. This data has the advantage of being captured for a wide area over a long period to encapsulate trip making variability across a region.

The data was defined for each origin-destination pair in a bespoke zone system through five variables:

- Mode: rail, highway motorised, slow, static;
- Period: am (07:00-10:00), inter-peak (10:00-16:00), pm (16:00-19:00), overnight;
- Day classification: weekday, Saturday, Sunday;
- Purpose: work, other, unknown; and

- Direction: from home, to home, non-home based.

The zone system, herein referred to as request sectors, was provided to Citilogik to allocate the processed MPOD data. There were 524 request sectors which defined by a spatial geography of:

- LSOA (lower super output area) within Lincoln district, plus the towns within the study area;
- MSOA (middle super output area) for the remainder of the study area; and
- District and aggregations thereof outside of the study area based on route choice and proximity to the study area.

The study area was defined by eleven districts:

- The seven districts within Lincolnshire, namely Lincoln, Boston, East Lindsey, North Kesteven, South Holland, South Kesteven and West Lindsey;
- Bassetlaw and Newark and Sherwood in Nottinghamshire; and
- North East Lincolnshire and North Lincolnshire in Humberside. .

The request sectors by district are summarised in Table 4-1 below.

The sample collected only covers the subset of the population who use Vodafone devices. This is estimated at around a 24% share of the UK mobile market[1]. The sample was expanded by Citilogik to the population at the request sector level, in a process which takes into account mobile phone penetration and local market share. A subset of Vodafone devices are not tracked as part of the data collection process, including roamers, minors, data only devices (e.g. tablets) and some public sector devices.

The request sectors are illustrated in Figure 4-1 and Figure 4-2 below.

Data events were only processed within a region referred to by Citilogik as the 'Geofence'; this terminology is replicated here. This area is shown in Figure 4-2. All zones which were intersected or encompassed by the Geofence boundary were classified as Geofence zones. The distinction between Geofence zones outside of the study area and other external zones is made in Chapter 6 with reference to impact on the data processing.

It should be noted that the scope of the dataset collected means that the information can be used for other towns within Lincolnshire, although the spatial detail available would need to be reviewed prior to application.

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[1] https://www.statista.com/statistics/261003/vodafones-market-share-by-country/

Table 4-1 Summary of Request Sectors by District

District	County	Number of Request Sectors
Lincoln	Lincolnshire	56
North Kesteven	Lincolnshire	49
West Lindsey	Lincolnshire	28
East Lindsey	Lincolnshire	37
South Kesteven	Lincolnshire	43
South Holland	Lincolnshire	24
Boston	Lincolnshire	24
Newark and Sherwood	Nottinghamshire	33
Bassetlaw	Nottinghamshire	22
North Lincolnshire	Humberside	58
North East Lincolnshire	Humberside	86
Mobile Phone Data External Areas		64
Total		**524**

Figure 4-1 MPOD Data Request Sectors - Lincoln

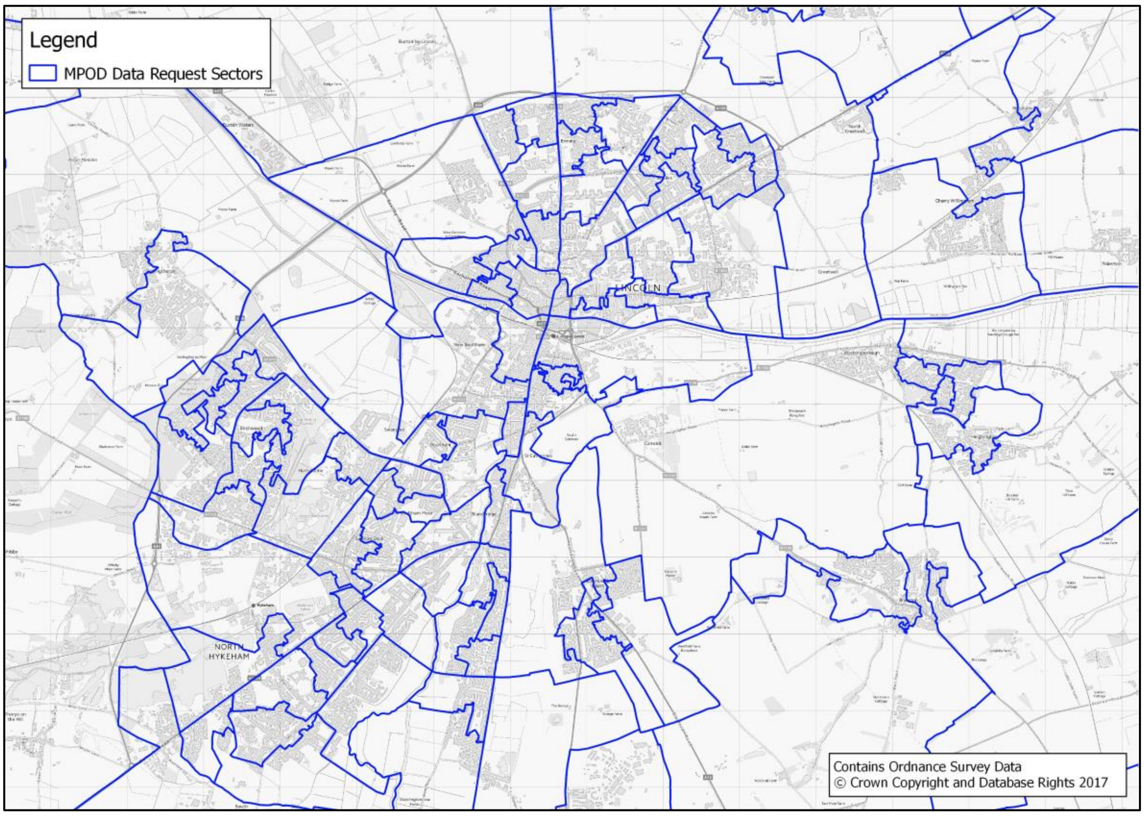
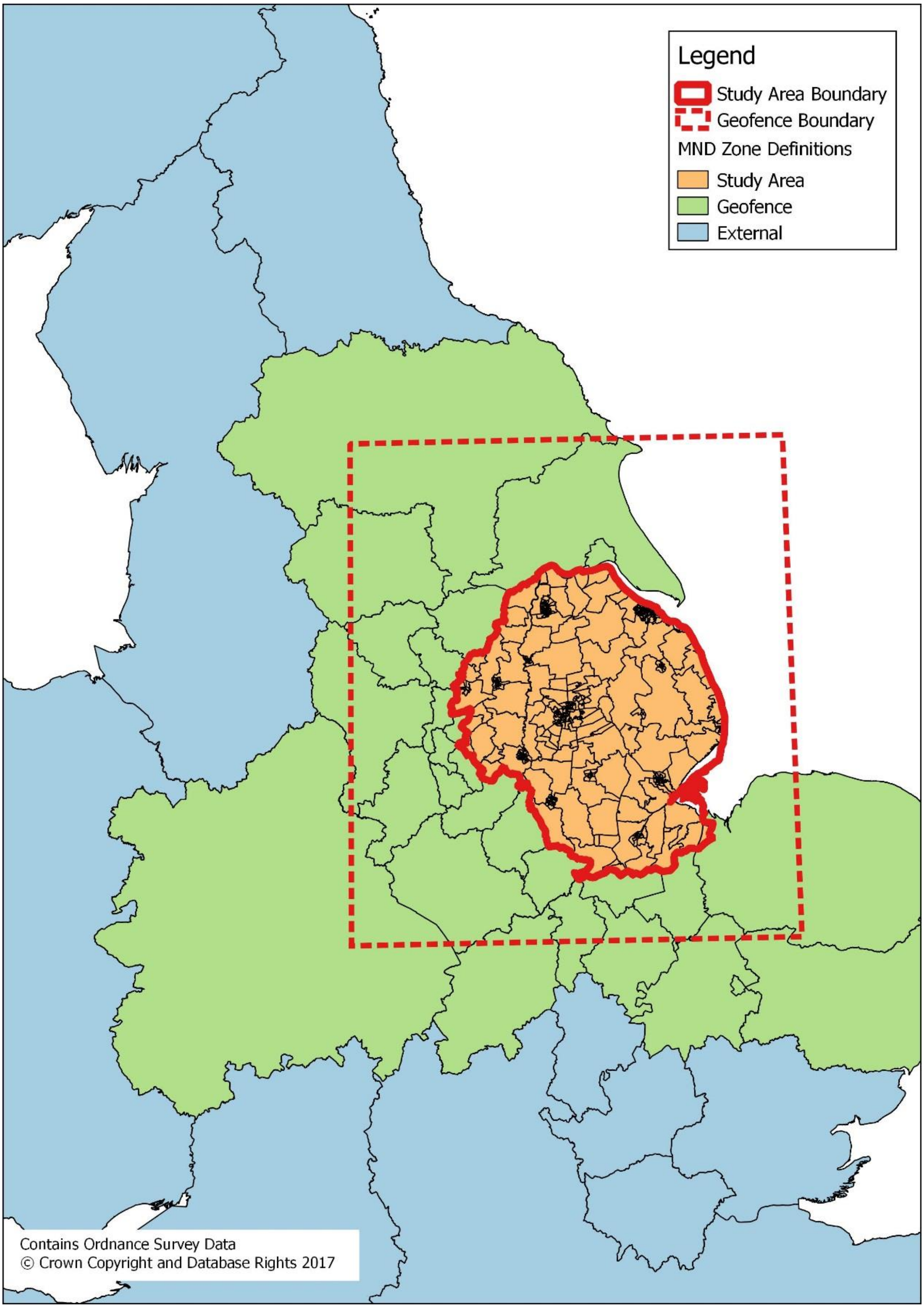


Figure 4-2 MPOD Data Request Sectors - External



4.2.2 TrafficMaster Origin-Destination Data (TMOD)

TrafficMaster origin-destination data (TMOD) provides a same of all trips – classified as cars, LGVs and HGVs – between all LSOA pairs in Great Britain. This is an alternative formulation of the dataset used for journey time data analysis – see Section 4.4 below for a detailed specification.

Whilst the origin-destination data is generally understood to offer a low sample in general, is was available for an observation period of six months and provides a stronger sample for Goods Vehicles due to the nature of vehicles the GPS technology is fitted in. Further, the spatial definition of LSOA is directly compatible with the MPOD request sectors which provided a direct compatibility between the demand datasets.

4.3 Traffic Count Data

The scope of the GLTM study area necessitated a new commission of traffic surveys, undertaken in November 2016. This included:

- Ninety-nine automatic traffic counts (ATCs): permanent or temporary counters to measure daily traffic volumes, subset into intervals of an hour or less, at a particular location observed over a suitable period of time to gather sufficient data to understand travel behaviour and day to day variability at that location; and
- Forty-four manual classified counts (MCCs): single day video surveys undertaken to measure the vehicle split composition at a certain location and, in most cases, undertaken at junctions with data recorded by turning movements added an additional layer of information about traffic patterns and routeing at those locations.

These are mapped in Figure 4-3 below.

In addition to the newly commissioned counts, a number of historic counts available and provided by LCC (e.g. for LEB, WGC and others) were also used to fill the gap that currently not available from the new surveys.

All of the historic count data sites are mapped in Figure 4-4 below.

In total, 48 historic LCC counts were utilised for the purpose of the GLTM model development plus 56 counts from other sources including TRADS, the Midlands Regional Transport Model and the DfT Count Database.

Figure 4-3 New Survey Locations by Count Type

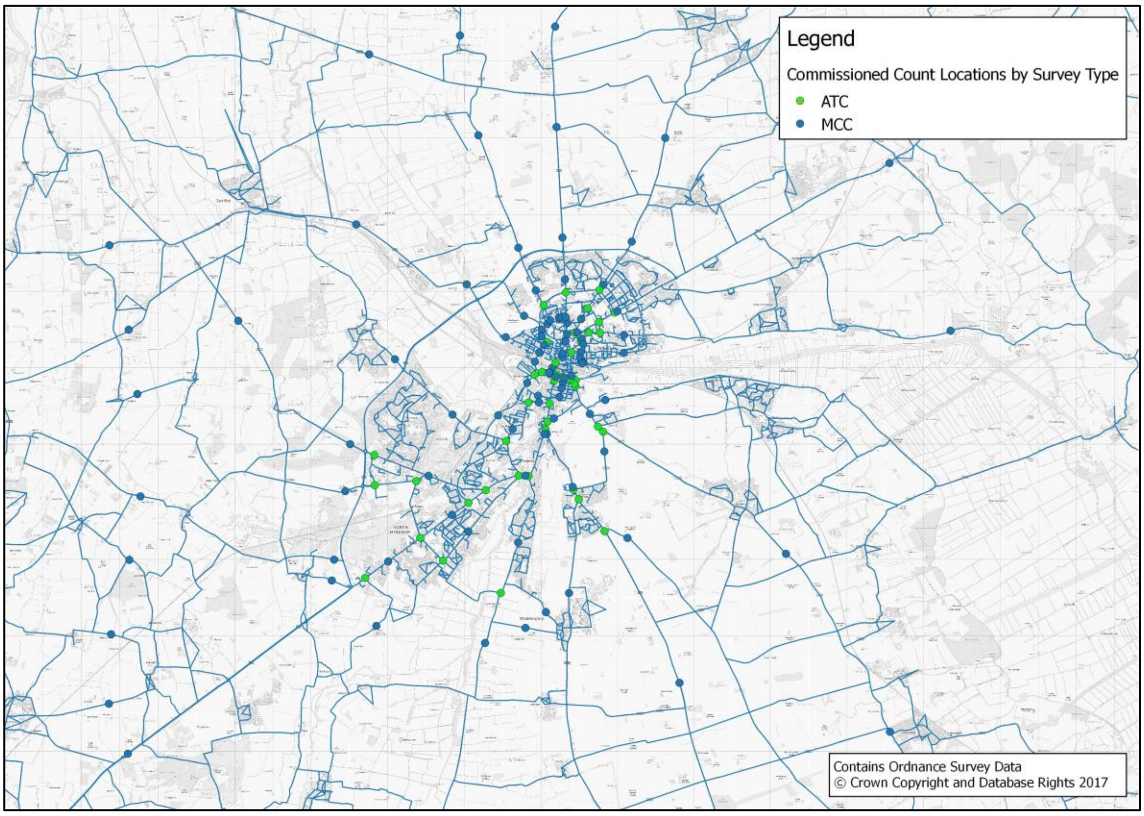
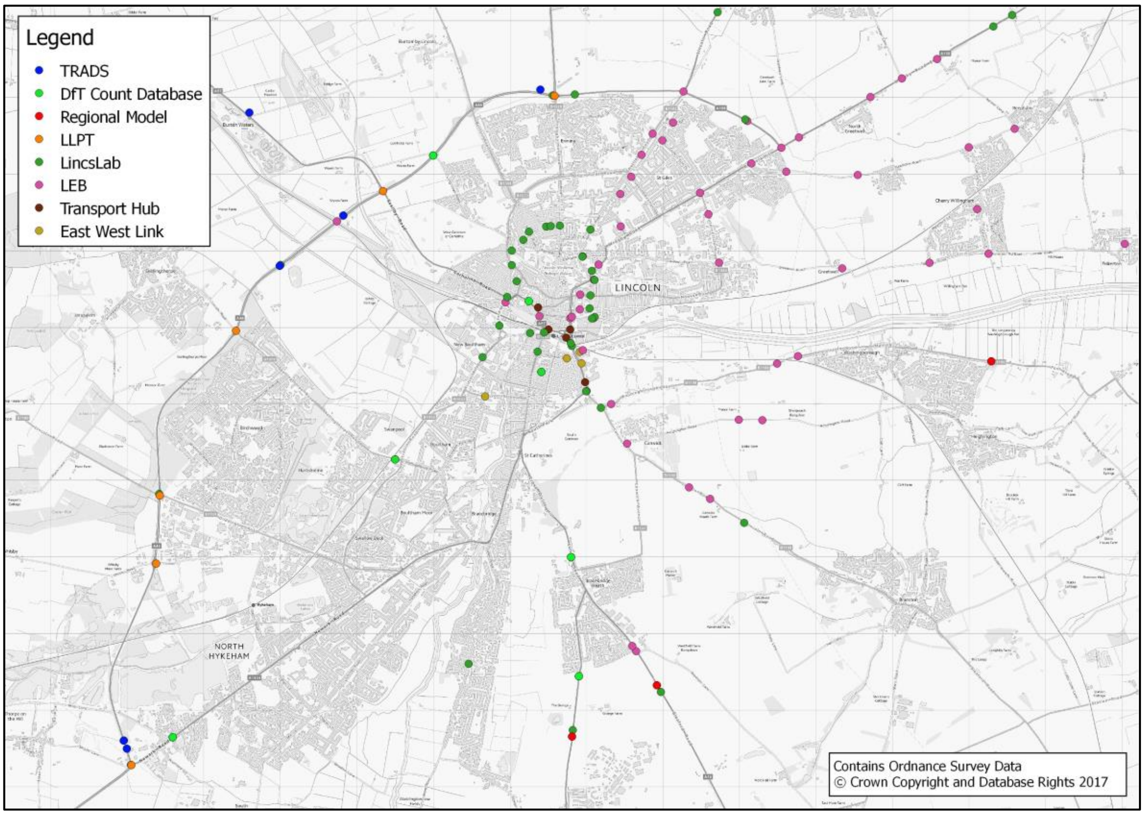


Figure 4-4 Existing Count Locations by Source



The data collection and verification process was described in detail in the TDCR. In summary:

- A review of existing count data was undertaken including a critical analysis of the locations, age and known confidence in this data.
- Sources identified included other LCC projects for which surveys had been recently undertaken, the Regional Models developed for Highways England plus standard sources including TRADS online database and the DfT Count Database.
- The outcome of this analysis was the commission of ninety-nine ATCs and forty-four MCCs for the model build.
- An extensive data verification and cleaning process was undertaken for all of the received data – this included 'site-by-site' checks including removal of outliers and directionality alongside wider checks on consistency across the dataset.
- Due to utilising data from many sources, there were locations of data overlap which had to be reconciled. This included the use of monthly and annual normalisation factors derived from the permanent counts.

Section 3.4.6 of the TDCR referenced that the model calibration and validation may require further consideration of traffic counts in proximity to the Transport Hub and East-West Link Road, where network conditions have changed – see Section 2.5 – and would have led to natural inconsistencies. However, a review of this data found that the monthly variation factors were sufficient with no action relating to changed road openings and/or closures required.

The count locations are mapped in Figure 4-7 and Figure 4-8 by data source and by survey type respectively. The following graphs in Figure 4-5 and Figure 4-6 summarise the provenance and age of the data collected.

(Note that three counts from 2006 were sourced from the LEB study post the data collection process. Whilst the age of this data falls outside of the recommend range, they are located on rural roads in the buffer fixed speed area and were added for additional detail in those locations only.)

Figure 4-5 Final Count Dataset Summary - Month and Year of Survey

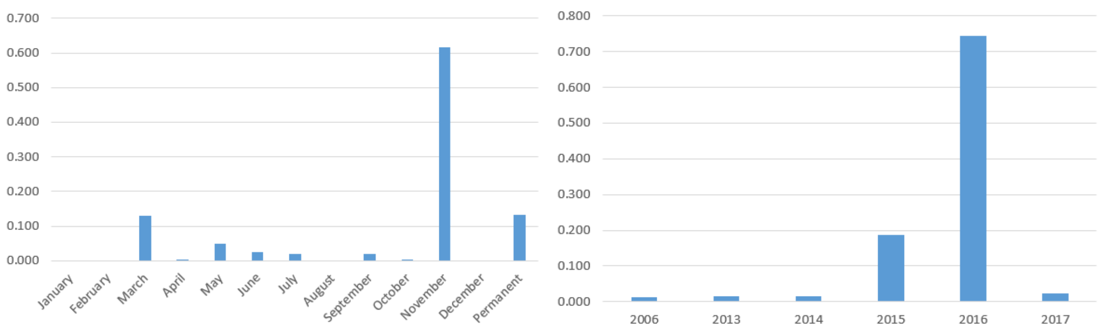


Figure 4-6 Final Count Dataset Summary - Source of Survey

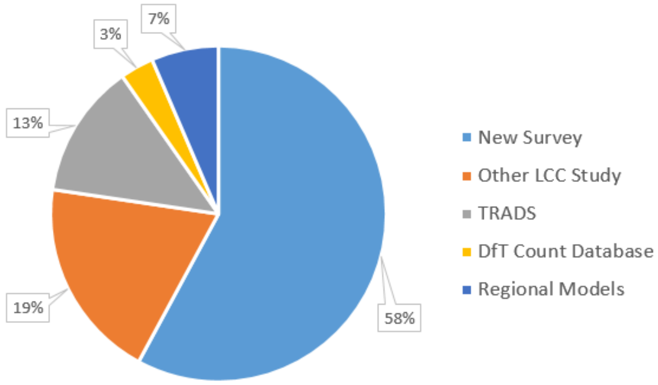


Figure 4-7 Final Count Dataset Locations by Data Source – Study Area

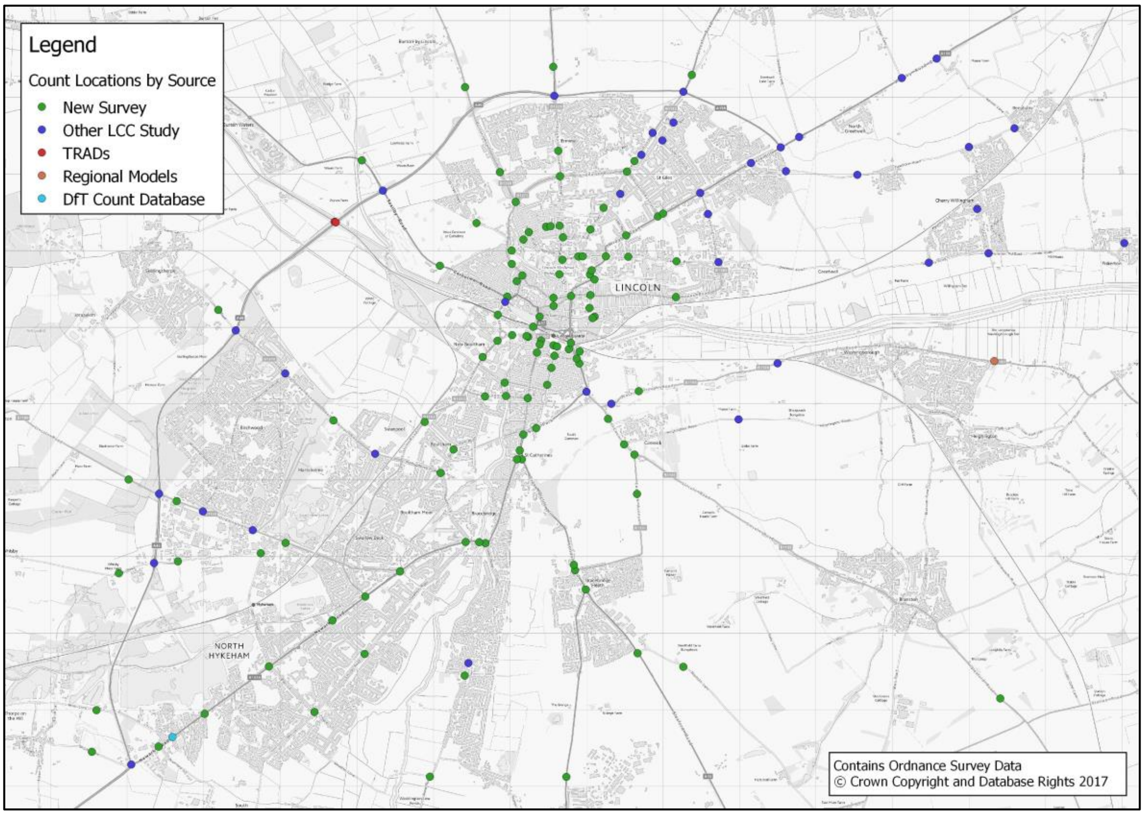
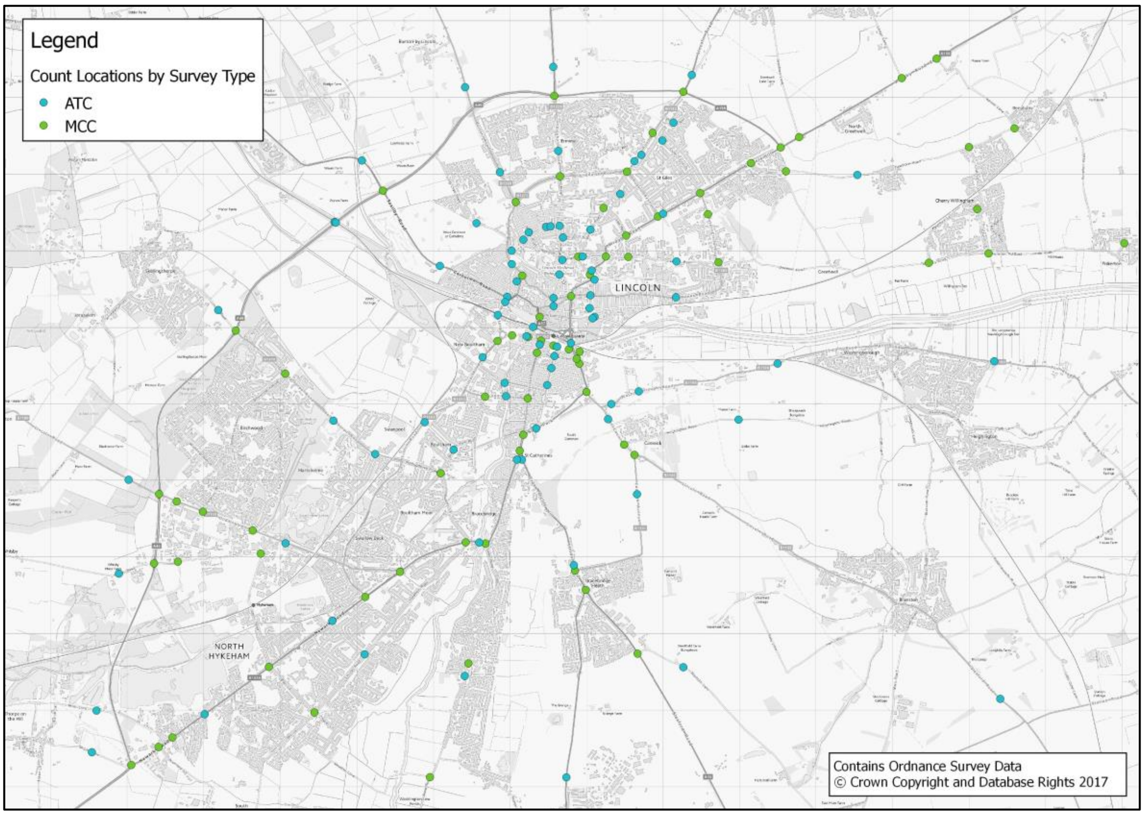


Figure 4-8 Count Locations by Survey Type – Study Area



4.4 Journey Time Data

TrafficMaster Journey Time (TMJT) is a dataset owned by the Department for Transport (DfT) which is sourced via Global Positioning System (GPS) data gathered from devices and trackers fitted to a variety of fleet vehicles (Cars, LGVs and HGVs) and buses. The data is collected by the devices through identifying the location of each devices every 1 to 10 seconds giving an extensive dataset of journey times on ITN links.

It is acknowledged that the car sample population for TMJT can be skewed towards high end vehicles which may lead to some bias in the data however it can be considered as the most comprehensive dataset readily available for journey times.

TMJT data for six neutral months in 2016 (April, May, June, September, October and November) was provided by LCC in order to give a complete record of journey times and speeds along all of the Integrated Transport Network (ITN) links within the modelled area for that period. This data has been processed for all ITN links that correspond to a defined model journey time link and combined to form thirty-six bi-directional routes which are mapped in Figure 4-9 and Figure 4-10 below. Note that the route numbers in the images correspond to those used for reporting in Appendix H.

Extreme values or anomalies which occur due to limitations of the data recording were analysed and excluded from the database were relevant. The processed observed journey times by route are summarised in Table 4-2.

Figure 4-9 Journey Time Routes - Study Area

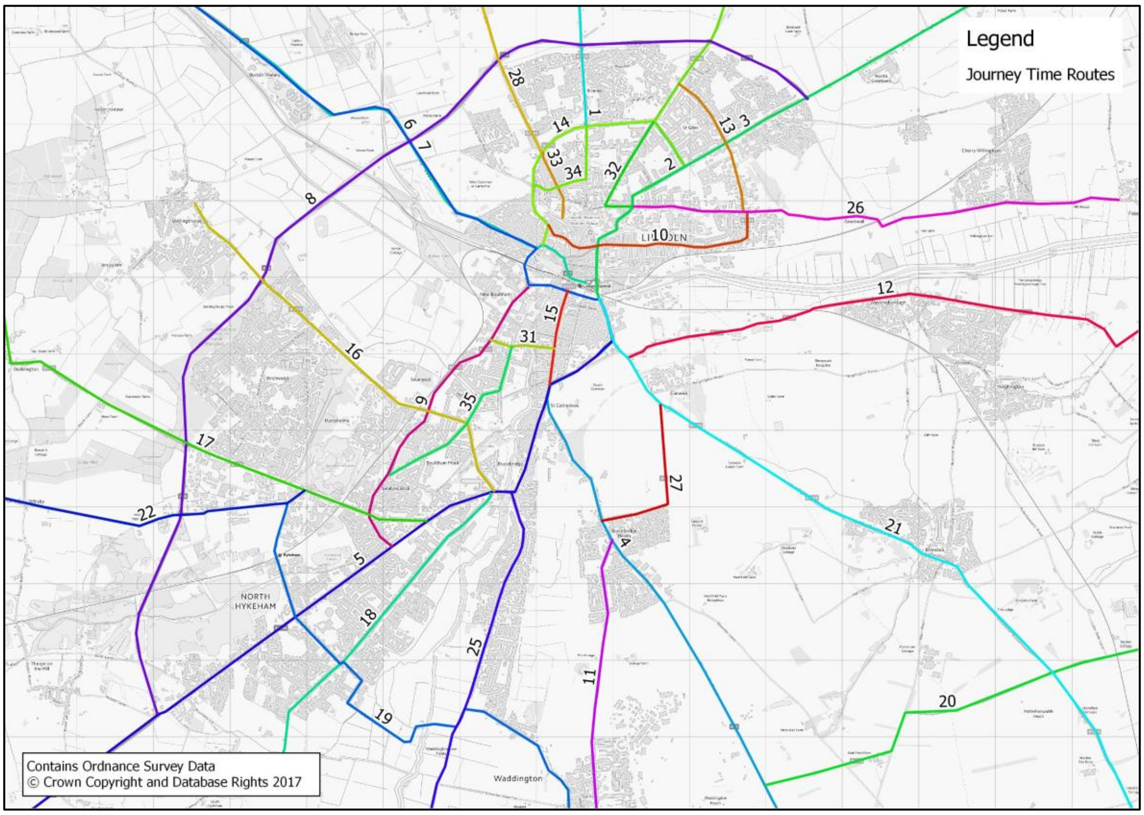


Figure 4-10 Journey Time Routes - Wider Area

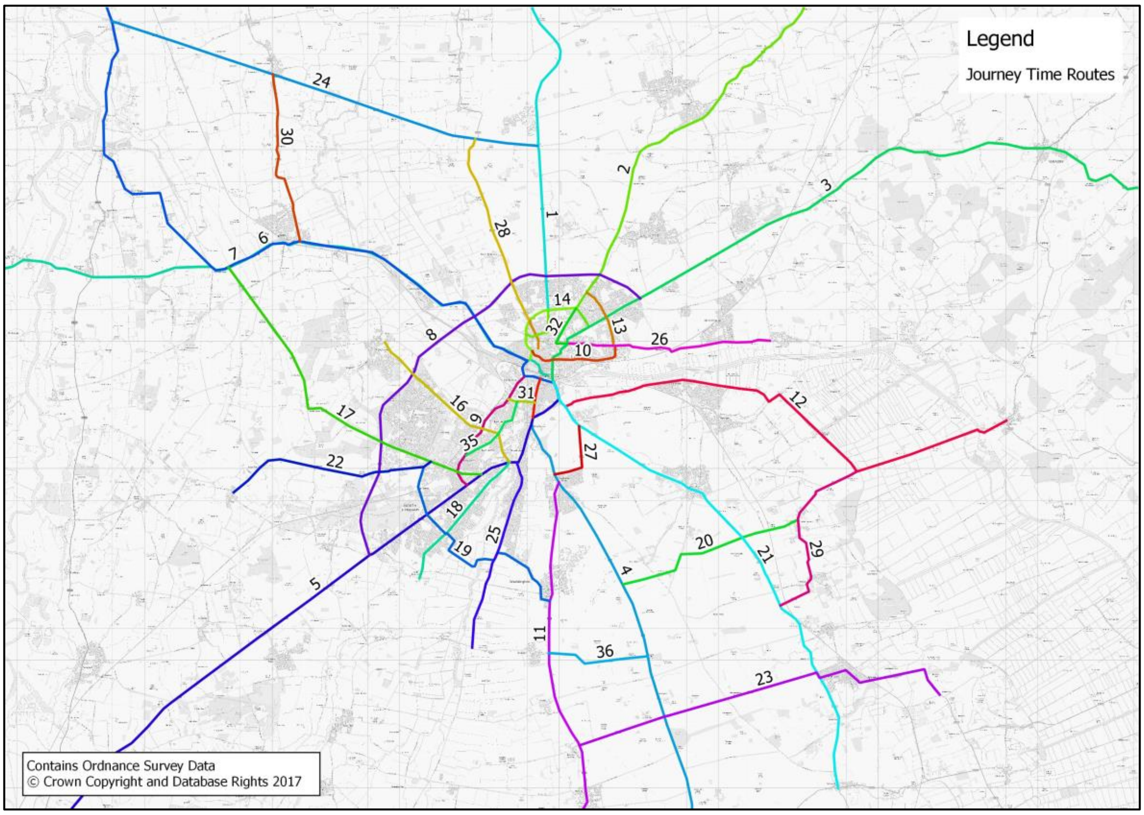


Table 4-2 Summary of Observed Journey Times

Route (direction)	Distance (km)	Obs. Journey Time (mm:ss)		
		AM	IP	PM
Route 1: A15_Caenby NB	20.9	22:51	22:43	24:29
Route 1: A15_Caenby SB	20.8	24:24	22:38	24:36
Route 2: A46_Middle_Rasen NB	23.5	24:46	24:58	26:48
Route 2: A46_Middle_Rasen SB	23.5	25:21	24:24	24:47
Route 3: A158_Horncastle EB	33.6	34:01	34:36	34:59
Route 3: A158_Horncastle WB	33.6	34:45	34:29	34:37
Route 4: A15_Sleaford NB	26.1	27:33	24:28	26:18
Route 4: A15_Sleaford SB	26.1	24:59	24:10	26:40
Route 5: A46_Newark NB	23.2	29:07	24:49	27:28
Route 5: A46_Newark SB	23.2	26:05	26:07	29:39
Route 6: A57_East_Markham EB	23.1	27:06	24:53	25:15
Route 6: A57_East_Markham WB	23.1	23:08	24:21	26:31
Route 7: A57_A156_Gainsborough NB	30.2	30:32	31:08	33:24
Route 7: A57_A156_Gainsborough SB	30.1	33:27	32:16	31:37
Route 8: A46_Orbital_NW NB	14.9	14:29	13:12	15:35
Route 8: A46_Orbital_NW SB	14.9	15:41	14:13	17:07
Route 9: B1003_Boultham NB	4.3	09:55	09:47	09:04
Route 9: B1003_Boultham SB	4.2	07:53	08:55	09:51
Route 10: W_Parade_Monks_Road EB	3.4	08:26	08:16	08:21
Route 10: W_Parade_Monks_Road WB	3.1	07:56	07:59	08:55
Route 11: A607_Leadenham NB	17.2	18:07	17:23	17:33
Route 11: A607_Leadenham SB	17.2	17:20	17:17	17:34
Route 12: B1190_Bardney EB	15.6	15:22	15:33	15:00
Route 12: B1190_Bardney WB	15.6	16:56	16:10	15:59
Route 13: Outer_Circle_Drive NB	1.9	03:59	04:28	05:06
Route 13: Outer_Circle_Drive SB	1.9	04:51	04:50	04:27
Route 14: B1273_Langdales_Road NB	2.9	04:47	05:04	07:16
Route 14: B1273_Langdales_Road SB	2.9	07:08	06:59	07:08
Route 15: B1262_High_Street NB	1.3	04:15	04:38	04:13
Route 15: B1262_High_Street SB	1.3	02:39	02:55	03:28
Route 16: Skellingthorpe_Road EB	5.7	14:09	12:00	15:08
Route 16: Skellingthorpe_Road WB	5.7	10:58	10:03	11:37
Route 17: B1190_Doddington_Road EB	11.2	14:22	14:24	15:18
Route 17: B1190_Doddington_Road WB	11.1	12:47	12:15	12:53
Route 18: Hykeham_Road_Mill_Lane NB	4.7	09:29	08:02	08:48
Route 18: Hykeham_Road_Mill_Lane SB	4.7	07:08	07:00	07:43
Route 19: HykehamStation_Waddington EB	7.6	13:18	12:40	15:43
Route 19: HykehamStation_Waddington WB	7.6	11:58	11:06	12:02
Route 20: B1178_Potterhanworth EB	6.1	05:25	05:18	05:12
Route 20: B1178_Potterhanworth WB	6.1	05:21	05:23	05:23
Route 21: B1188_Scopwick NB	16.9	18:21	16:44	18:07
Route 21: B1188_Scopwick SB	17.0	16:34	16:21	17:06
Route 22: Whisby_Road_Eagle_Moor EB	6.7	07:31	07:25	07:30
Route 22: Whisby_Road_Eagle_Moor WB	6.7	06:47	06:47	06:55
Route 23: B1202_Metheringham EB	13.9	12:25	12:16	12:47
Route 23: B1202_Metheringham WB	13.9	13:02	12:31	13:10

Route (direction)	Distance (km)	Obs. Journey Time (mm:ss)		
		AM	IP	PM
Route 24: Till_Bridge_Lane EB	14.0	10:55	11:02	10:53
Route 24: Till_Bridge_Lane WB	14.0	11:13	11:13	11:27
Route 25: Brant_Road NB	6.1	07:51	06:49	06:51
Route 25: Brant_Road SB	6.1	06:41	06:42	06:49
Route 26: Greetwell_Road_Fiskerton_Road EB	6.7	07:38	07:08	07:33
Route 26: Greetwell_Road_Fiskerton_Road WB	6.7	09:04	08:10	08:33
Route 27: B1131 NB	2.2	03:09	02:21	02:40
Route 27: B1131 SB	2.2	02:35	02:28	02:34
Route 28: B1398_North_Carlton SB	6.1	05:41	05:36	05:55
Route 28: B1398_North_Carlton NB	6.1	06:31	05:44	05:45
Route 29: B1202_Potterhanworth NB	6.0	06:48	07:06	06:36
Route 29: B1202_Potterhanworth SB	6.0	06:42	07:06	06:58
Route 30: Sutton_Road_Saxilby_Road NB	5.5	05:32	05:29	05:34
Route 30: Sutton_Road_Saxilby_Road SB	5.5	05:40	05:34	05:34
Route 31: B1360_New_Boultham EB	0.8	02:52	03:58	04:57
Route 31: B1360_New_Boultham WB	0.8	02:57	03:19	02:45
Route 32: Nettleham_Road_Eastgate NB	1.6	02:51	03:13	03:49
Route 32: Nettleham_Road_Eastgate SB	1.7	03:14	03:12	03:19
Route 33: Burton_Road_Union_Road NB	0.9	02:22	02:30	02:46
Route 33: Burton_Road_Union_Road SB	0.9	02:21	02:24	02:22
Route 34: Rasen_Lane_Newport NB	1.4	03:29	03:08	03:06
Route 34: Rasen_Lane_Newport SB	1.4	03:01	03:00	03:09
Route 35: Boultham_Park_Road_Moorland_Avenue NB	2.4	04:37	04:41	04:34
Route 35: Boultham_Park_Road_Moorland_Avenue SB	2.4	03:37	03:45	03:45
Route 36: B1178_Tower_Lane EB	3.2	03:36	02:45	03:38
Route 36: B1178_Tower_Lane WB	3.2	03:03	02:53	03:10

4.5 Traffic Signal and Level Crossing Data

Traffic signal data was required for all signalised junctions within the simulation area. The signal specifications were obtained from LCC for the identified junctions which included data such as:

- Phase and stage diagrams;
- Phase minimum/maximum sets;
- Timetables defining minimum and maximum sets to apply by time period; and
- Phase intergreen times.

In total, data was received for forty-eight sites in Lincoln and fifteen sites in North Kesteven. The locations were mapped prior to the network build as shown in Figure 4-11.

Additionally, observed barrier downtime data was obtained from LCC for four of the six main level crossings within the simulation area including High Street – see Section 5.8.

However, as noted in Section 2.5, the High Street level crossing is not in the base network since construction work to pedestrianise this area was underway by August 2016. These locations (excluding High Street) are mapped in Figure 4-12.

Figure 4-11 Locations of Traffic Signals and Pedestrian Crossings

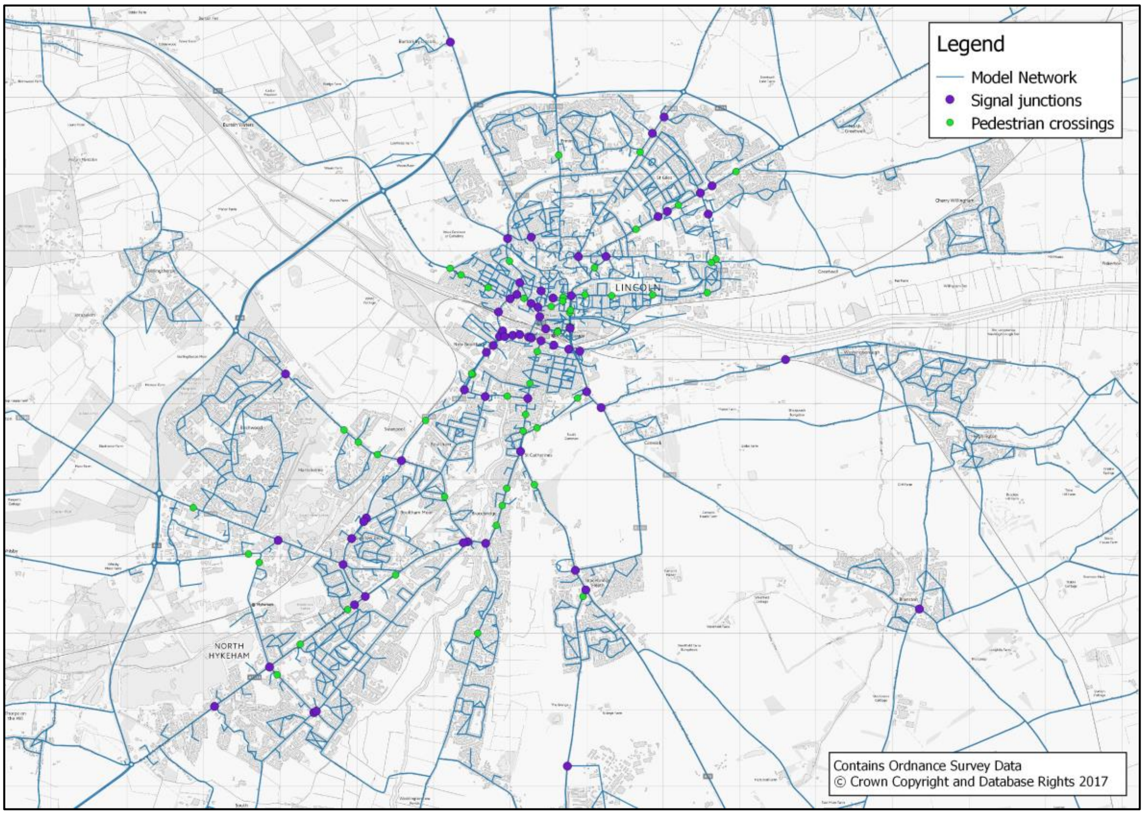
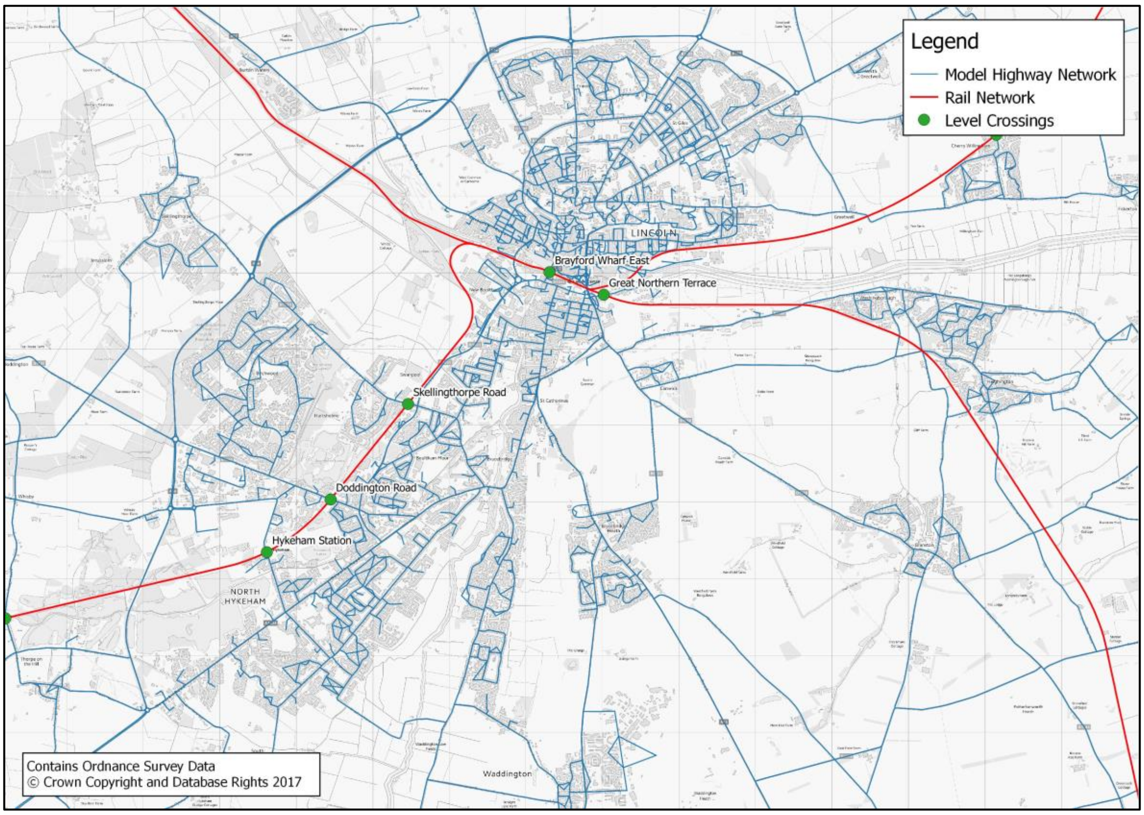


Figure 4-12 Locations of Level Crossings



4.6 Additional Data Sources

Further data sources were required to support the base matrix build; in particular the National Travel Survey (NTS) and the National Trip End Model (NTEM) including:

- Trip ends;
- Trip purposes;
- Mode share;
- Time of outward and return journeys;
- Trip time and trip length profiles; and
- Vehicle occupancies.

Further details of their application within the matrix build process are given throughout Chapter 6.

A large amount of GIS data is available through Ordnance Survey's (OS) OpenData program which can be used freely provided that copyright acknowledgement is included. The data obtained from OpenData included:

- Base mapping at various scales for reporting and presentation; and
- Shapefiles for various geographical boundary definitions to define the zone system and other sector and/or reporting areas.

4.7 Screenline Definitions

A set of 18 bi-directional screenlines have defined providing a wide coverage for the modelled area. These are illustrated in Figure 4-13 and Figure 4-14 below and can be grouped into X subgroups:

- Outer cordon – four screenlines to capture the demand on the periphery of the simulation area and speed-flow curve buffer area on approach to the area of detailed modelling;
- Bypass cordon – four screenlines drawn adjacent to the existing north and western bypass, the future eastern bypass and proposed southern bypass through North Hykeham to capture the demand and routeing into the main area of modelling;
- City centre cordon – four screenlines capturing the demand to and from Lincoln city centre area;
- City centre inner cordon – a cordon contained within the previous one to capture at an even more detailed level in that area which contains the Transport Hub construction area and East-West Link Road; and
- Five strategic screenlines including the railway line, three capturing east-west movements in the city centre and the boundary of the Lincoln/North Hykeham urban areas.

Figure 4-13 Model Screenlines - Study Area

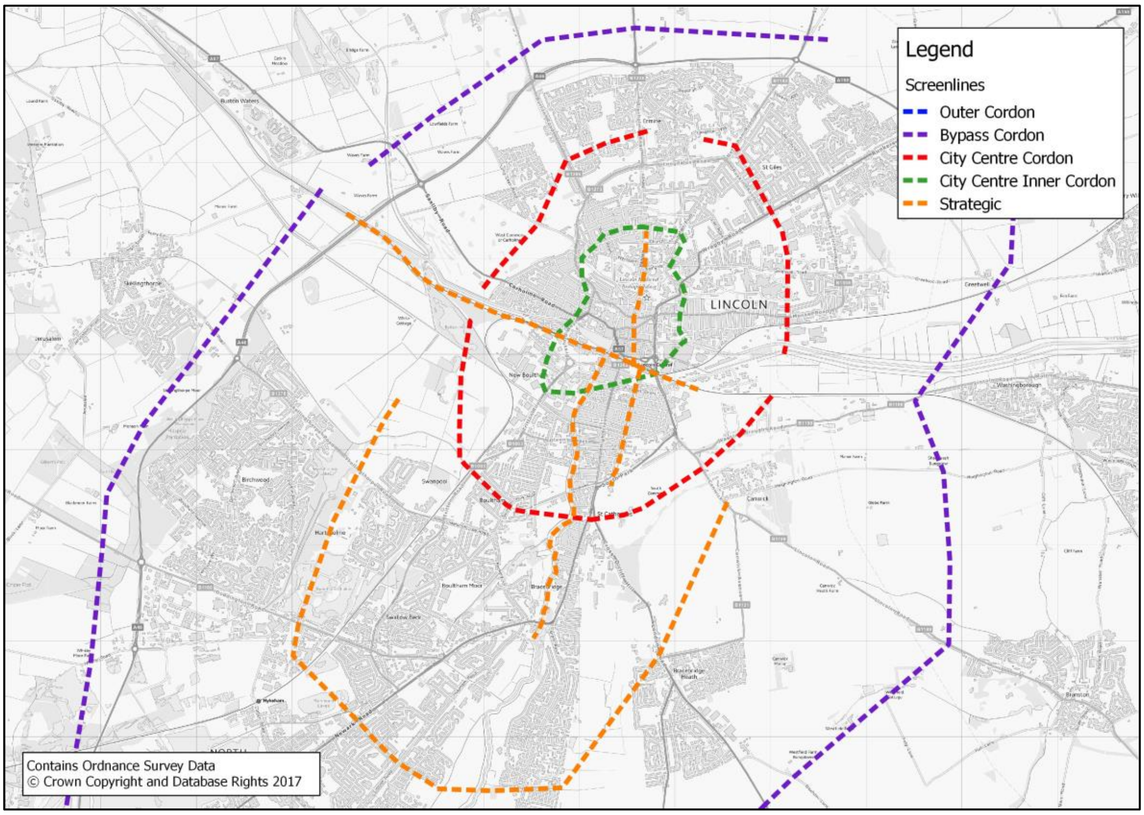
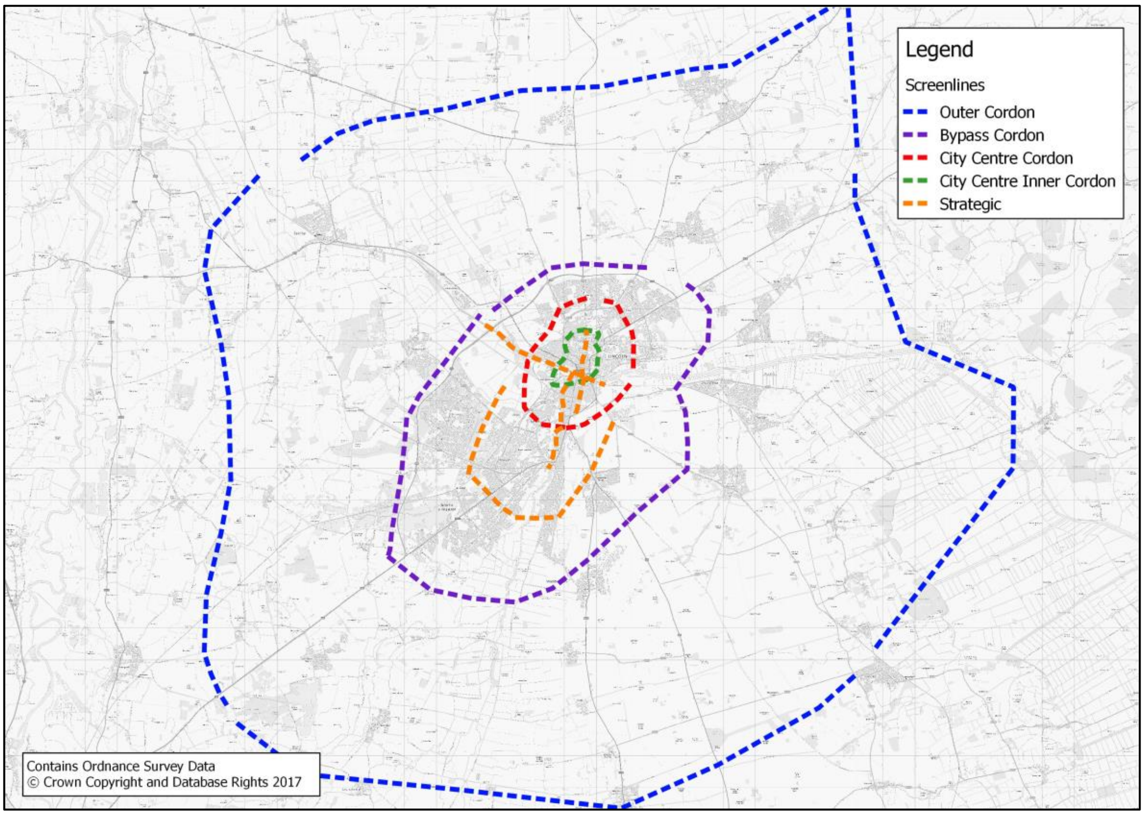


Figure 4-14 Model Screenlines – Wider Area



4.8 Description of Calibration and Validation Data

The count data collected, as described in Section 4.3, was categorised into two independent subsets:

- Calibration counts: to be used in the matrix estimation process to refine the prior matrices to better fit the observed traffic flows; and
- Validation counts: independent of those used in the matrix estimation to be used to test the model performance where it had not been refined through the calibration process.

The locations of all counts, colour coded as calibration or validation, are mapped in Figure 4-15 and Figure 4-16 below. Detailed summary of all the counts with observed volume that were used for the model development is provided in Appendix A.

Figure 4-15 Count Locations by Cal/Val – Study Area

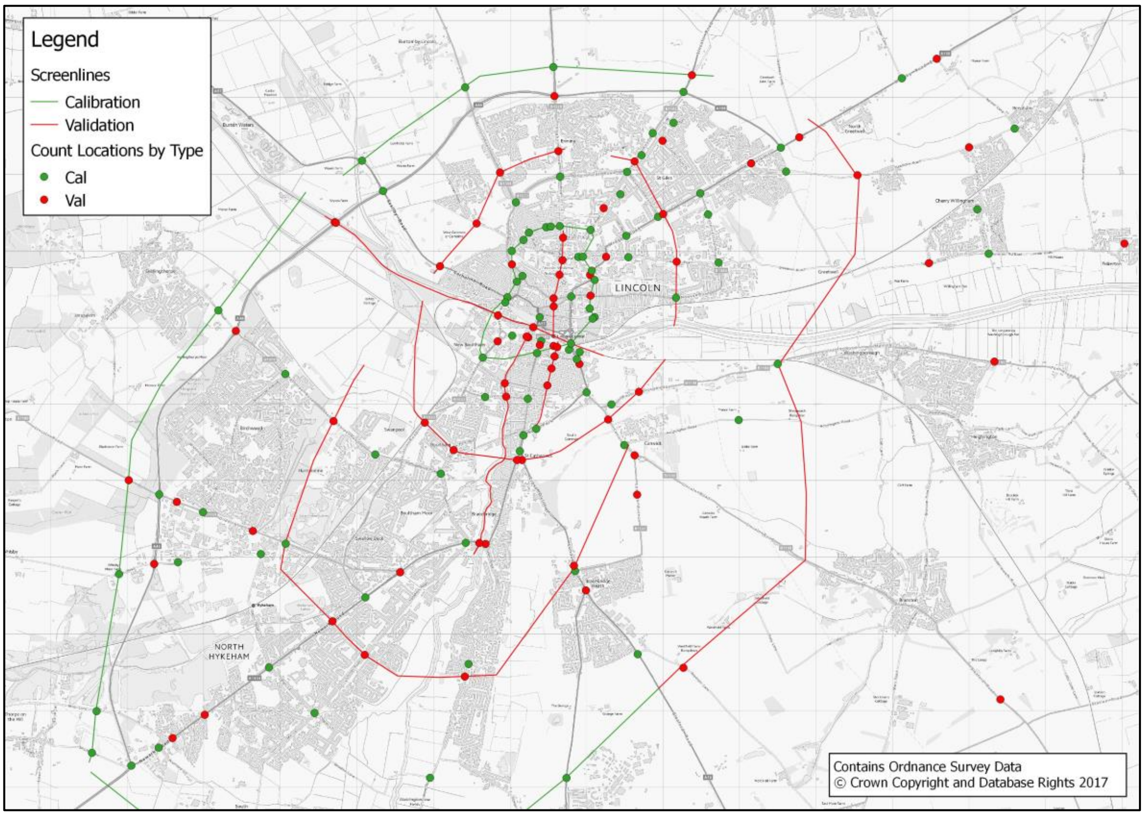
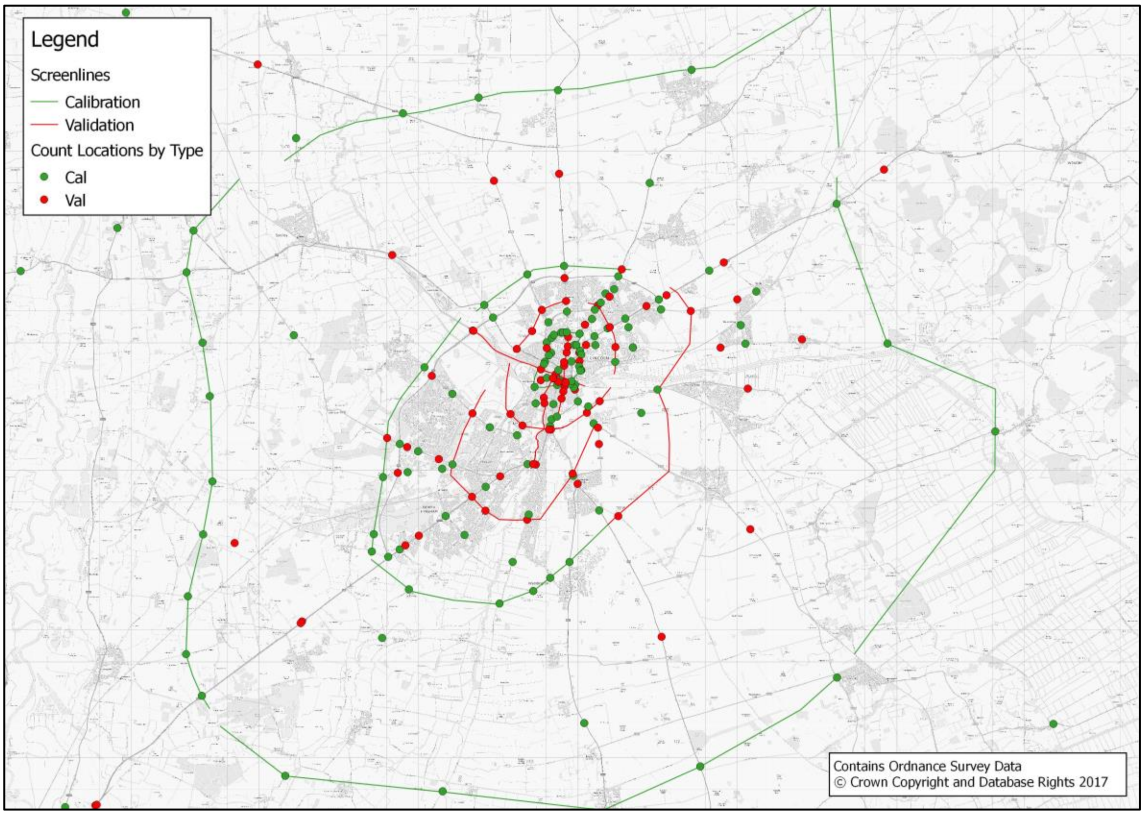


Figure 4-16 Count Locations by Cal/Val – Wider Area



5 Model Development – Highway Network

5.1 Introduction

Highway assignment models require a simplified representation of the highway network using a series of nodes and links where links represent particular sections of the roads and nodes represent junctions within the networks.

As agreed within the scope, the highway models should sufficiently cover the area of interest in order to not only present accurately traffic conditions, but also able to represent traffic from surrounding areas that travel to/from the study area or pass through the study area.

Within the study area, the highway networks are modelled in detail, including all the roads that have major impacts on traffic operations. Outside the study area, a skeletal network was developed, with the key routes that carry traffic from/to or pass through the study area included. The extent of the network coverage is shown in Figure 5-1 and Figure 5-2 below.

Figure 5-1 Model Coverage - Study Area

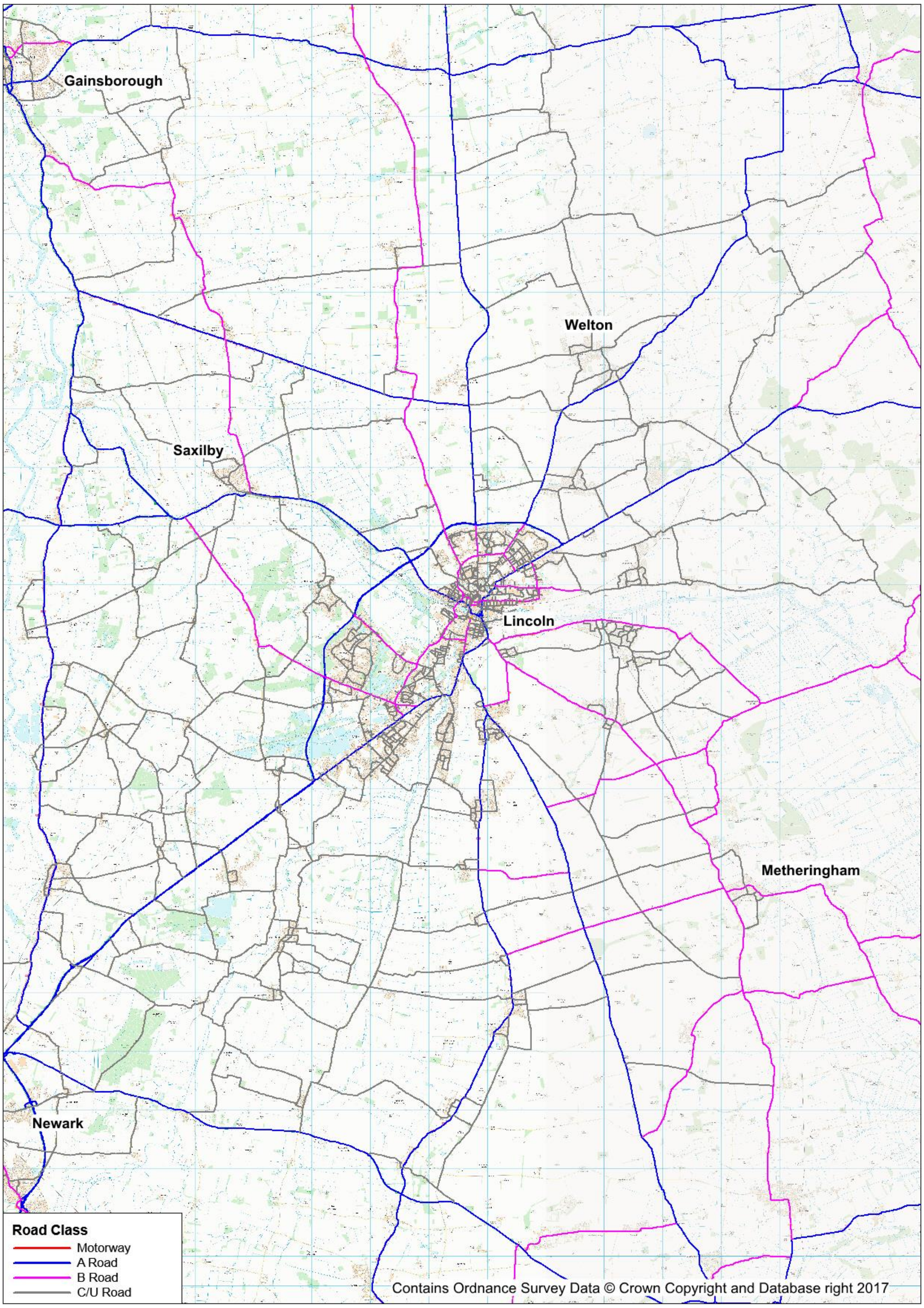
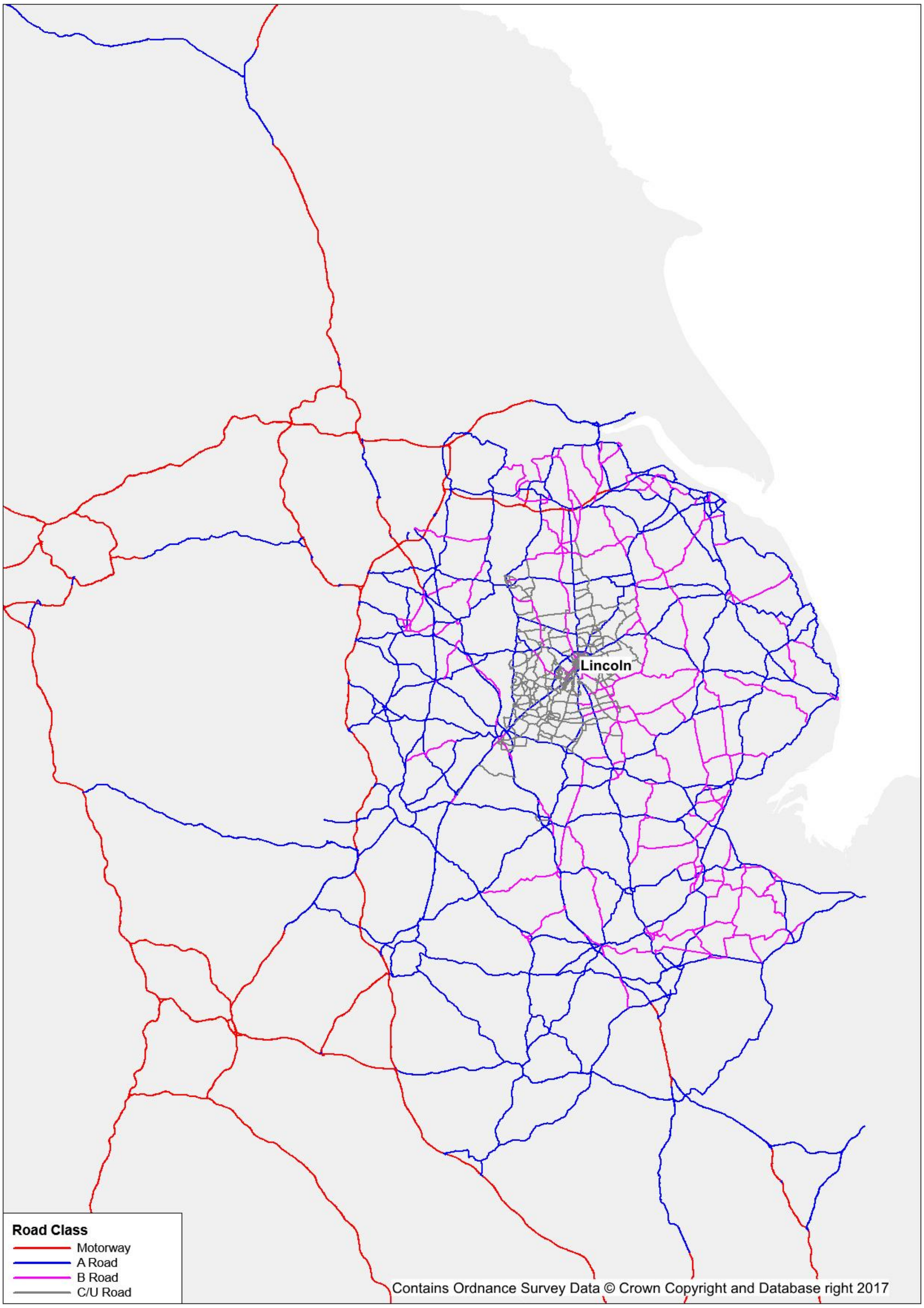


Figure 5-2 Model Coverage - External



5.2 Network Structure

For the GLTM highway network, a three tier hierarchical structure was developed for network coding and detail which was presented in Figure 2-2.

- Area 1: the model study area defined by a cordon around the existing A46 bypass and the under construction Eastern Bypass consisting of Lincoln and North Hykeham. Within this area a full simulation with accurate junction coding and link speed flow curves has been applied to accurately represent travel costs. This area is highlighted in light green in Figure 2-2.
- Area 2: external area adjacent to the study area defined by a cordon roughly bounded by Newark, Gainsborough, Market Rasen and Sleaford. Within this area, a less detailed coding has been adopted where travel costs have been represented through speed flow curves. This area is highlighted in dark grey in Figure 2-2.
- Area 3: remainder of external area including more detailed level of network coverage in rest of Lincolnshire plus Humberside and Nottinghamshire. This area was included to serve as a mean of connectivity for traffic from external regions to the study area. Fixed speed coding has been therefore adopted. This area is highlighted in light grey in Figure 2-2.

5.3 Representation of Ongoing Roadworks

As described in Section 2.5, various phases of roadworks were ongoing throughout the model build process.

To assure consistency with the primary data collection period for the demand data and commissioned counts, the GLTM network is representative of the conditions in November 2016:

- The East-West Link Road has been included;
- The recently pedestrianised area on High Street between Tentercroft Street and St Mary's Street is excluded from the highway network;
- The northbound carriageway on High Street, south of Tentercroft Street, has only one lane operational;
- The road closures associated with construction of the Transport Hub have been included, including the closure of the roundabout near the old bus station; and
- Closure of southbound traffic on Brayford Wharf E (i.e. open for northbound traffic only).

5.4 Link Coding

The starting point for development of the network in SATURN was the TrafficMaster ITN layer. Geographical features are represented in this dataset as either as points or lines. Points are fixed spatially by one coordinate pair, for example junctions, whereas lines are fixed by a series of connected coordinate points to represent linear map features such as roads and railways. Every road link and junction within the ITN has a unique reference number and reference tables connect nodes and links together in a similar way to that in a traffic model.

Ariel images have provided a valuable source of information on the network to be modelled. Detail such as the number of lanes, lane markings and flare lengths have been ascertained based on this data source. Where no existing layers or aerial photography were available, detailed site visits were undertaken.

Links in SATURN have been coded by direction, based on the following information:

- Road class (Motorways, Trunk roads, A road, B road and C/unclassified roads);
- Road type (single or dual carriageway);
- Speed limit;
- Number of lanes; and
- Any other restriction on the roads (e.g. height, weight restriction, etc.)

The model network extent for Lincoln city centre is mapped in Figure 5-3 below. A summary by road type is reported in Table 5-1 below.

Figure 5-3 Model Network - Lincoln centre

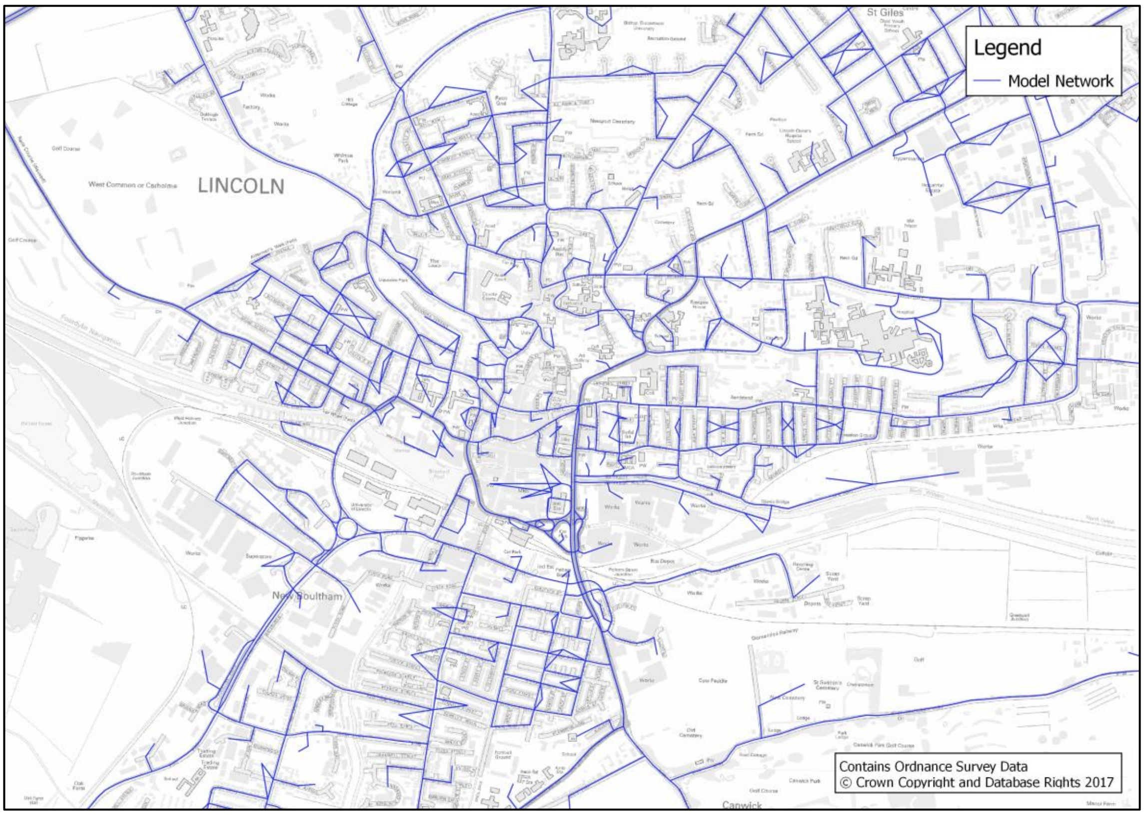
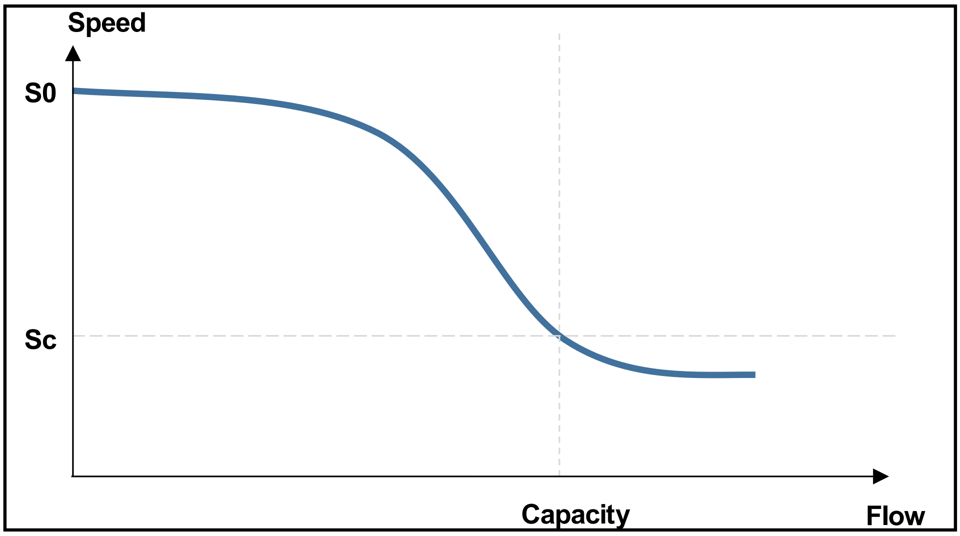


Table 5-1 Summary of Link Coding by Road Type

Road Type	Number of Modelled Links	Total Modelled Length (km)
Motorway	1,494	4,290
A Road	3,961	6,752
B Road	1,405	2,430
Local Road	3,659	1,593
Total	**10,519**	**15,064**

Based on the information above, a set of appropriate speed-flow curves was then adopted to reflect a relationship between traffic volume and travel speed on a link. A generic form of a speed-flow curve is illustrated in Figure 5-4 below.

Figure 5-4 Example of Speed-Flow Curve



For each speed-flow curve, capacity, free-flow speed (S_0), speed at capacity (S_c) and the rate of speed decline relative to flow increase was determined by various factors including the road class, road type, number of lanes and consideration of street characteristics including on street parking or traffic management which may prohibit the free flow of traffic.

Speed flow curves for the GLHAM are derived from COBA 11 Part 5 and used for links within the buffer area and on longer links within the simulation area where volume delay is likely to be of importance to the traffic routeing. The list of all the speed-flow curves adopted for the GLHAM models is provided in Appendix B.

5.5 Fixed Speed Network

For zones external to the study area, associated network is mainly used to create connectivity from those external zones to the study area. At this level, route choices are limited and therefore a much simpler approach was adopted, i.e. fixed speed network.

Fixed speeds have been derived from TrafficMaster journey time data using the same time period as the data used to obtain journey time information.

5.6 Junction Coding

Junctions play a key role within the simulation area. They affect route choice particularly with respect to turning delay and hence were coded with as close a level of detail as possible to accurately reflect these delays.

Characteristics represented include:

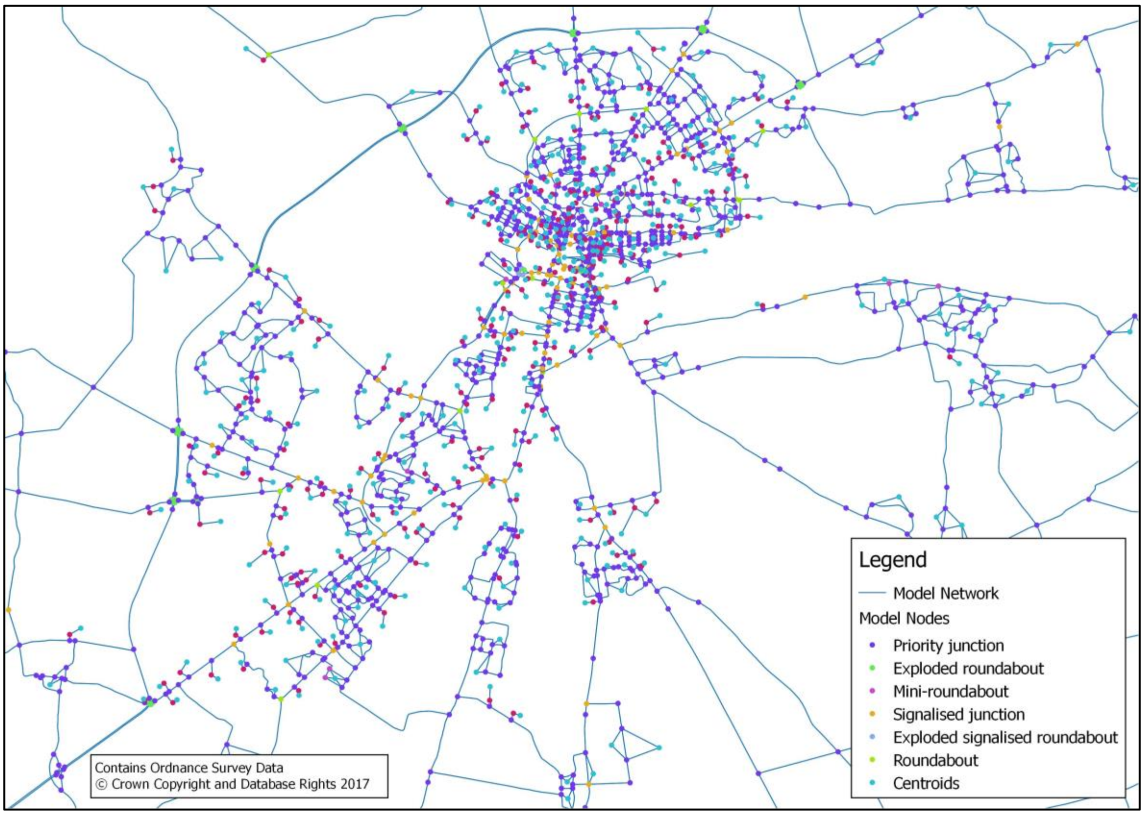
- Junction type (priority, roundabout, signalised);
- Saturation flows for all movements;
- Configuration and geometry including number of approach arms, width of approach arms plus flare lengths and lane discipline including permitted and banned turns; and
- Additional parameters relevant to specific junction types such as gap acceptance values and signal data.

A total of 2,557 junctions were coded within the model as summarised in Table 5-2 and mapped in Figure 5-5.

Table 5-2 Summary of Junction Coding by Type

SATURN Type	Description	Number of Nodes
0	External node	300
1	Priority junction	1341
	Exploded roundabout	48
2	Mini-roundabout	10
3	Signalised junction	104
	Exploded signalised roundabout	3
4	Dummy	0
5	Roundabout (with U-turns)	18
n/a	Zone centroids	733

Figure 5-5 Model Nodes by Junction Type

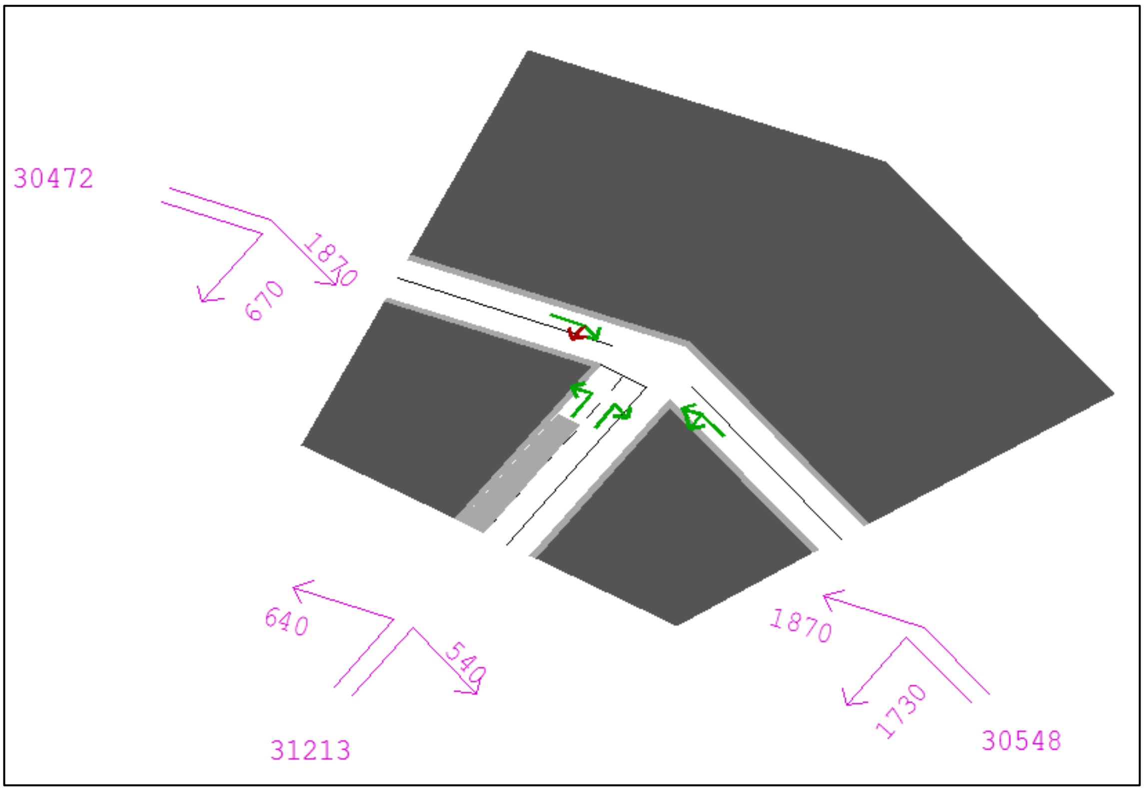


5.6.1 *Priority Junctions*

Default saturation flows for major and minor arms were based on the calculations provided in DMRB Volume 6 Section 2 Part 6 TD42/95. These were reviewed and adjusted during the calibration and validation process alongside other junction parameters in order to more accurately represent delays and to reflect local site variation.

Figure 5-6 shows an example of a priority junction node coded in SATURN. The turn data displayed are saturation flows in pcus per hour.

Figure 5-6 Coding Example - Priority Junction



5.6.2 Signalised Junctions

Signalised junctions within the simulation area required additional characteristics to be coded including:

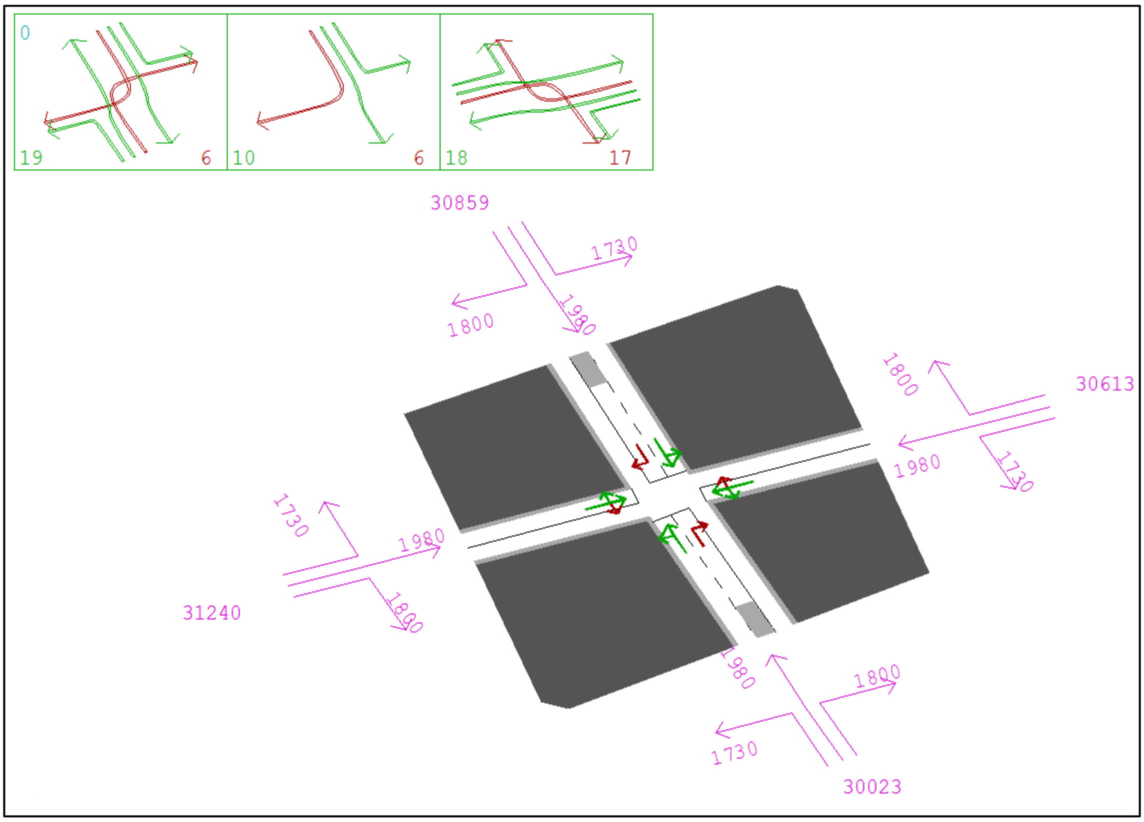
- Staging plans;
- Cycle times;
- Stage green times; and
- Stage intergreen times.

Traffic signal specifications were obtained from LCC to derive this data. However, specifications typically give minimum and maximum green times for stages to be optimised for live traffic conditions through dynamic signal operations such as MOVA and SCOOT. It is only possible to code fixed signal timings in SATURN therefore the stage maximum green times were used as a starting point and further adjusted where relevant during the calibration and validation process.

The saturation flows for signalised junctions were based on calculations presented in TRL Report 67 (Kimber, McDonald and Hounsell) for different turning movement types (left turn, ahead, right turn) by lane width according to turning radii. These were reviewed and adjusted during the calibration and validation process alongside other junction parameters in order to more accurately represent delays and to reflect local site variation.

Figure 5-7 shows an example of a signalised junction node coded in SATURN. The turn data displayed are saturation flows in pcus per hour.

Figure 5-7 Example Coding - Signalised Junction



5.6.3 *Roundabouts*

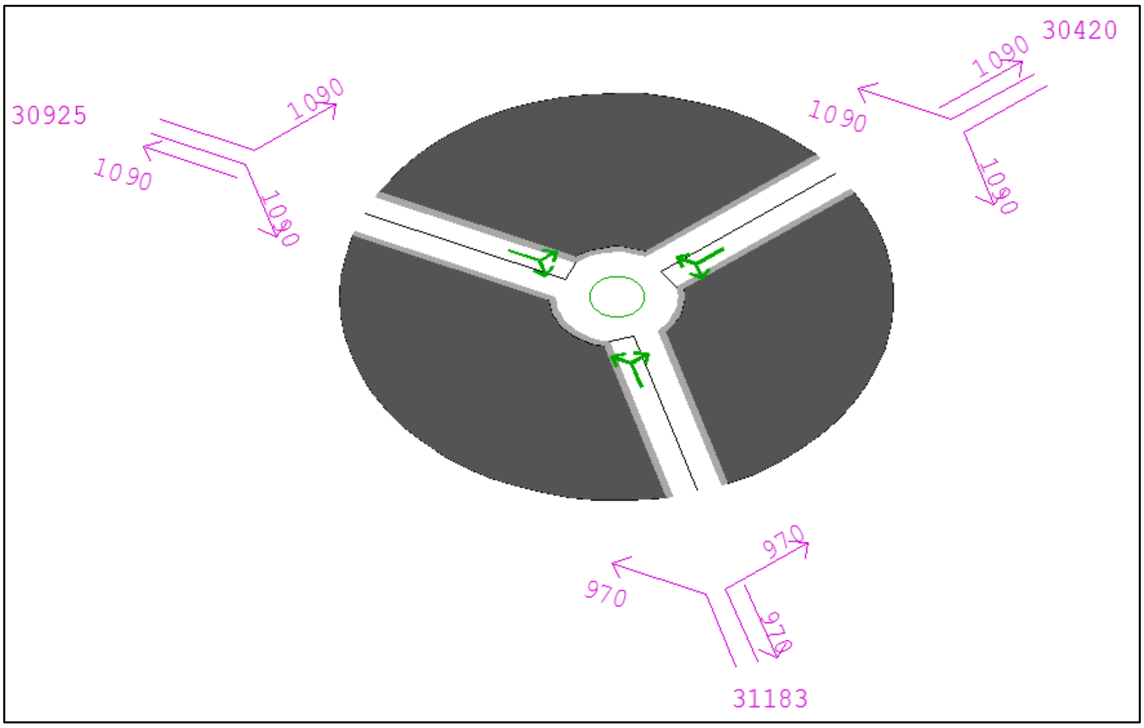
Roundabouts within the simulation area required characteristics to be coded including:

- Entry capacity at each approach (pcus per hour);
- Circulatory capacity (pcus per hour); and
- Total circulatory time (seconds).

Explicit parameters such as entry width, inscribed diameter and flare length were used to derive the capacities using the Kimber TRL method used for ARCADY.

Figure 5-8 shows an example of a roundabout node coded in SATURN.

Figure 5-8 Coding Example - Roundabout



5.6.4 *Exploded Roundabout*

The limitation of traditional roundabout coding is that it only applies for small sized roundabout where traffic flow approaching the roundabout is not significant or where no clear definition of lane marking for any particular movement (i.e. traffic can utilise all ales on approaches to exit the roundabout). For large roundabouts where traffic flows are significant and where lane markings are clearly defined for a particular movements, the coding of the traditional roundabout is inappropriate to model delay associated with different turning movements. Larger roundabouts were therefore coded as a series of priority junctions with major arms on the circulatory sections and minor arms as on approaches to the roundabouts. An example of an exploded roundabout at A46/A57 Saxilby Road is provided in Figure 5-9 below.

Figure 5-9 Coding Example - Exploded Roundabout

5.7 Level Crossings

Access to Lincoln Central Station for services on the Sheffield-Lincoln line and Nottingham-Lincoln line (which both enter the station from the western side) is via a key level crossing on Brayford Wharf East. Further from the city centre, the Nottingham-Lincoln line traverses another two level crossings on the radial routes Skellingthorpe Road and Doddington Road plus a further crossing next to Hykeham station. There are other minor crossings outside of the main urban areas.

These will contribute to traffic delays and may impact route choice if drivers perceive a longer route is preferable to avoid the time delays. This is particularly important for the peak periods when rail service frequency will typically be higher.

SATURN does not have functionality to explicitly model level crossing operations however their impact can be approximated. In GLTM they are coded BY proxy as signalised junctions with a single traffic stage whereby the intergreen time represents the barrier downtime. Timings are derived by rail operations.

5.8 Public Transport Services and Bus Priority

Bus services are coded into GLHAM as pre-loaded demand. This is of particular importance to the peak periods when services will typically have a higher frequency and their impact on general traffic flow will be greater. In addition, the modelled AM peak hour of 08:00-09:00 will be impacted by school bus services.

The bus routes were coded into the SATURN network using information on bus frequency. The list of bus routes included in the model is given in Table 5-3 and also presented graphically in Figure 5-10 below.

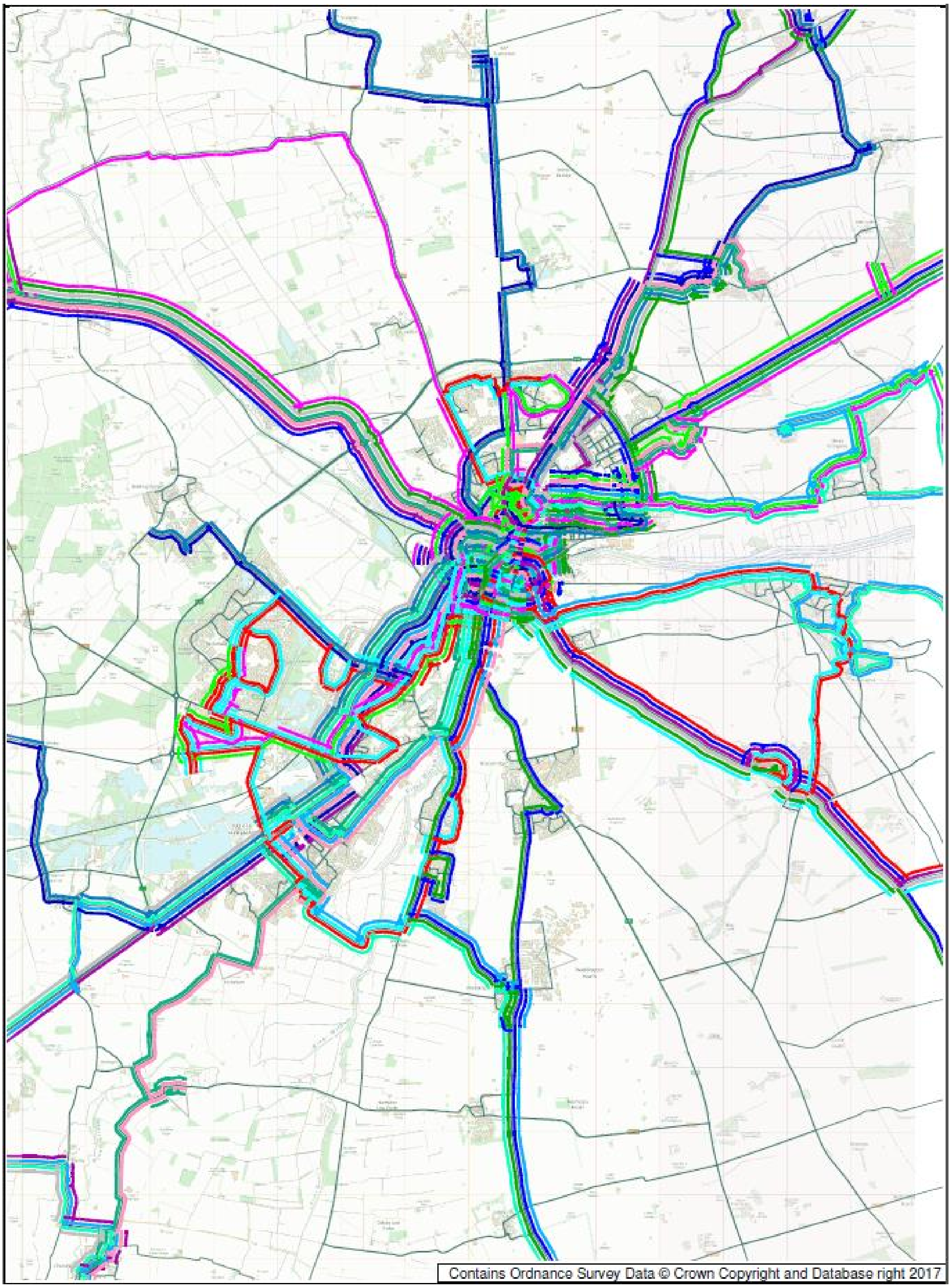
Table 5-3 List of Bus Routes Coded in the Model

No.	Operator	Service Description	Type	Dir.	Weekday Frequency		
					AM	IP	PM
1	Stagecoach	Lincoln to Grantham	Public	SB	1	10	2
1	Stagecoach	Grantham to Lincoln	Public	NB	2	12	2
2	Stagecoach	Lincoln to Branston	Public	SB	3	18	3
2	Stagecoach	Branston to Lincoln	Public	NB	3	18	3
3	Stagecoach	Lincoln to Fiskerton	Public	EB	0	11	0
3	Stagecoach	Fiskerton to Lincoln	Public	WB	1	10	2
4	Stagecoach	Lincoln to County Hospital	Public	EB	2	12	2
4	Stagecoach	Lincoln Hospital to Lincoln	Public	WB	2	12	2
5	Stagecoach	Lincoln to Glebe Park	Public	NB	3	18	3
5	Stagecoach	Glebe Park to Lincoln	Public	SB	3	18	3
6	Stagecoach	Lincoln to Skegness	Public	EB	1	6	1
6	Stagecoach	Skegness to Lincoln	Public	WB	2	6	1
7	Stagecoach	Lincoln to Ermine Estate	Public	NB	3	18	3
7	Stagecoach	Ermine Estate to Lincoln	Public	SB	3	18	3
8	Stagecoach	Lincoln to Ermine Estate	Public	NB	3	18	2
8	Stagecoach	Ermine Estate to Lincoln	Public	SB	3	18	3
11	Stagecoach	Lincoln to Welton	Public	NB	1	6	2
11	Stagecoach	Welton to Lincoln	Public	SB	2	5	1
12	Stagecoach	Lincoln to Welton	Public	NB	1	6	2
12	Stagecoach	Welton to Lincoln	Public	SB	2	5	1
13	Stagecoach	Lincoln to Waddington	Public	SB	2	12	2
13	Stagecoach	Waddington to Lincoln	Public	NB	2	12	2
14	Stagecoach	Lincoln to North Hykeham	Public	SB	1	12	2
14	Stagecoach	North Hykeham to Lincoln	Public	NB	1	6	1
26	Stagecoach	Lincoln to North Hykeham	Public	SB	3	17	3
26	Stagecoach	North Hykeham to Lincoln	Public	NB	3	18	3
27	Stagecoach	Lincoln to North Hykeham	Public	SB	3	18	3
27	Stagecoach	North Hykeham to Lincoln	Public	NB	3	18	3
29	Stagecoach	Lincoln to Skellingthorpe	Public	WB	0	7	1
29	Stagecoach	Skellingthorpe to Lincoln	Public	EB	2	5	0
44	Stagecoach	Lincoln to Birchwood	Public	WB	2	23	4
44	Stagecoach	Birchwood to Lincoln	Public	EB	4	24	2
66	Stagecoach	Birchwood to Lincoln	Public	EB	6	35	6
66	Stagecoach	Lincoln to Birchwood	Public	WB	6	36	6
777	PC Coaches	Carltons to Lincoln	Public	Circular	0	6	1
WR	PC Coaches	Lincoln Walk and Ride	Public	Circular	0	13	1
IC5	Brylaine	Lincoln to Boston	Public	SB	1	7	1
IC5	Brylaine	Boston to Lincoln	Public	NB	1	6	0

No.	Operator	Service Description	Type	Dir.	Weekday Frequency		
					AM	IP	PM
53	Stagecoach	Grimsby to Lincoln	Public	SB	0	6	1
53	Stagecoach	Lincoln to Grimsby	Public	NB	1	5	2
100	Stagecoach	Lincoln to Scunthorpe	Public	NB	1	5	1
100	Stagecoach	Scunthorpe to Lincoln	Public	SB	1	6	1
N63S	PC Coaches	Waddington to Branston	School	EB	1	0	0
N63S	PC Coaches	Branston to Waddington	School	WB	0	1	0
N70S	PC Coaches	Waddington to Branston	School	EB	1	0	0
N70S	PC Coaches	Branston to Waddington	School	WB	0	1	0
N75S	PC Coaches	Welton to Lincoln	School	SB	0	0	0
N75S	PC Coaches	Lincoln to Welton	School	NB	1	0	0
PC22	PC Coaches	Welton to Nettleham	School	SB	0	1	0
PC22	PC Coaches	Nettleham to Welton	School	NB	1	0	0
573	Stagecoach	Bracebridge Heath to Branston	School	EB	1	0	0
573	Stagecoach	Branston to Bracebridge Heath	School	WB	0	0	0
543	Stagecoach	Brant Road to North Hykeham	School	WB	1	0	0
543	Stagecoach	North Hykeham to Brant Road	School	EB	0	1	0
544	Stagecoach	Bracebridge Heath to North Hykeham	School	WB	1	0	0
544	Stagecoach	North Hykeham to Bracebridge Heath	School	EB	0	1	0
106	Stagecoach	Lincoln to Gainsborough	Public	NB	0	2	1
106	Stagecoach	Gainsborough to Lincoln	Public	SB	0	3	1
107	Stagecoach	Lincoln to Gainsborough	Public	NB	0	0	1
107	Stagecoach	Gainsborough to Lincoln	Public	SB	1	0	0
103	Stagecoach	Lincoln to Scunthorpe	Public	NB	1	3	1
103	Stagecoach	Scunthorpe to Lincoln	Public	SB	1	3	1
67	Travel Wright	Saxilby to Newark	Public	SB	0	3	0
67	Travel Wright	Newark to Saxilby	Public	NB	0	2	0
44A	Stagecoach	Lincoln to Birchwood	Public	WB	2	0	0
44A	Stagecoach	Birchwood to Lincoln	Public	EB	0	1	2
46	Stagecoach	Lincoln to Newark	Public	SB	0	0	1
46	Stagecoach	Newark to Lincoln	Public	NB	0	0	1
47	PC Coaches	Lincoln to Newark	Public	SB	1	2	0
47	PC Coaches	Newark to Lincoln	Public	NB	1	2	0
48	PC Coaches	Lincoln to Witham St Hughes	Public	SB	0	3	1
48	PC Coaches	Witham St Hughes to Lincoln	Public	NB	0	3	0
49	PC Coaches	Bassingham Lincoln	Public	NB	0	3	1
49	PC Coaches	Lincoln to Bassingham	Public	SB	0	3	0
31	Stagecoach	Lincoln to Sleaford	Public	SB	1	2	0
31	Stagecoach	Sleaford to Lincoln	Public	NB	0	3	0
X31	Stagecoach	Lincoln to Sleaford	Public	SB	0	1	0
X31	Stagecoach	Sleaford to Lincoln	Public	NB	0	0	0
23	PC Coaches	Lincoln to Market Rasen	Public	NB	0	1	1
23	PC Coaches	Market Rasen to Lincoln	Public	SB	1	1	0

No.	Operator	Service Description	Type	Dir.	Weekday Frequency		
					AM	IP	PM
10	PC Coaches	Lincoln to Horncastle	Public	EB	1	3	1
10	PC Coaches	Horncastle to Lincoln	Public	WB	1	3	1
10	Stagecoach	Lincoln to Louth	Public	EB	1	2	1
10	Stagecoach	Louth to Lincoln	Public	WB	0	3	0
3A	Stagecoach	Lincoln to Fiskerton	Public	EB	0	1	2
3A	Stagecoach	Fiskerton to Lincoln	Public	WB	1	1	0
4	PC Coaches	Lincoln to Nettleham	Public	NB	0	5	0
4	PC Coaches	Nettleham to Lincoln	Public	SB	0	5	0
81	Brylaine	North Hykeham to Welbourn	School	SB	1	0	0
81	Brylaine	Welbourn to North Hykeham	School	NB	0	1	0
541	Stagecoach	Ermine Estate to Westgate School	School	SB	1	0	0

Figure 5-10 Bus Routes Included in the Model



5.9 Generalised Cost

Traffic routeing is implemented in SATURN through a function of generalised cost. This normalises time, distance and monetary charges into a standard unit. The function is defined as

$$GC = T + \frac{(D \times VOC) + M}{VOT}$$

where:

- GC Generalised cost in minutes;
- T Travel time in units of minutes (including delays and time penalties)
- D Travel distance in kilometres;
- M Monetary charges in pence (e.g. toll fares);
- VOT Value of time in pence per minute (PPM); and
- VOC Vehicle operating costs in pence per kilometre (PPK).

The parameters for PPM and PPK have been derived by user class from the July 2017 WebTAG Databook and are listed in Table 5-4.

Table 5-4 Parameters for Generalised Cost Formulation

User Class	AM Peak		Inter Peak		PM Peak	
	PPM	PPK	PPM	PPK	PPM	PPK
Business	30.12	12.30	30.84	12.30	30.53	12.30
Commute	20.18	5.80	20.51	5.80	20.25	5.80
Other	13.92	5.80	14.83	5.80	14.58	5.80
LGV	21.27	13.32	21.27	13.32	21.27	13.32
HGV	49.67	37.76	49.67	37.76	49.67	37.76

5.10 Representation of Tolls

Toll charges are represented in the network since they contribute to the generalised cost associated with their respective links. They are specified by user class due to differing values of time which may lead to variation for whether the charge is offset by a time and/or distance time saving through using the toll route.

5.10.1 Toll Routes

There are three toll links modelled within the GLTM buffer network. Although they are not within the simulation area, the additional costs will impact on route choice within the buffer network including the entry and exit points to the study area.

- Dunham Bridge Toll (A57)

  The Dunham Bridge crosses the River Trent between Darlton and Newton, on the periphery of the simulation area approximately 15km west of Lincoln. The price per crossing is 40p for cars, 60p for LGVs and £1.00 for HGVs.[2]

- Humber Bridge (A15)

  The Humber Bridge connects East Riding to North Lincolnshire district in Humberside. Trips to or from the north east and Humberside have the option to circumvent the toll charge using the M62/M18/M180. A single crossing costs £1.50 for cars and LGVs, £4.00 for HGVs up to 2 axles and/or not exceeding 7.5 tonnes gross vehicle weight and £12.00 for larger HGVs exceeding those criteria.[3]

  A weighted average was calculated between the two subgroups of HGVs to derive a single charge value of £9.15 for HGVs, using flow data for 2014/15 provided on the Humber Bridge webpage.[4]

  A discount rate of 10% is applied for HumberTAG users however this was not considered for the model prices.

- M6 Toll

  The M6 was included in the buffer network to allow more accurately the impact of travel costs of highways relative to the PT in the context of the multi-modal demand model for external trips between the north and the south. A trip costs £5.50 for the majority of cars and £11.00 for LGVs and HGVs during the period 06:00-23:00[5]. As per the Humber Bridge, the 5% discount rates have not been included.

5.10.2 Conversion to Modelled Toll Costs

For consistency of representing costs across the modelling, the market price charges above were converted to perceived costs in 2010 prices for the highway assignment model. This required three values taken from WebTAG:

- The GDP deflator for 2016 was 108.8 to depreciate to the cost base year 2010;
- For business trips, a market cost over perceived cost divisor of 1.19; and
- A business/non-business split for LGVs as 0.88/0.12. (Note that the equivalent split for HGVs has a value of 1.00 for business)

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[2] http://www.dunhambridge.co.uk/tolls.php (23/03/2017)

[3] http://www.humberbridge.co.uk/toll_information/toll_charges.php (23/03/2017)

[4] http://www.humberbridge.co.uk/explore_the_bridge/bridge_history_and_detail/traffic_figures.php (23/03/2017)

[5] https://www.m6toll.co.uk/pricing/(23/03/2017)

The second value was applied to the business and HGV user classes, plus the LGV user class through a weighted average based on the split stated in the third value.

The outturn prices for the model are summarised in Table 5-5 below.

Table 5-5 Modelled Toll Charges

User Class	Dunham Bridge	Humber Bridge	M6 Toll
Business	31	116	425
Commute	37	138	505
Other	37	138	505
LGV	47	118	869
HGV	77	707	849

**in pence, 2010 prices, perceived costs*

5.11 PCU Conversion Factors

Equivalent trip volumes of different vehicle types will have a different impact on the network capacity due to different sizes of the vehicles. For assignment, the demand is converted into standardised passenger car units (PCUs) which are taken from WebTAG.

A combined PCU factor for OGVs (Other Goods Vehicles) and PSVs (Passenger Service Vehicles) was derived using a weighted average based on the respective split derived from the MCCs undertaken in November 2016.

Table 5-6 PCU Factors

Modelled Vehicle Type	WebTAG Vehicle Type	WebTAG PCU Factor	Weighting	Outturn Model PCU Factor
Car	Car	1.0		1.00
LGV	LGV	1.0		1.00
HGV	OGV1	1.9	0.53	2.25
	OGV2	2.9	0.20	
PSV	PSV	2.5	0.27	

6 Model Development – Highway Demand

6.1 Introduction

This chapter describes the development of the base year highway demand matrices for GLTM. Highway assignment models require a representation of travel demand in the form of trip matrices which are loaded on the network (supply) as model zones. The zones are defined to be areas of similar land use and characteristics which would accessing and egressing the model network at a similar location. The area of interest will have the greatest detail with zones becoming more aggregate further from the simulation area.

As described in Section 4.2, MPOD data was collected as the primary data source within a bespoke zone system, herein referred to a request sectors, for development of the GLTM demand matrices, which included the complete data specification. The rationale for this choice of data is detailed in previous reporting including the MSR and TDCR.

6.2 Model Zone System

A zone system was required to be developed for the study based on the principles that the level of detail should be fine enough to enable detailed modelling within the areas of interest but not too detailed to compromise development and subsequent model run times.

The starting point for the GLTM zone system was the request sector system used for the mobile phone data, which was based on LSOA or aggregations thereof – see Section 6.1 for a detailed description. It was necessary to develop a many-to-many relationship through:

- Disaggregation of request sectors within Lincoln centre to complement the detailed network coverage;
- Some disaggregation within the rural areas around the wider county due to large MSOA zones which covered multiple conurbations with different access points to the network; and
- Aggregations of request sectors in the other urban towns within the mobile phone data study area where the network detail did not necessitate the level of detail in the request sector zone system.

The outturn GLTM zone system has 733 zones, of which around 377 are within the area that is covered by the bypasses. This conversion from request sectors is summarised in Table 6-1; the zone system is illustrated in Figure 6-1, Figure 6-2 and Figure 6-3 below.

Table 6-1 Number of Zones by District

District	County	Number of Zones	Number of Request Sectors
Lincoln	Lincolnshire	310	56
North Kesteven	Lincolnshire	138	49
West Lindsey	Lincolnshire	77	28
East Lindsey	Lincolnshire	38	37
South Kesteven	Lincolnshire	19	43
South Holland	Lincolnshire	9	24
Boston	Lincolnshire	4	24
Newark and Sherwood	Nottinghamshire	56	33
Bassetlaw	Nottinghamshire	19	22
North Lincolnshire	Humberside	17	58
North East Lincolnshire	Humberside	13	86
Mobile Phone Data External Areas		33	64
Total		733	524

Figure 6-1 Model Zone System - Lincoln Centre

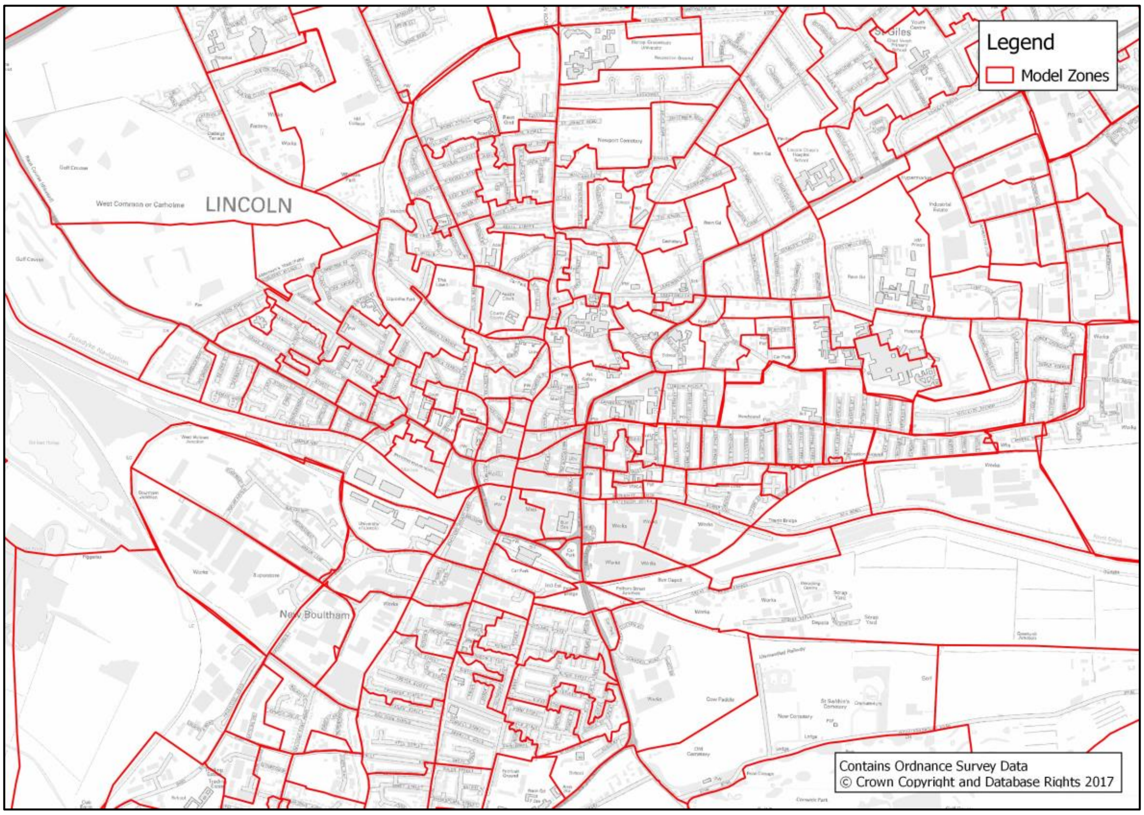


Figure 6-2 Model Zone System - Simulation Area

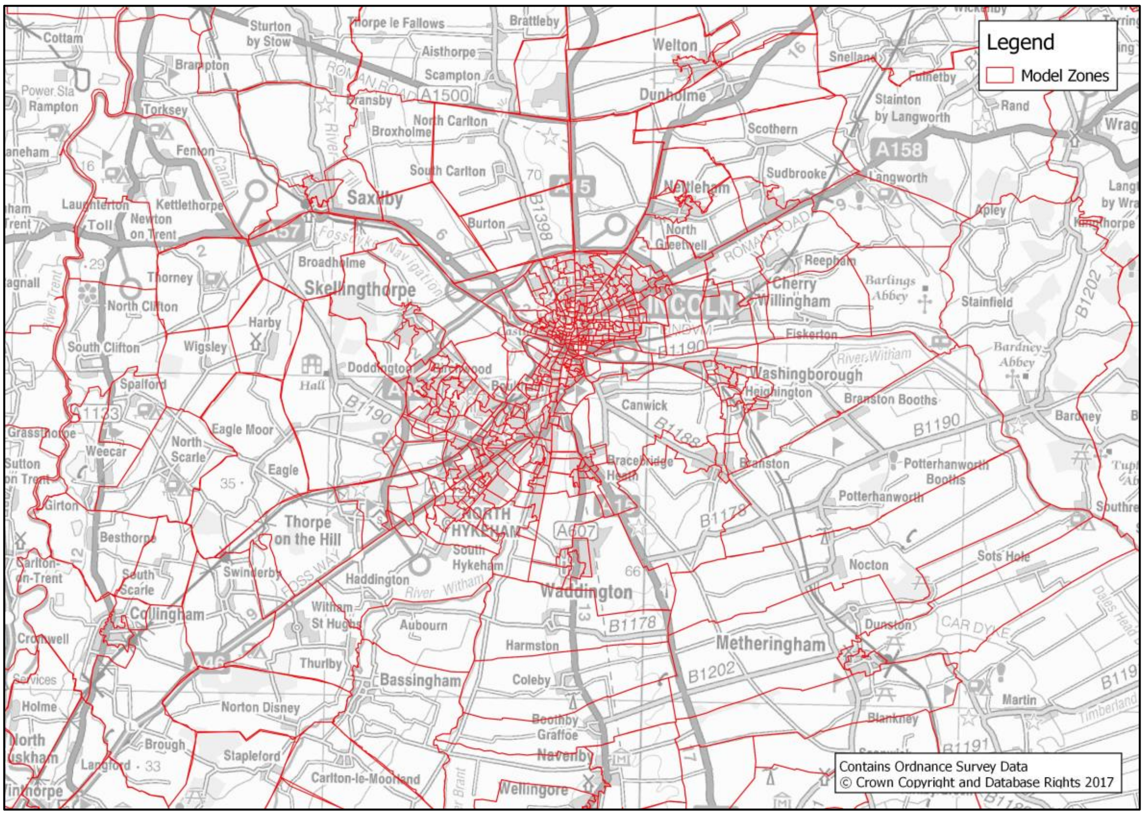
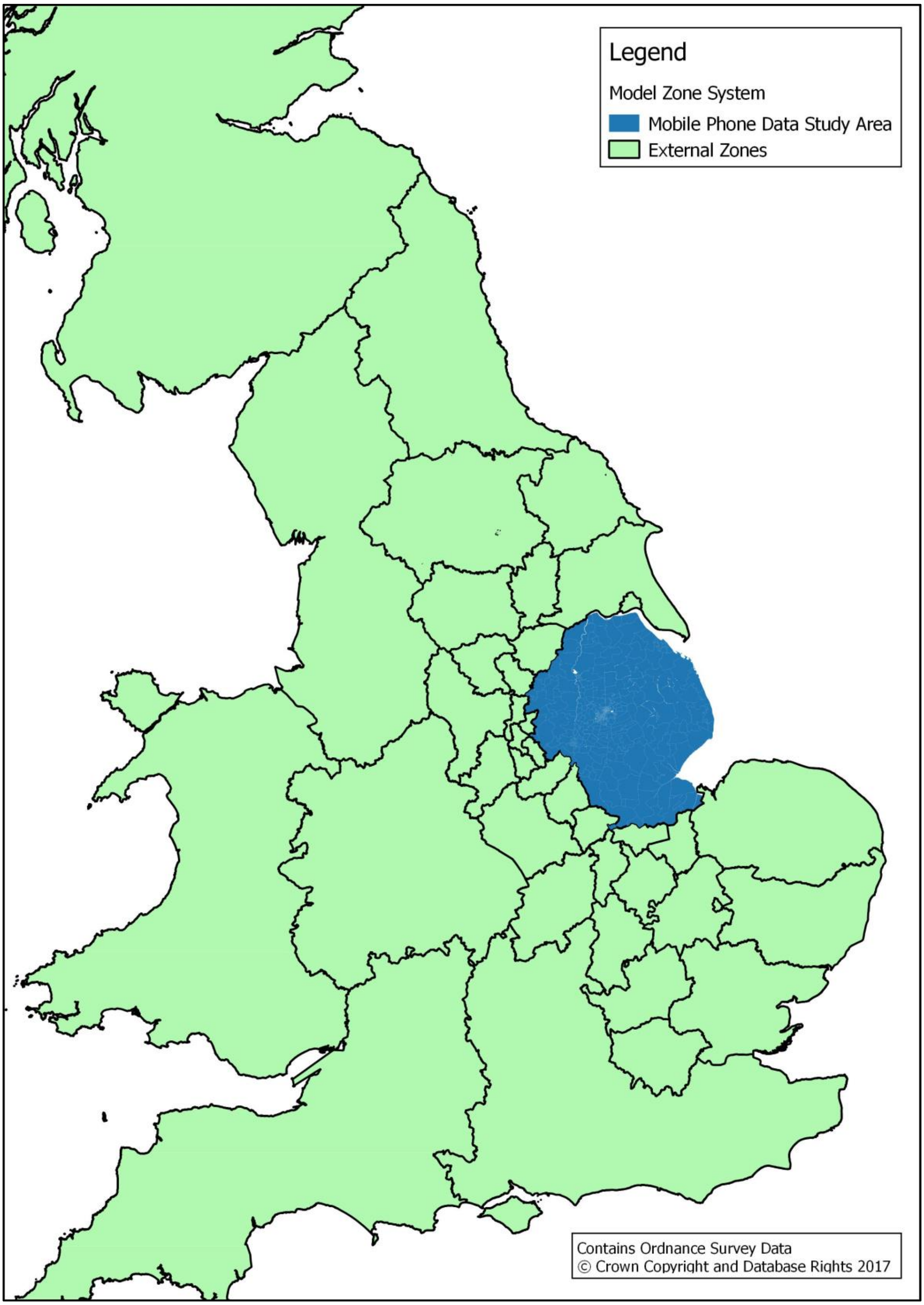


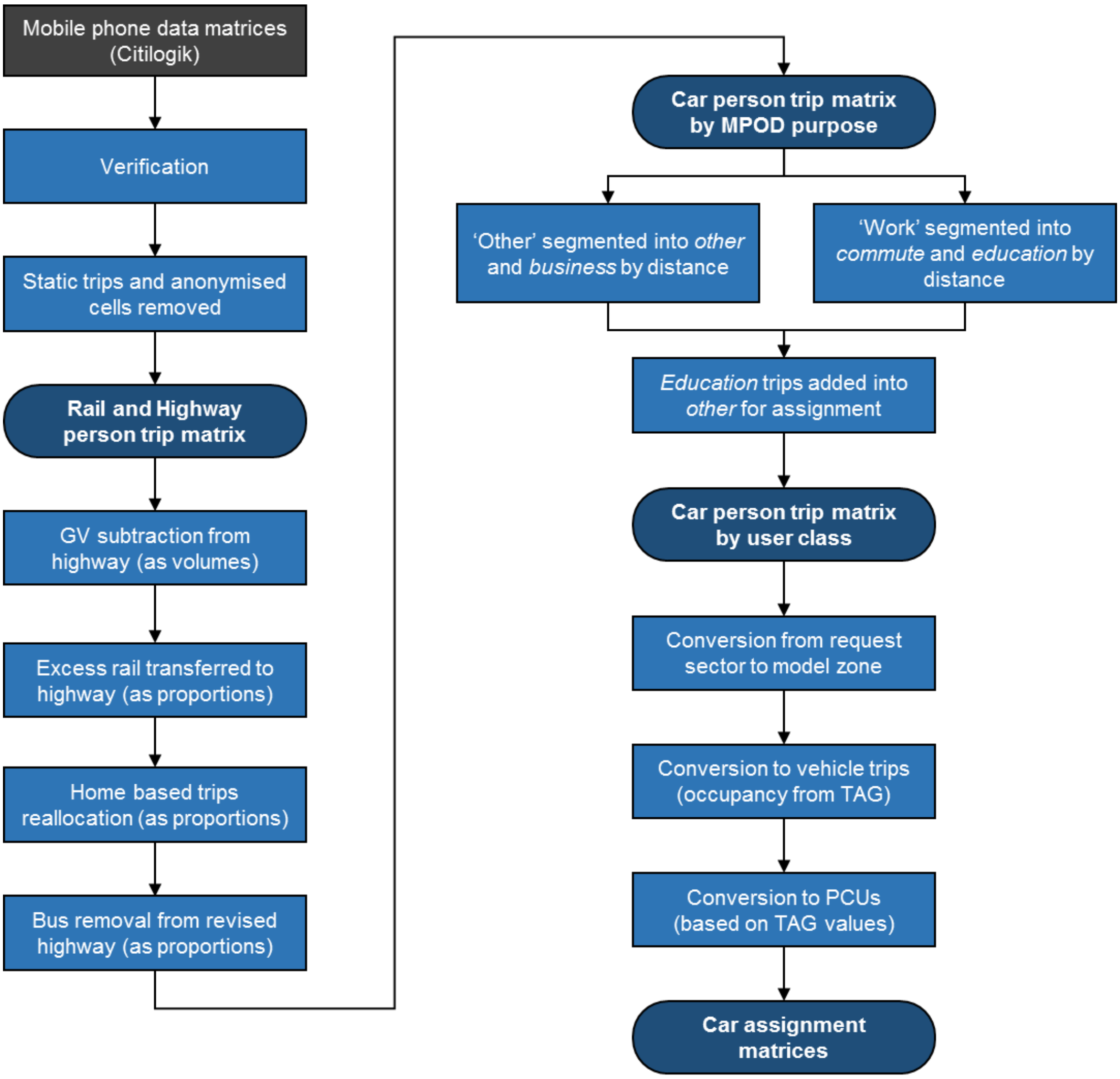
Figure 6-3 Model Zone System - External Area



6.3 Overview of MPOD Matrix Development

The methodology for developing the MPOD base demand matrices was informed by the verification process described in the following section and is summarised in Figure 6-4 below. Each of the removal and adjustment stages are also described in the subsections below.

Figure 6-4 MPOD Matrix Development Process



6.4 Verification of MPOD Data

Travel demand matrices were developed by Citilogik from mobile phone data events of Vodafone customers and supplied to the GLTM modelling team. As part of the commission, Citilogik prepared a data verification note summarising various metrics used in modelling against logic tests and independent datasets including symmetry, trip rates and combinations of time of day and time period. This was attached to the TDCR as an Appendix.

It is worth noting that this comparison was undertaken by Citilogik prior to data anonymisation. To comply with data protection requirements, any cell in the MPOD data that fell below a threshold of 15 trips (observed over the 28 day data collection period) was rounded to a value of 15 in the version of the dataset supplied to the GLTM modelling team.

Another important note regarding the MPOD data specification is that trips were either classified under the label 'work' – in this context referring to commuting in the sense of a regular journey to a usual place of work, not employer business – or 'other'. The purpose split was based on analysis by Citilogik to determine frequent dwell locations for devices and, through time of day analysis, assign these places to be a device's 'home' or 'work' location.

An independent verification of the data was undertaken by the modelling team to confirm the conclusions reported by Citilogik and to further analyse the contents of the dataset for other facets or limitations which would impact on the matrix build. This reporting is documented in detail with appropriate tabulations and graphs in Appendix C. The following presents a summary of the findings.

- A trip for a mobile device user was defined from the time of the last event registered in the starting dwell cell until the time of the first event registered in the finishing dwell cell. If a dwell exceeded a 30 minute threshold, the device was deemed to be static. Therefore, a static trip was recorded by a mobile device not moving for over 30 minutes within the coverage area of a single cell.
- To protect data privacy and confidentiality, a minimum threshold for trips per cell was set at a value of 15. Any cells with fewer than 15 trips had the value rounded up to 15. Note that this does not include cells with zero trips – they were simply excluded from the received matrix. These represented a low proportion of the matrix – on average 4.5% of cells per row or column.
- There were twenty-seven request sectors in the study area which had no trip ends at all in the MPOD matrix. Citilogik confirmed this was because there were no Vodafone cells in those zones. Most of these locations are at an LSOA level, in urban areas across the wider county. These cells would subsequently be infilled using a synthetic matrix process described in this section.
- The ten external request sectors outside the Geofence, as illustrated in Figure 4-2, had no trip-ends in the raw MPOD data. This was due to pre-defined facet of the data processing. The trips to/from these sectors to the study area had been allocated to the request sector at which the trip crossed the Geofence boundary instead. For more detail, see Section 6.5.6 below.
- The MPOD data was supplied in two categories – highway motorised and rail. There was an excess of rail trips, including several routes identified as implausible for rail travel. The combined demand for rail and highway motorised was close to TEMPRO at a high level, when GVs were accounted for. Hence, the excess rail trips needed to be transferred to highway.
- It was not within the project scope for Citilogik to attempt to differentiate the highway motorised data by vehicle type. Therefore the highway motorised

category would need to be split into car, LGV, HGV, and bus by the modelling team.

- There was a shortfall in home based trips due to limitations of the MPOD processing identifying the home end of a trip. The home based / non-home based ratio would need to be adjusted.
- The MPOD data could have purpose 'work' – referring to commuting to a regular place of work, not employer business – or 'other'. The 'other' category would need to be split into other and employer business segments for gravity modelling and assignment.
- The purpose split and trip length analysis suggested that education trips – defined as travel to or from a place for learning, including parent pick up and drop off – were included in the MPOD 'work' category. These trips would need to be transferred into the other demand segment; the remaining trips would make up the commute demand segment.

6.5 Development of MPOD Matrices

6.5.1 GV Matrix Development and Removal

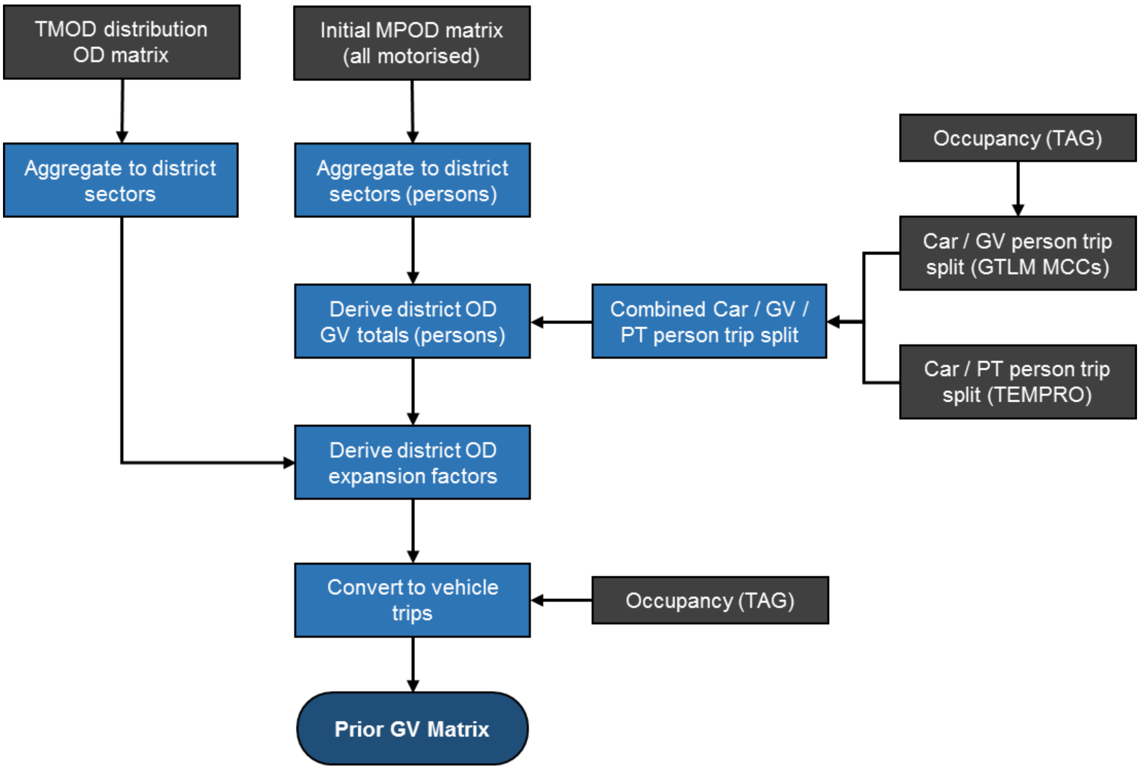
The first stage was to remove GVs from the dataset. LGV and HGV matrices were required for highway assignment as individual user classes as well therefore GV matrices were separately for that use, but which could then be subtracted volumetrically from the MPOD data as well. The process was undertaken by time period separately and is summarised in Figure 6-5 and as follows:

- TMOD data – see Section 4.2 – was the best available source of demand data for GVs. This contains a sample of movements at LSOA level so it could be easily aggregated, where necessary, into the request sector system.
- However, the sample size in TMOD was unknown and difficult to quantify. Further, there were likely to be regional variations to this based on differing GV usage. Therefore, the MPOD data was chosen as the best data source to derive target volumes for GV.
- The targets were to be derived at district level, between all combinations of the eleven districts which comprised the MPOD study area.
- At this stage, the MPOD data contained all highway (including PT) and rail as person trips. The MCC data was used to derive the LGV and HGV proportions versus car, and converted to persons using occupancy from TAG. The car versus PT person trips split was derived for the study area from TEMPRO. These ratios were combined to create a single split for car / LGV / HGV / PT in persons.
- The derived LGV and HGV splits were applied to the MPOD data for district to district movements to derive target GV volumes. The TMOD sample volume for the same geographies was expanded to this target.
- The outturn matrices were LGVs and HGVs in person trips – these matrices were used to subtract GV from the MPOD matrix by purpose. The HGV were all

assumed to be non-home based employer business – this was based on the TAG proportion of 100% business for HGVs. For LGVs, the TAG split of 88:12 for business/non-business was used as the starting point with NTS data used to split the two proportions further into home based and non-home based.

- The matrices were converted back to vehicle trips (using TAG occupancy values) for assignment and peak hour factors consistent with those used for the MPOD data were applied, since the MPOD data was used to derive the expansion factors (see Table 6-10).

Figure 6-5 GV Matrix Development Process



The stage to derive the expansion factors was based on combining two ratios which had potential for error from both of the inputs, alongside the use of global occupancy. (However, the HGV occupancy from TAG was 1.00 so that was unaffected through occupancy adjustment).

To verify the method, the outturn matrices were compared to screenline flows – in particular the bypass cordon capturing the strategic movements into and out of the main area of interest. The results demonstrated, for AM peak and inter peak, a close adherence to screenline totals for the GV matrices giving reassurance to the volumes subtracted from MPOD and confidence that the outputs form a suitable basis to form the prior GV matrices. For the PM peak, the lower observed flows, in particular for LGVs, was consistent with later analysis (see Table 6-21) which showed that the MPOD data had underestimated trips in the PM peak. Through this method, the expansion factors would likewise underestimate the GV for that period.

This method was preferred to an approach which used screenlines to derive the expansion factors since such a calculation would only expand cross-screenline movements therefore areas within screenline boundaries would have a deficient GV volume and this would not be subtracted from the MPOD.

Table 6-2 GV Prior Matrix Comparison – AM Peak

Screenline	LGVs				HGVs			
	Obs.	Mod.	Diff.	GEH	Obs.	Mod.	Diff.	GEH
Inbound								
Northern Bypass	272	302	30	1.8	197	207	10	0.7
Eastern Bypass	304	299	-6	0.3	157	128	-29	2.4
Southern Bypass	371	400	29	1.5	202	238	36	2.5
Western Bypass	124	159	36	3.0	61	120	69	7.1
Total	**1071**	**1161**	**89**	**2.7**	**617**	**704**	**87**	**3.4**
Outbound								
Northern Bypass	315	367	52	2.8	213	269	56	3.6
Eastern Bypass	243	363	121	6.9	131	133	2	0.2
Southern Bypass	374	359	-15	0.8	235	194	-41	2.8
Western Bypass	126	122	-4	0.4	69	154	84	8.0
Total	**1057**	**1211**	**154**	**4.6**	**649**	**751**	**102**	**3.9**

Table 6-3 GV Prior Matrix Comparison – Inter Peak

Screenline	LGVs				HGVs			
	Obs.	Mod.	Diff.	GEH	Obs.	Mod.	Diff.	GEH
Inbound								
Northern Bypass	243	217	-26	1.7	171	180	9	0.7
Eastern Bypass	251	202	-50	3.3	122	87	-35	3.4
Southern Bypass	272	249	-23	1.4	176	239	63	4.4
Western Bypass	109	68	-41	4.4	40	76	35	4.6
Total	**875**	**735**	**-140**	**4.9**	**508**	**581**	**72**	**3.1**
Outbound								
Northern Bypass	259	214	-45	2.9	183	166	-17	1.3
Eastern Bypass	225	198	-27	1.9	132	89	-43	4.1
Southern Bypass	276	247	-29	1.8	175	180	6	0.4
Western Bypass	108	86	-22	2.3	42	96	53	6.4
Total	**868**	**745**	**-123**	**4.3**	**532**	**531**	**-1**	**0.1**

Table 6-4 GV Prior Matrix Comparison – PM Peak

Screenline	LGVs				HGVs			
	Obs.	Mod.	Diff.	GEH	Obs.	Mod.	Diff.	GEH
Inbound								
Northern Bypass	316	215	-101	6.2	131	147	16	1.4
Eastern Bypass	311	227	-85	5.2	116	47	-69	7.6
Southern Bypass	278	239	-40	2.5	128	95	-33	3.1
Western Bypass	154	78	-76	7.0	26	80	54	7.4
Total	**1059**	**759**	**-300**	**10.0**	**402**	**370**	**-32**	**1.6**
Outbound								
Northern Bypass	267	209	-58	3.7	159	131	-28	2.3
Eastern Bypass	245	182	-63	4.3	106	36	-70	8.3
Southern Bypass	381	257	-123	6.9	148	93	-55	5.0
Western Bypass	102	114	11	1.1	21	114	93	11.3
Total	**995**	**762**	**-233**	**7.8**	**434**	**374**	**-60**	**3.0**

6.5.2 *Rail Transfer to Highway*

The verification tests showed a mode share for rail in the MPOD study area of 8% compared to a TEMPRO value for the study area of 2%. National reporting for rail mode share is typically around 3%. From the make-up of the study area and known availability of rail routes and frequencies, it would not be expected to have a higher share than the national average.

It was noted as part of the verification process that the highway and rail combined compared well against TEMPRO for trip rates therefore it was assumed that the excess rail trips were miscategorised highway trips, a limitation of the algorithm used to identify rail. In particular, it was noted by Citilogik that the excess rail were largely short distance trips.

An adjustment process was defined which would preserve all aspects of the combined motorised MPOD matrix but transfer a proportion of the excess rail trips to highway. This is illustrated in Figure 6-6. Following the verification process:

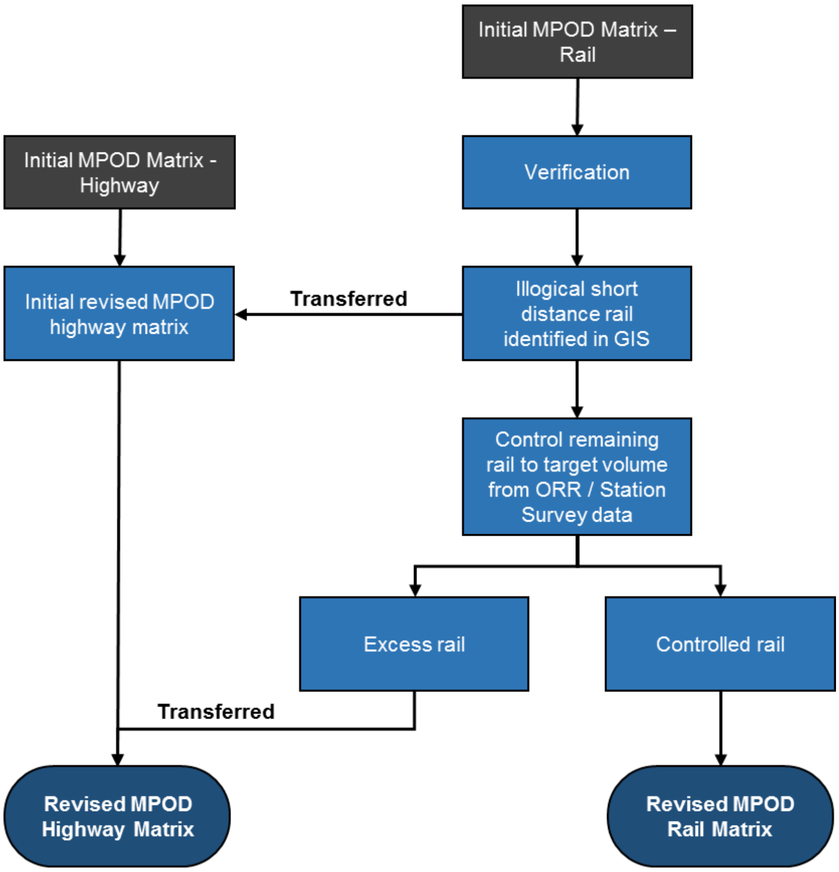
- GIS was used to establish illogical rail movements by defining a lower bound on request sector to request sector rail trips. This was based on the crow-fly minimum distance to a station and minimum station to station distances.
- Further, two district to district pairwise movements with a high rail component but flagged as unlikely for rail demand during the verification process were also classified as illogical.
- All of these illogical trips were transferred to highway.

- There was still an excess of rail as a mode share post transfer of illogical trips to highway. A target volume for study area rail was derived based on a station survey for Lincoln Central Station and Office of Rail and Road (ORR) data.
- The station survey was undertaken for a single weekday during the peak periods. This was expanded to a daily total using time period factors for rail from TEMPRO.
- ORR annual patronage data is available for every rail station in Great Britain. The value for Lincoln Central was divided by the daily total for the station survey to derive an annualisation factor of 324.
- The ORR data for all stations in the MPOD study area was combined and divided by 324 to derive the study area target volume.
- The remaining rail (post stage one) was controlled to the derived district targets at a daily level, with the excess trips being transferred to highway, pro-rata at request sector level by the post stage one rail distribution.

The outcome of this was:

- A highway motorised matrix consisting only of car and bus; and
- A rail matrix to be taken forward in the public transport model development.

Figure 6-6 Rail Transfer to Highway Process



6.5.3 *Home Based Adjustment*

The verification tests showed that the daily ratio of home based to non-home based trips was weighted too heavily to the latter when compared against TEMPRO, see Table 6-5.

Table 6-5 Daily Home Based Proportion Verification

Purpose	MPOD	TEMPRO (Study Area)
Home Based	0.51	0.88
Non-Home Based	0.49	0.12
SUM	1.00	1.00

Since the problem was believed to be caused by limitation of the MPOD processing, a high level control was applied to adjust the home based / non-home based target proportion split derived from TEMPRO. This adjustment was applied at time period level by district.

There was no variation introduced for different purposes, since that was not believed to be a factor.

The adjustment was undertaken for all motorised combined. It was implemented as a factor, with destination choice plus the purpose split and directionality ratios preserved.

6.5.4 *Bus Removal*

The final remaining mode subtraction was to remove bus persons from the highway person trip matrix. The census Journey to Work (J2W) dataset is a P/A matrix of travel to work mode share between all LSOA / MSOA pairs and therefore provides a reliable indicator of mode share distribution. Implicitly, there is some indication of bus level of service availability encoded within the data however a limitation of any assumption from that would be an assumed equal propensity of different social groups to use the bus for commuting compared to other (and maybe to a lesser extent, business) trip purposes.

The process undertaken was as follows, and as presented in Figure 6-7:

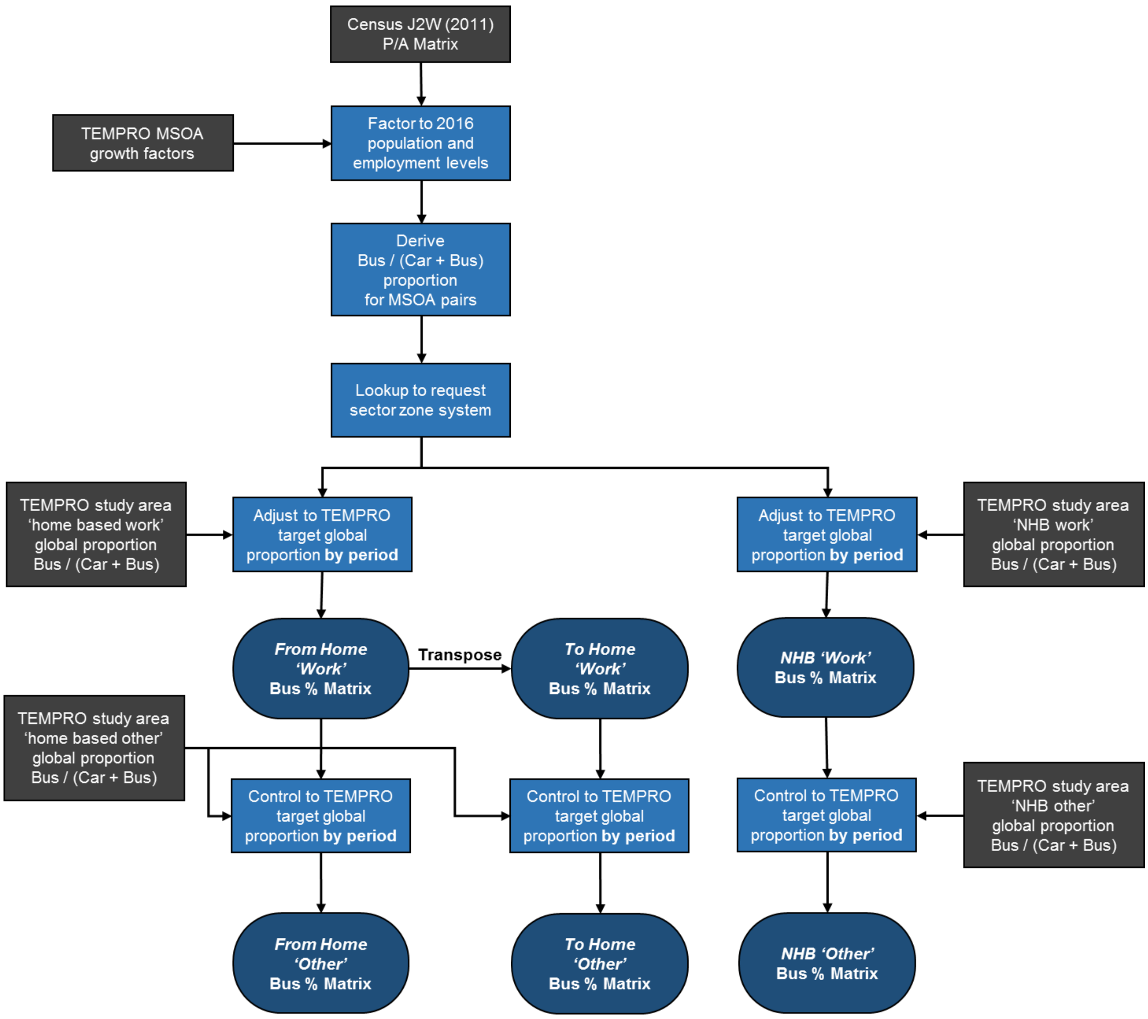
- MSOA to MSOA bus mode share proportion (versus car only) were calculated from J2W for zone pairs.
- For zone pairs with less than 5 observations, the global values, calculated for all OD pairs minus intra-London, were applied.
- This formed the basis of the MPOD ‘from home work’ distribution. It was adjusted by period by controlling to the global bus proportion (versus car only) from TEMPRO (see Table 6-6) to form the period bus proportion removal matrices for ‘from home work’.

- The transpose of these, by period, were taken as the ‘to home work’ period bus proportion removal matrices. The ‘from home work’ matrix was used for non-home based as a measure of the availability of bus services in the origin zone.
- Target overall proportions for bus mode share (against car) were derived from TEMPRO for MPOD ‘other’ (which at this stage still comprised of other and business) by direction and time period. By direction, the ‘work’ distributions were controlled to the TEMPRO global targets for their respective ‘other’ direction to derive the ‘from home / to home / nhb other’ removal bus proportion matrices.

Table 6-6 Target Bus Mode Share (versus Car) by MPOD Purpose

Purpose	AM Peak	Inter Peak	PM Peak
Home Based ‘Work’	16%	16%	12%
Home Based ‘Other’	9%	15%	9%
Non-Home Based ‘Work’	4%	6%	7%
Non-Home Based ‘Other’	4%	7%	7%

Figure 6-7 Bus Mode Share Proportion Matrix Development Process



6.5.5 *Purpose Split*

As referenced earlier, the MPOD purpose split was categorised as 'work' (i.e. commuting) or 'other' (i.e. business and other). However, the verification tests suggested that education trips may be included within the 'work' category. A 'work' location in MPOD was identified through frequency and time of day analysis and it is stated in the Citilogik methodology note that up to two 'work' locations were tracked per device. Since an education trip may be undertaken frequently by parents through pick up and drop off, this is not inconsistent with how 'work' trips are inferred. Based on the verification evidence, education trips were assumed to be contained within 'work'.

Therefore, two purpose splits were required:

- 'Other' to be segmented into other and employer business; and
- 'Work' to be segmented into commuting and education (with education added into other for assignment user class).

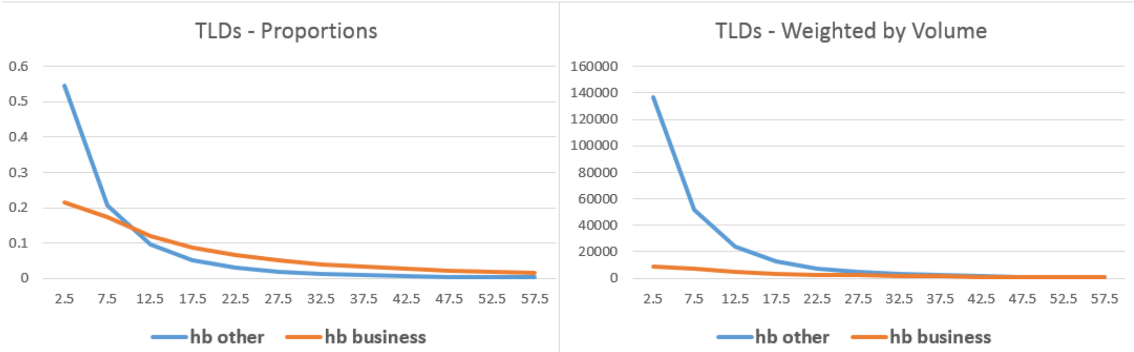
Purpose split varies by distance – typically other will have the largest proportion of shorter distance trips whereas business will have a higher average trip length. Therefore, a continuous function was required to implement the purpose splits varying by distance.

This was required for twelve scenarios defined by the following variables:

- Purposes: other/business and commute/education;
- Periods: am peak, inter peak and pm peak;
- Directions: home based and non-home based.

For example, consider the split between other/business for home based trips in the AM peak. The left graph in Figure 6-8 shows the NTS trip length distribution fitted to a log normal distribution for other and business independently. At ~12.5km business has the higher proportion however that doesn't take into account other typically has a much higher volume than business – the right hand graph shows the same trip length distributions but weighted by their respective volume from TEMPRO.

Figure 6-8 Example of Purpose Split Variation by Distance



A continuous function f was derived as the ratio of the other (blue) curve against the business (orange) curve from the right-hand graph. It was established, through testing curves from various families (including logarithmic, power and exponential), that f should be a polynomial, in this case of degree three (i.e. cubic).

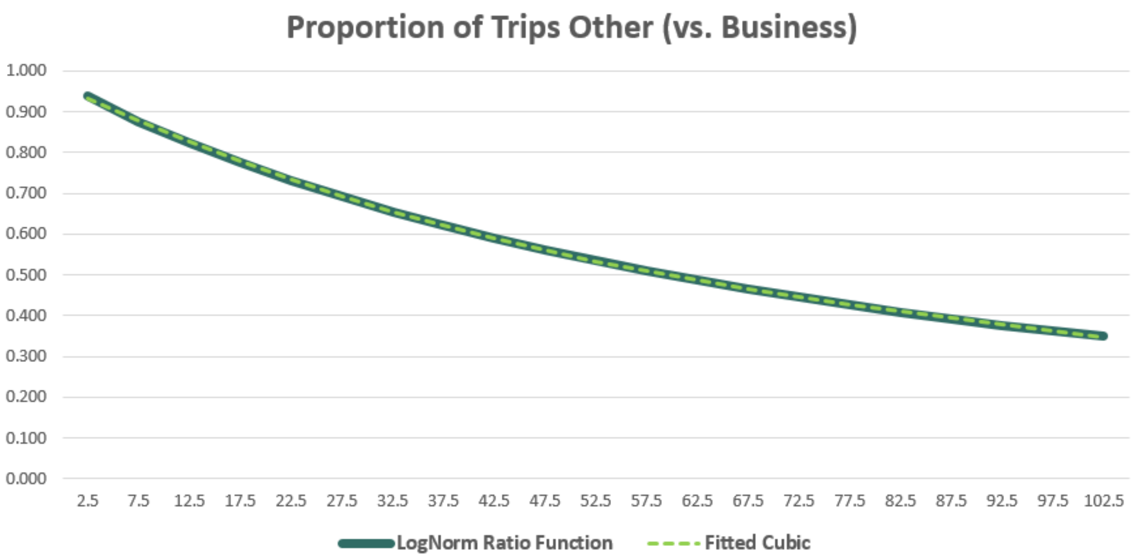
With the above definition, from zone i to zone j with distance x km:

- $f(x)$: the proportion of trips to be classified as other; and
- $1 - f(x)$: the proportion of trips to be classified as business.

The function f is plotted in Figure 6-9 below.

Note due to small sample size in NTS for trips greater than 105km, an upper bound was placed on the range for which f was derived – this helped in preventing issues around overfitting a higher degree polynomial due to noise from low sampling. Therefore, it was defined $f(x) = f(102.5)$ for $x > 102.5$.

Figure 6-9 Example of Purpose Split Fitted Curve



A similar approach was undertaken for the remaining scenarios defined above. These are detailed in Appendix D.

6.5.6 *Request Sector Disaggregation*

There were two stages to the request sector disaggregation.

- Primarily, the disaggregation of request sectors to model zones within the area of detailed modelling. (Aside, there were a few cases of aggregating request sectors to model zones in the towns within the MPOD study area but not within proximity to the simulation area – for example Boston and Cleethorpes)
- Secondly, the reallocation of a proportion of the trips in Geofence zones to the external zones as a facet of the initial processing of the MPOD data raised in Section 6.3.

For the former, production and attraction weightings were derived for all zones within a request sector using census datasets for population and employment at output area level. These are summarised in Table 6-7 below. For some request sectors within the city centre, it was necessary to apply this method through inspection where the output area definitions where too large or random for the preferred zone boundaries and/or to be able to isolate specific sites of interest and car parks, which would not have their own specific output area.

Table 6-7 Request Sector Disaggregation Weightings

Purpose	Direction	Production Weight	Attraction Weight
Business / Commute	From Home	Population (16+)	Workday Population (All)
	To Home	Workday Population (All)	Population (16+)
	Non-Home Based	Workday Population (All)	Workday Population (All)
Other	From Home	Population (All)	Workday Population (Leisure and Services)
	To Home	Workday Population (Leisure and Services)	Population (All)
	Non-Home Based	Workday Population (All)	Workday Population (Leisure and Services)

There are two zones which comprised the current construction site area for the Transport Hub. These were given factors of zero for the base model and have been retained for forecast development zones when the Transport Hub will open.

TAG advises a purpose split for LGVs of 88:12 for business/non-business. Therefore, the disaggregation weightings used for business were taken for LGV as well as the most reasonable indicator from the data available.

For HGVs, open data from the Operator Licensing Business System (OLBS) was obtained consisting of a register of all goods and public service vehicle operator licence holders in Great Britain. The geographical locations were mapped to zone to derive HGV splitting factors for the request sectors, weighted by the number of licenses held. A sense check on the mapping showed the data points mapped to the industrial sites within Lincoln, as would be expected.

For the second stage, to redistribute trips from some Geofence zones back to the relevant external zones a lookup was derived, as shown in Table 6-8, with Google used to verify the major ‘entry’ (or exit) route to the Geofence for each of those zones. From this lookup, splitting factors were derived to redistribute some of the trips from the listed Geofence ‘entry’ sectors to the respective external zones. The areas under consideration were sufficiently large to use NTS data to derive the splitting factors based on volumes of trips in the sample to/from each of these areas and the MPOD study area for each group within an 'entry' sector.

Table 6-8 Redistribution to External Zones

External Zone	Geofence 'entry' Link	Geofence 'entry Sector
Scotland	A1	515 (North Yorkshire)
North East		
North West	M62	510 (West Yorkshire)
Wales	through West Midlands	522 (West Midlands)
South West		
South East	A1(M)	497 (Huntingdonshire)
London		
Bedfordshire		
Essex		
Hertfordshire		

6.5.7 *Preparation for Assignment*

The processed MPOD car matrices were still defined for person trips over peak periods, as per the original data specification. Occupancy values from the TAG Databook (July 2017) and peak hour factors derived from the commissioned ATCs were used to convert the matrices for peak hour vehicle trip assignment.

The GV matrices were defined in vehicle trips but required conversion to peak hour as per the car matrices. The derived PCU factor for HGVs was 2.25, see Section 5.11.

Table 6-9 Occupancy Factors

	Business	Commute	Other
AM Peak	1.13	1.16	1.15
Inter-Peak	1.13	1.15	1.14
PM Peak	1.71	1.82	1.79

Table 6-10 Modelled Peak Period Factors

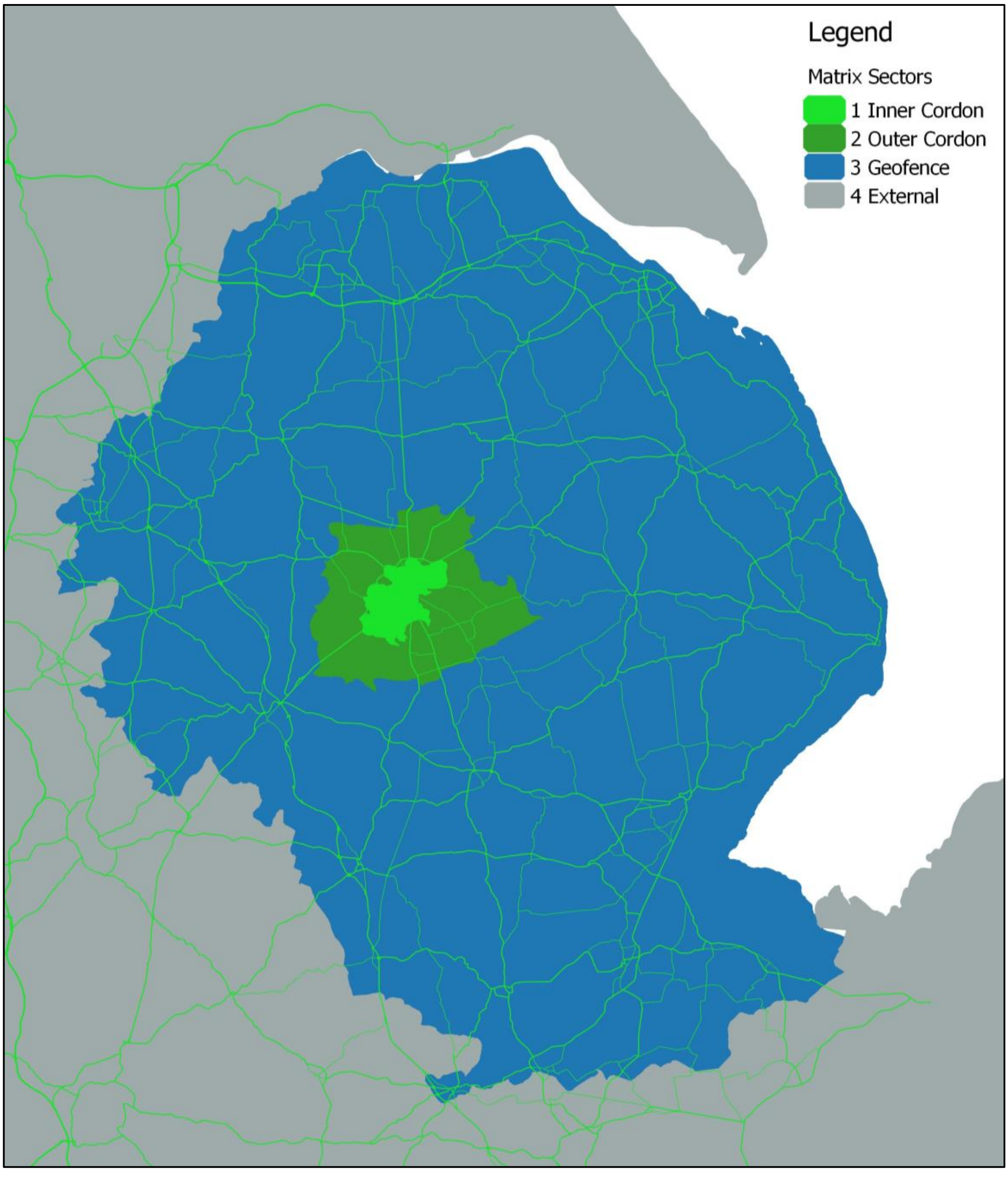
AM Peak (08:00 09:00)	Inter Peak (Ave. Hour)	PM Peak (17:00 18:00)
2.838	6	2.802

6.5.8 *Output MPOD matrix*

The output MPOD matrices are summarised in Table 6-11 at a sector level. The matrix sector definitions are illustrated in Figure 6-10 whereby:

- The inner cordon is defined by all zones within the existing bypass, LEB and proposed LSB;
- The outer cordon consists of the remaining zones within the simulation area roughly bounded up to Gainsborough in the north west, Newark in the south west, Sleaford in the south east and Market Rasen in the north east;
- The Geofence consists of the remaining zones within the MPOD study area as defined previously; and
- The external area consists of all zones outside of the MPOD study area.

Figure 6-10 Matrix Sectors



Lincolnshire COUNTY COUNCIL HIGHWAYS ALLIANCE

Table 6-11 MPOD Matrix Sector Summary by Purpose and Period

AM Peak

	Business	1	2	3	4	Total
1	Within Bypass Cordon	500	148	321	263	**1,233**
2	Within Outer Cordon	256	154	306	122	**838**
3	Within Geofence	586	279	10,962	7,090	**18,917**
4	External	300	80	6,734	6,491	**13,605**
	Total	**1,642**	**661**	**18,323**	**13,966**	**34,592**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	1,697	272	260	55	**2,283**
2	Within Outer Cordon	548	381	259	29	**1,217**
3	Within Geofence	544	237	23,554	4,769	**29,105**
4	External	93	14	3,962	5,537	**9,605**
	Total	**2,882**	**904**	**28,035**	**10,390**	**42,210**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	3,706	664	445	112	**4,926**
2	Within Outer Cordon	1,243	908	581	54	**2,786**
3	Within Geofence	844	583	45,191	7,567	**54,186**
4	External	140	36	7,510	10,476	**18,162**
	Total	**5,934**	**2,191**	**53,727**	**18,209**	**80,061**

Inter Peak

	Business	1	2	3	4	Total
1	Within Bypass Cordon	241	75	227	210	**752**
2	Within Outer Cordon	66	59	105	53	**283**
3	Within Geofence	189	118	5,573	4,191	**10,072**
4	External	203	61	4,452	4,172	**8,887**
	Total	**699**	**313**	**10,357**	**8,625**	**19,994**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	1,381	232	76	8	**1,697**
2	Within Outer Cordon	222	299	115	2	**638**
3	Within Geofence	60	117	16,575	816	**17,568**
4	External	6	1	905	2,623	**3,535**
	Total	**1,669**	**649**	**17,672**	**3,449**	**23,438**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	4,449	934	687	218	**6,288**
2	Within Outer Cordon	930	956	547	58	**2,490**
3	Within Geofence	668	558	51,646	8,331	**61,204**
4	External	250	78	9,251	11,870	**21,449**
	Total	**6,297**	**2,526**	**62,132**	**20,477**	**91,432**

PM Peak

	Business	1	2	3	4	Total
1	Within Bypass Cordon	253	105	227	152	**738**
2	Within Outer Cordon	86	79	130	34	**330**
3	Within Geofence	191	137	5,579	3,687	**9,594**
4	External	248	83	4,857	4,025	**9,213**
	Total	**778**	**404**	**10,794**	**7,899**	**19,875**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	2,736	531	388	76	**3,730**
2	Within Outer Cordon	371	533	245	12	**1,161**
3	Within Geofence	268	250	28,798	3,309	**32,626**
4	External	75	31	4,858	5,738	**10,701**
	Total	**3,450**	**1,345**	**34,289**	**9,135**	**48,219**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	4,175	1,062	757	129	**6,122**
2	Within Outer Cordon	900	984	608	28	**2,520**
3	Within Geofence	626	610	48,045	7,990	**57,271**
4	External	181	65	10,071	10,932	**21,249**
	Total	**5,882**	**2,721**	**59,481**	**19,079**	**87,163**

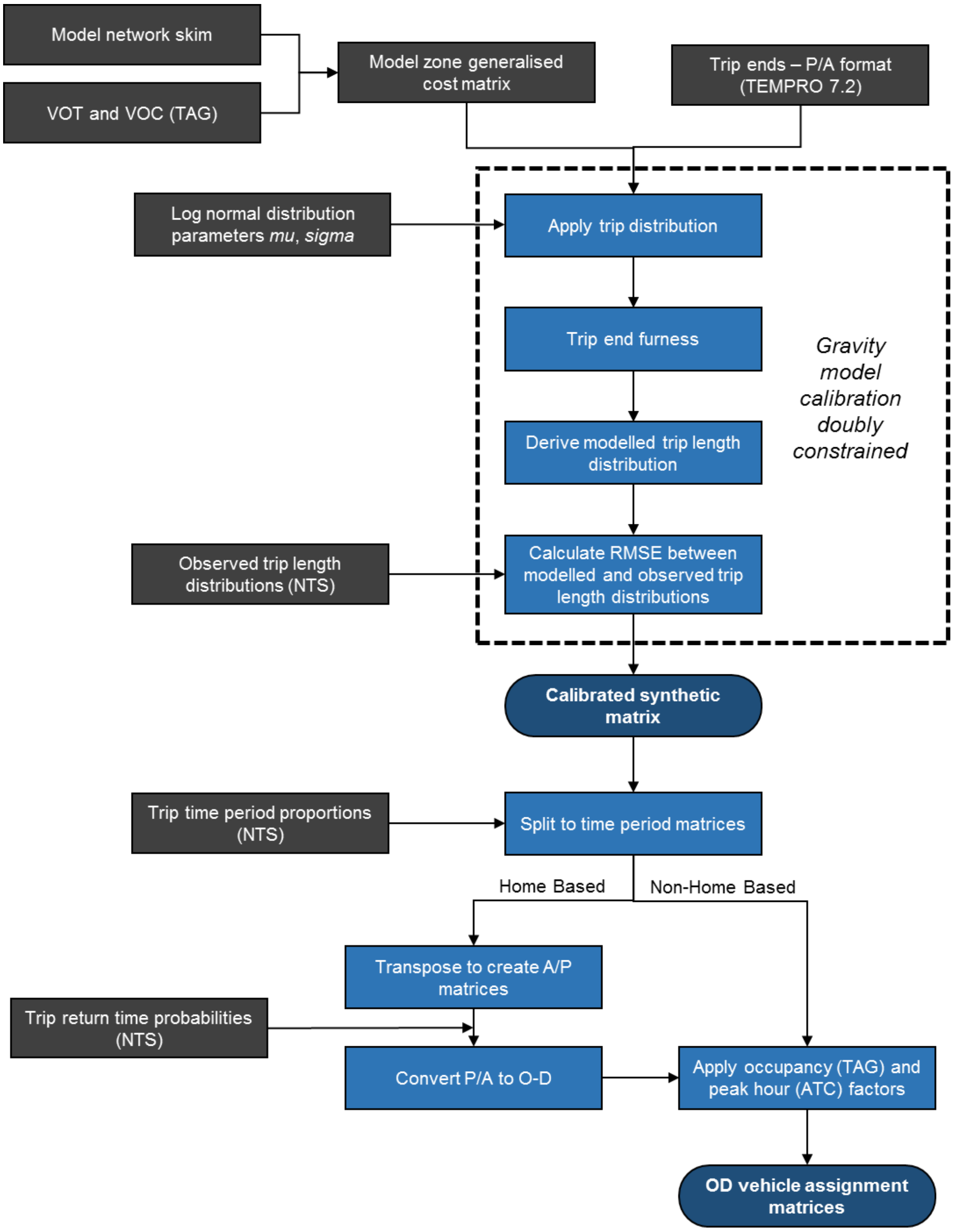
6.6 Synthetic Matrix Development

A set of synthetic matrices were required for two purposes:

- To directly infill anonymised and unobserved cells in the MPOD matrix; and
- To merge with the MPOD matrix for short distance trips, for which the verification tests had shown were underrepresented.

The process to develop the synthetic matrices is summarised in the flowchart in Figure 6-11.

Figure 6-11 Synthetic Matrix Development Process



6.6.1 Specification

The synthetic matrices were developed through calibrating a trip distribution to observed data. The shape of the observed data will therefore determine the trip distribution in the outturn matrices. Observed data was taken from the National Travel Survey (NTS) which contains travel diary records including origin area, destination area, trip purpose, mode, distance travelled and time taken.

Trip making characteristics will vary for different localities depending on factors including the area type, the quality of existing highway network against public transport availability and proximity to other urban centres which may have high levels of inter-connectivity.

It is preferable to take observed data at the most local spatial level available – in this case Lincolnshire – however the sample size was insufficient to split the data by time period.

Various extensions to the range of the survey area were considered including neighbouring counties or the East Midlands region. However, for the latter, it would be expected that Lincoln would have a different trip making pattern than the other larger urban areas in the region including Derby, Leicester, Nottingham and Northampton which have greater transport connectivity options. This was demonstrated through comparing the trip length distribution (TLD) for Lincolnshire against that for all of the East Midlands.

Therefore, it was decided to calibrate the gravity models at a daily level to the Lincolnshire trip length profile with period split to be applied afterwards, as opposed to running time period models on trip length profiles from a wider area, less appropriate for Lincoln.

6.6.2 Input Data

The following inputs were prepared for use in the synthetic matrix build.

- Trip ends: productions and attractions extracted from TEMPRO for an average weekday to match the specification, see above, by period, assignment purpose and direction (home based or non-home based);
- Cost skims: distance, time and toll skims for each time period by assignment purpose from an MPOD matrix assignment to ensure some representation of delays were included in the outturn costs;
- Values of time and vehicle operating costs for each assignment purpose and period from WebTAG – these were used to combine the cost skims into a single matrix of generalised cost by purpose (with a weighted average to combine the three time periods across purpose); and
- Observed daily trip length distribution profiles from NTS for Lincolnshire by purpose and direction (home based or non-home based).

6.6.3 Gravity Model Application

The distribution of origin productions to destination zones was undertaken using a gravity model approach. A bespoke application was used which utilises Microsoft Excel as a front end for SATURN in-built matrix applications through defining and running an iterative search on the parameters for the chosen deterrence function to optimise the outturn trip length distribution based on the zonal trip ends and pairwise generalised costs that has the closed fit to the observed trip length distribution.

In a trip distribution context, the attractiveness between two zones is proportional to the product of the productions from the origin zone and the attractions to the destination zone. The divisor is taken to be a more sophisticated function of generalised cost rather than simply distance – in this instance the log normal.

The 'attractiveness' from zone i to zone j,F_{ij} , by purpose is defined to be the value of the log-normal function with some fitted purpose specific parameters μ and σ:

$$F_{ij} = \frac{1}{x\sigma\sqrt{2\pi}} exp\left[-\frac{(lnx-\mu)^2}{2\sigma^2}\right], x > 0$$

where $x$is the generalised cost of travel between zone i to zone j.

Define:

- $P_i$to be the number of productions for zone i
- A_i to be the number of attractions for zone j

The number of trips from zone i to zone j in the gravity model is given by:

$$t_{ij} = P_i \frac{A_j F_{ij}}{\sum_x A_x F_{ix}}.$$

The application was run for six purposes generating six daily synthetic matrices. The calibrated parameters are shown in Table 6-12 below.

Table 6-12 Calibrated Log-Normal Parameters

Purpose	mu	sigma
Home based business	2.75	0.71
Home based commute	2.54	0.61
Home based other	2.37	0.64
Non-home based business	2.81	0.68
Non-home based commute	2.53	0.58
Non-home based other	2.56	0.59

6.6.4 Conversion to OD

NTS data for Lincolnshire was analysed, firstly, to derive the time period split factors by purpose for the daily from home (outbound) and non-home based matrices which had been developed from the gravity model.

Table 6-13 Synthetic Matrix - Time Period Disaggregation Factors

Purpose	AM	IP	PM	OP
Business from home	0.56	0.28	0.08	0.08
Commute from home	0.67	0.13	0.05	0.15
Other from home	0.27	0.44	0.16	0.12
Business non-home based	0.18	0.59	0.18	0.04
Commute non-home based	0.60	0.33	0.04	0.03
Other non-home based	0.11	0.58	0.23	0.08

To convert the home based PA matrices to origin-destination for each purpose the home based (outbound) matrices for all periods were transposed creating the respective AP matrices. The inbound matrix for each period was then derived as the sum of a proportion of each of the AP matrices using time period trip return probability matrices derived from NTS data for Lincolnshire. The factors are tabulated in Table 6-14.

Table 6-14 Synthetic Matrix - Trip Return Probabilities

Business		IN			
		AM	IP	PM	OP
OUT	AM	0.07	0.47	0.38	0.08
	IP	0.00	0.44	0.32	0.24
	PM	0.00	0.00	0.29	0.71
	OP	0.09	0.56	0.30	0.05
Commute		**IN**			
		AM	IP	PM	OP
OUT	AM	0.03	0.21	0.72	0.05
	IP	0.00	0.16	0.47	0.38
	PM	0.00	0.00	0.27	0.73
	OP	0.01	0.33	0.55	0.12
Other		**IN**			
		AM	IP	PM	OP
OUT	AM	0.10	0.70	0.15	0.04
	IP	0.00	0.66	0.29	0.05
	PM	0.00	0.00	0.27	0.73
	OP	0.07	0.06	0.02	0.84

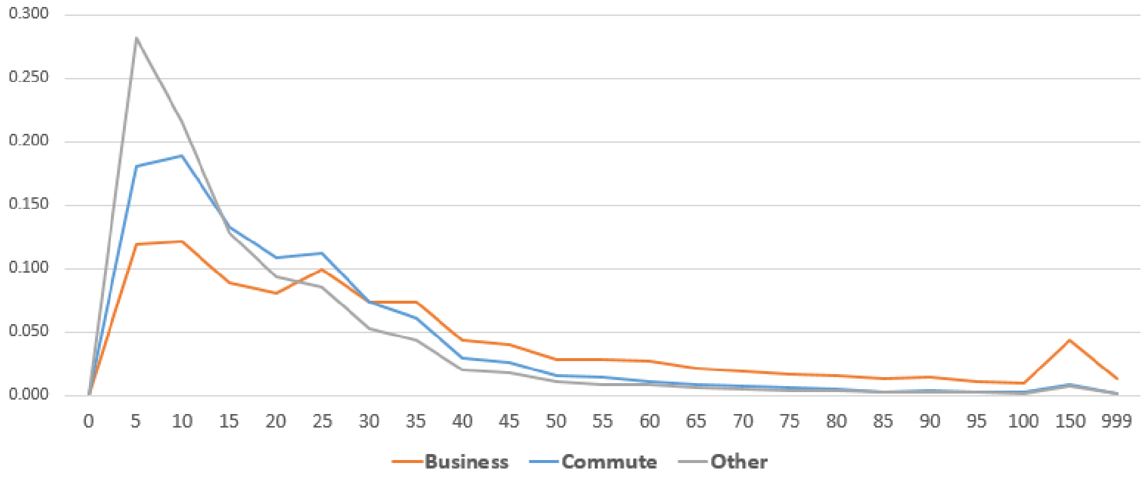
6.6.5 *Preparation for Assignment*

The occupancy and peak hours given above in Table 6-9 and Table 6-10 respectively were used to convert the matrices into peak hour vehicle trips for assignment.

The resultant matrices were specified by assignment purpose, by time period but disaggregated by direction (from home, to home and non-home based) for the matrix merge which required differentiation by direction.

The graphs below in Figure 6-12 shows the daily trip length distribution for the outturn synthetic matrices by purpose, with external-external trips removed since they are not calibrated. The secondary peak around 20-25km, most noticeably for business but also to a lesser extent for commute and other, is the roughly the distance from Lincoln centre to Gainsborough and Newark (plus Sleaford and Market Rasen) as the nearest adjacent towns which explains the increased interaction for that distance band.

Figure 6-12 Synthetic Matrices – Daily Trip Length Distribution by Purpose



6.6.6 *Output Synthetic Matrix*

The output synthetic matrices are summarised in Table 6-15 at a sector level.

Table 6-15 Synthetic Matrix Sector Summary by Purpose and Period

AM Peak

	Business	1	2	3	4	Total
1	Within Bypass Cordon	708	107	316	541	**1,672**
2	Within Outer Cordon	224	27	78	149	**478**
3	Within Geofence	322	44	5,726	2,167	**8,259**
4	External	223	50	2,089	427,843	**430,204**
	Total	**1,477**	**228**	**8,208**	**430,700**	**440,614**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	4,364	642	887	303	**6,196**
2	Within Outer Cordon	1,576	193	320	116	**2,205**
3	Within Geofence	1,331	220	40,028	7,434	**49,013**
4	External	259	52	8,176	2,630,531	**2,639,019**
	Total	**7,530**	**1,107**	**49,411**	**2,638,385**	**2,696,432**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	5,792	752	699	178	**7,422**
2	Within Outer Cordon	1,827	272	207	54	**2,359**
3	Within Geofence	1,532	247	35,883	4,265	**41,928**
4	External	257	36	5,108	2,008,983	**2,014,386**
	Total	**9,408**	**1,308**	**41,897**	**2,013,480**	**2,066,094**

Inter Peak

	Business	1	2	3	4	Total
1	Within Bypass Cordon	811	120	276	235	**1,442**
2	Within Outer Cordon	120	12	34	70	**237**
3	Within Geofence	315	26	4,742	1,807	**6,890**
4	External	253	57	1,880	351,984	**354,174**
	Total	**1,499**	**214**	**6,932**	**354,097**	**362,742**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	1,360	271	319	73	**2,024**
2	Within Outer Cordon	252	27	43	22	**344**
3	Within Geofence	327	33	9,295	1,846	**11,501**
4	External	87	18	1,837	605,632	**607,574**
	Total	**2,027**	**349**	**11,494**	**607,573**	**621,443**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	8,372	1,601	1,425	290	**11,688**
2	Within Outer Cordon	1,355	215	217	72	**1,858**
3	Within Geofence	1,435	171	51,724	6,987	**60,317**
4	External	334	63	6,954	2,880,063	**2,887,414**
	Total	**11,495**	**2,050**	**60,320**	**2,887,411**	**2,961,276**

PM Peak

	Business	1	2	3	4	Total
1	Within Bypass Cordon	591	151	309	216	**1,266**
2	Within Outer Cordon	81	20	49	40	**190**
3	Within Geofence	322	52	4,584	1,655	**6,612**
4	External	270	92	1,746	340,927	**343,034**
	Total	**1,263**	**314**	**6,688**	**342,837**	**351,103**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	3,694	1,328	1,436	305	**6,763**
2	Within Outer Cordon	598	173	253	67	**1,091**
3	Within Geofence	1,124	256	37,089	7,588	**46,057**
4	External	310	100	6,927	2,435,034	**2,442,371**
	Total	**5,726**	**1,857**	**45,705**	**2,442,994**	**2,496,282**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	7,405	1,929	1,728	301	**11,362**
2	Within Outer Cordon	1,110	316	287	56	**1,768**
3	Within Geofence	1,523	290	45,384	6,037	**53,235**
4	External	359	86	5,964	2,535,673	**2,542,082**
	Total	**10,397**	**2,621**	**53,363**	**2,542,066**	**2,608,448**

6.7 Matrix Merging

The matrix merge was a two stage process:

- Firstly, the anonymised cells – identified from the raw MPOD data as having a rounded value '15' –were adjusted to the respective volumes in the synthetic matrix by period, purpose and direction. The MPOD data had identified these trips – distinct from zero trip movements – but with an upper bound on the volume so the synthetic matrix was used to adjust for this. (Whilst it is plausible that a cell could have a genuine value of '15', there was no mechanism for the modelling team to distinguish these from an anonymised '15'; it was assumed the former would be a low, if not negligible, proportion of the cells with value '15' over the twenty-eight day data capture period).
- Secondly, the short distance cells were blended with a ratio of 90:10 for synthetic versus MPOD by period and purpose. This was calibrated, through testing, for a distance cut-off of 10km.Trips with distance greater than 10km were retained as 100% from MPOD. The only exception was the cells for trips to/from the twenty-seven zero trip zones in the MPOD matrix which had to be infilled with 100% from the synthetic matrices by period, purpose and direction.

The outturn of this process, illustrated in Figure 6-13, were the prior matrices for calibration. The proportion of MPOD trips in the prior matrices by sector are presented in Table 6-16.

Figure 6-13 Matrix Merging Process

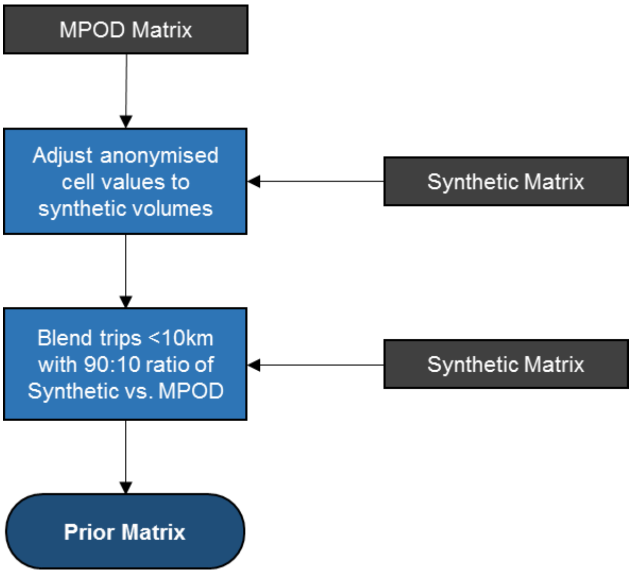


Table 6-16 Proportion of MPOD Trips in Prior Matrix by Sector

	Cars - AM Peak	1	2	3	4	Total
1	Within Bypass Cordon	12%	36%	98%	100%	**29%**
2	Within Outer Cordon	32%	71%	98%	100%	**57%**
3	Within Geofence	97%	98%	78%	99%	**83%**
4	External	100%	100%	99%	92%	**93%**
	Total	**33%**	**67%**	**82%**	**93%**	**86%**

	Cars - Inter Peak	1	2	3	4	Total
1	Within Bypass Cordon	10%	28%	98%	100%	**25%**
2	Within Outer Cordon	32%	81%	98%	100%	**61%**
3	Within Geofence	98%	99%	78%	99%	**81%**
4	External	100%	100%	99%	75%	**81%**
	Total	**25%**	**58%**	**82%**	**81%**	**77%**

	Cars - PM Peak	1	2	3	4	Total
1	Within Bypass Cordon	13%	34%	98%	100%	**33%**
2	Within Outer Cordon	40%	74%	97%	100%	**67%**
3	Within Geofence	98%	98%	78%	99%	**82%**
4	External	100%	100%	99%	93%	**94%**
	Total	**30%**	**57%**	**82%**	**93%**	**86%**

6.8 Prior Matrices

The prior matrices are summarised in Table 6-17 at a sector level.

Lincolnshire COUNTY COUNCIL HIGHWAYS ALLIANCE

Table 6-17 Prior Matrix Sector Summary by Purpose and Period

AM Peak

	Business	1	2	3	4	Total
1	Within Bypass Cordon	743	149	484	545	1,920
2	Within Outer Cordon	292	88	335	197	912
3	Within Geofence	771	289	12,610	8,041	21,711
4	External	390	100	7,741	15,927	24,158
	Total	2,195	626	21,171	24,710	48,702

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	4,243	547	569	115	5,473
2	Within Outer Cordon	1,353	289	330	54	2,026
3	Within Geofence	1,105	278	47,535	8,777	57,696
4	External	145	23	8,152	88,526	96,846
	Total	6,846	1,138	56,585	97,472	162,041

	Other	1	2	3	4	Total
1	Within Bypass Cordon	5,593	724	620	135	7,071
2	Within Outer Cordon	1,573	571	554	60	2,757
3	Within Geofence	1,028	555	53,264	8,253	63,099
4	External	142	38	8,260	21,138	29,578
	Total	8,335	1,887	62,697	29,586	102,505

	LGV	1	2	3	4	Total
1	Within Bypass Cordon	1,216	235	366	96	1,913
2	Within Outer Cordon	350	217	264	57	888
3	Within Geofence	438	208	10,279	2,562	13,486
4	External	104	37	2,204	23,563	25,909
	Total	2,108	697	13,112	26,279	42,195

	HGV	1	2	3	4	Total
1	Within Bypass Cordon	525	146	234	60	964
2	Within Outer Cordon	160	111	138	33	442
3	Within Geofence	262	116	6,194	1,539	8,111
4	External	58	18	1,334	1,131	2,542
	Total	1,005	390	7,900	2,763	12,059

Inter Peak

	Business	1	2	3	4	Total
1	Within Bypass Cordon	754	112	315	265	1,446
2	Within Outer Cordon	113	30	111	72	326
3	Within Geofence	287	123	7,227	4,698	12,334
4	External	259	77	4,960	9,587	14,883
	Total	1,413	341	12,613	14,622	28,989

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	1,439	261	198	24	1,923
2	Within Outer Cordon	250	140	99	6	494
3	Within Geofence	186	97	18,974	1,802	21,060
4	External	28	4	1,884	11,451	13,367
	Total	1,904	502	21,156	13,282	36,844

	Other	1	2	3	4	Total
1	Within Bypass Cordon	8,029	1,379	914	232	10,554
2	Within Outer Cordon	1,216	545	516	62	2,339
3	Within Geofence	929	517	66,933	9,392	77,771
4	External	282	85	10,314	18,099	28,780
	Total	10,456	2,526	78,677	27,786	119,444

	LGV	1	2	3	4	Total
1	Within Bypass Cordon	943	182	226	70	1,421
2	Within Outer Cordon	163	148	128	27	466
3	Within Geofence	226	131	7,389	1,466	9,212
4	External	67	31	1,524	24,034	25,655
	Total	1,399	491	9,267	25,597	36,754

	HGV	1	2	3	4	Total
1	Within Bypass Cordon	348	173	142	42	705
2	Within Outer Cordon	132	49	78	7	266
3	Within Geofence	168	117	4,829	975	6,089
4	External	37	27	999	1,073	2,136
	Total	686	366	6,047	2,097	9,196

PM Peak

	Business	1	2	3	4	Total
1	Within Bypass Cordon	578	143	314	199	1,234
2	Within Outer Cordon	94	46	137	45	323
3	Within Geofence	324	147	7,095	4,177	11,743
4	External	321	100	5,352	10,533	16,307
	Total	1,317	436	12,898	14,954	29,606

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	3,753	1,105	945	134	5,937
2	Within Outer Cordon	496	321	274	25	1,116
3	Within Geofence	590	289	48,231	7,741	56,852
4	External	129	47	8,484	93,283	101,942
	Total	4,968	1,763	57,935	101,182	165,847

	Other	1	2	3	4	Total
1	Within Bypass Cordon	7,291	1,849	1,543	242	10,926
2	Within Outer Cordon	997	660	635	48	2,340
3	Within Geofence	927	626	64,499	9,702	75,754
4	External	208	76	11,380	29,127	40,791
	Total	9,424	3,211	78,057	39,119	129,811

	LGV	1	2	3	4	Total
1	Within Bypass Cordon	864	213	256	62	1,394
2	Within Outer Cordon	168	152	153	27	500
3	Within Geofence	229	148	6,717	1,340	8,434
4	External	68	31	1,581	18,002	19,682
	Total	1,329	544	8,707	19,431	30,011

	HGV	1	2	3	4	Total
1	Within Bypass Cordon	207	52	136	25	420
2	Within Outer Cordon	90	22	61	6	180
3	Within Geofence	114	86	3,051	606	3,856
4	External	25	18	714	392	1,149
	Total	435	178	3,962	1,029	5,605

Prior to the calibration validation process, the following steps have been checked to evaluate the prior matrices:

- Verify purpose split against TAG; and
- Verify prior assignment flows against observed counts for trips that cross the study cordon.

Table 6-18 below shows the purpose split against those given in the TAG Databook. There is a close similarity for business, with some over-estimation of commute versus other. This may be a facet of the education trips, since school pick up or drop off may be part of trip tour on the way from or to work.

Table 6-18 Prior Matrix - Purpose Split

	Prior Matrix			TAG Databook		
	Business	**Commute**	**Other**	**Business**	**Commute**	**Other**
AM Peak	15.5	51.7	32.7	16.5	44.1	39.5
Inter Peak	15.6	19.9	64.5	16.5	11.8	71.7
PM Peak	9.1	51.0	39.9	11.8	41.3	46.9

The prior matrices were assigned to the network and compared against the observed counts on the key strategic screenlines, in particular the bypass cordon which captures all trips into and out of the main urban area for Lincoln. The results are shown by period in Table 6-19, Table 6-20 and Table 6-21 respectively.

Table 6-19 Car Prior Matrix Comparison – AM Peak

Cars Only	Obs.	Mod.	Diff.	%Diff.	GEH
Inbound					
Northern Bypass	2,275	2,494	219	10%	4.5
Eastern Bypass	2,635	2,715	81	3%	1.6
Southern Bypass	2,525	2,413	-112	-4%	2.3
Western Bypass	867	725	-142	-16%	5.0
Total	**8,302**	**8,348**	**46**	**1%**	**0.5**
Outbound					
Northern Bypass	1,535	1,468	-67	-4%	1.7
Eastern Bypass	1,338	1,468	130	10%	3.5
Southern Bypass	2,037	2,164	128	6%	2.8
Western Bypass	855	842	-12	-1%	0.4
Total	**5,764**	**5,942**	**178**	**3%**	**2.3**

Table 6-20 Car Prior Matrix Comparison – Inter Peak

Cars Only	Obs.	Mod.	Diff.	%Diff.	GEH
Inbound					
Northern Bypass	1,479	1,477	-2	0%	0.1
Eastern Bypass	1,570	1,548	-22	-1%	0.6
Southern Bypass	1,637	1,759	122	7%	3.0
Western Bypass	593	518	-74	-13%	3.2
Total	**5,280**	**5,303**	**23**	**0%**	**0.3**
Outbound					
Northern Bypass	1,454	1,487	33	2%	0.9
Eastern Bypass	1,710	1,673	-36	-2%	0.9
Southern Bypass	1,605	1,735	131	8%	3.2
Western Bypass	557	540	-17	-3%	0.7
Total	**5,326**	**5,436**	**111**	**2%**	**1.5**

Table 6-21 Car Prior Matrix Comparison – PM Peak

Cars Only	Obs.	Mod.	Diff.	%Diff.	GEH
Inbound					
Northern Bypass	1,845	1,627	-218	-12%	5.2
Eastern Bypass	1,624	1,431	-193	-12%	4.9
Southern Bypass	2,649	2,302	-346	-13%	7.0
Western Bypass	870	881	11	1%	0.4
Total	**6,988**	**6,242**	**-746**	**-11%**	**9.2**
Outbound					
Northern Bypass	2,363	2,302	-61	-3%	1.3
Eastern Bypass	2,923	2,807	-116	-4%	2.2
Southern Bypass	2,388	2,122	-266	-11%	5.6
Western Bypass	945	680	-264	-28%	9.3
Total	**8,618**	**7,911**	**-708**	**-8%**	**7.8**

All of the bypass screenlines are within GEH < 4 for inter-peak, with two exceptions in the AM peak but five exceptions in the PM peak, where four of those have a percentage difference of roughly -12% which is considered acceptable for the prior matrix.

For AM peak and inter peak, although some GEH and flow are in excess of the TAG criteria at individual screenline level, the total trips crossing the cordon are very close to the observed counts. This indicates some limitations of the MPOD data through the expansion to population at a localised level for specific areas of high or low market share and/or different demographics resulting in some high and low movements but, when, combined over the total screenline, have the correct order of magnitude at a trip end level.

For the PM peak, there is an overall underestimation of trips of roughly 10%. Whereas the AM peak has a more habitual nature of trip making (i.e. commute to work, school drop off etc.), the PM peak typically has more trip making variety and a greater propensity for trip chaining (e.g. evening clubs and events, shopping etc.). The dwell time to define a trip in the MPOD matrix was calibrated by Citilogik to be thirty minutes however this may have underestimated trips in the PM peak for those reasons aforementioned which, if drop-offs or short stays, may not have exceeded the minimum dwell.

There is an additional note for the PM peak on the Western Bypass outbound – this includes a count on Whisby Road west of the garden centre for which the modelled flow is lower than the observed data. There is a count to the east of the garden centre at the A46 junction for which the modelled flow is close to the observed data therefore this is a specific issue relating to trips in the PM leaving the garden centre which could not be fully rectified.

7 Highway Model Calibration

7.1 Introduction

This chapter outlines the calibration process undertaken for the GLHAM base year models. Standard techniques and best practice from TAG have been used to employ data from three work-streams to produce the calibrated base year highway models and validate these against existing data sources.

The calibration and validation process involved three sources of information:

- Traffic count ATC and journey time data collated and processed in accordance to the methodology set out in Chapter 4;
- Initial SATURN networks for each time period (AM peak, inter peak and PM peak) developed in accordance to the methodology set out in Chapter 5; and
- Initial trip matrices for each time period (AM peak, inter peak and PM peak) developed in accordance to the methodology set out in Chapter 6.

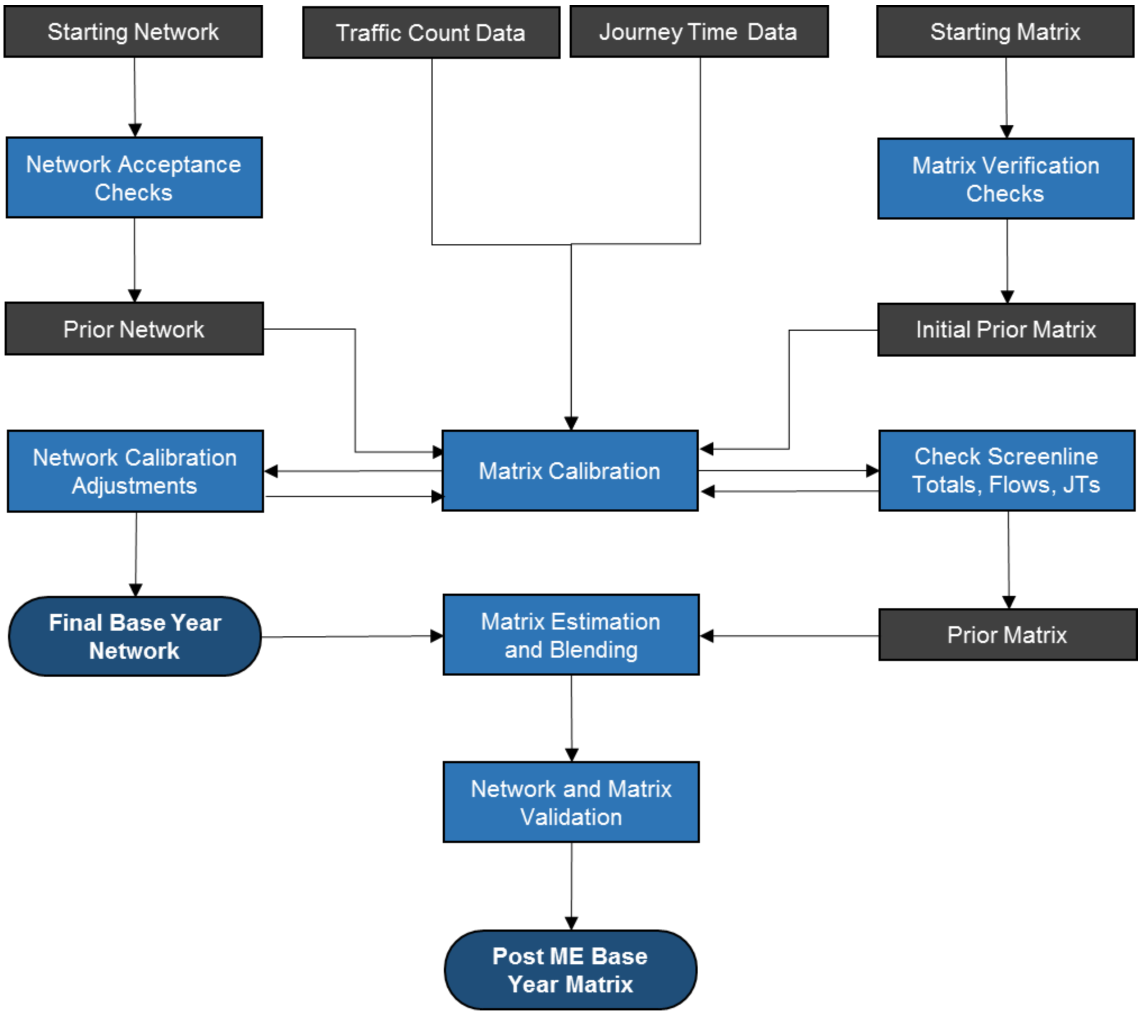
The process for calibrating the base year highway models is described in this chapter, including details of:

- Network calibration and checking;
- Local adjustments for matrix calibration;
- Prior matrix assignment reporting;
- The methodology for an application of matrix estimation within SATURN; and
- The impacts of matrix estimation against TAG guidance.

The highway model validation is covered in Chapter 8.

A summary of the calibration and validation process is illustrated in Figure 7-1 below.

Figure 7-1 Process for Calibration and Validation



7.2 Network Calibration – Acceptance Tests

Quality and calibration checks were carried out on the networks following the completion of network coding which were designed to assess the network suitability before moving into full calibration tasks. The rationale for the tests has been described previously in Section 3.4.

Detailed reporting of these checks can be found in Appendix E including tabulations and P1X outputs where relevant.

The summary results are presented below.

7.2.1 Test 1 – Network Completeness Check

The network was complete to the specification agreed in the MSR for the study area. As agreed with LCC, all roads within the study area had been coded in the simulation network and roads outside the study area had been coded as buffer network.

7.2.2 *Test 2 – SATURN Compilation Check*

The initial networks were built in SATNET which reported 1,256 *warnings* and 2,080 *serious warnings*. These were reviewed and adjusted if necessary. The outturn of this review was that the revised networks reported 320 *warnings* and 1,992 *serious warnings*.

7.2.3 *Test 3 – Inspection of Key Junctions*

All the major junctions/intersections in network have been coded. The network has been then reviewed and amended where appropriate to accommodate the detailed zones plan for the study area.

The following checks were completed:

- All junctions had the correct definitions;
- All junctions had consistent and appropriate representations based on the available data sources;
- Signalised junctions had correct timings based on the data available;
- Times to circle roundabouts were consistent and appropriate based on the data available; and
- Right turn on major arm definitions for priority junctions were applied consistently.

7.2.4 *Test 4 – Network Routeing*

Twenty-six strategic route options were tested in line with the TAG recommendation on number of routes to test.

All of the tested paths showed plausible routings, in particular for areas that are unexpectedly avoided or unexpectedly attractive on the unloaded network.

7.2.5 *Test 2 – SATURN Compilation Check*

It was verified against the specified acceptance criteria that:

- There was no change in link type between directions unless there is a specific justification such as a difference in speed limit or number of lanes;
- Dual carriageways had the same link type in both directions except where indicated by a difference such as speed limit or number of lanes; and
- The change in link type was consistent providing changes in speed limit when moving between urban and rural areas.

The percentage difference between the coded links lengths from SATURN and the crow-fly distances were checked for consistency.

7.2.6 *Test 6 – Flat Matrix Assignment*

The flat matrix assignment was checked against various measures:

- Routing between OD pairs (using a subset of those pairs from Test 4) appeared plausible with traffic using the major roads and taking the most obvious route in all cases;
- Bandwidths plots for actual flow showed a correct magnitude of difference between traffic on the strategic links and the minor roads; and
- Node delay plots for the urban area of Lincoln showed delay occurring at expected locations on key links in and around the city centre.

7.3 Network Calibration – Local Adjustments

As part of the calibration process, preliminary assignments were carried out using different iterations of the trip matrices to assist with debugging the networks. This needed to be carried out prior to running matrix estimation to prevent the matrix calibration from causing issues through compensating for network errors.

7.3.1 Delays and Flows

Additional network checks undertaken as part of the calibration included:

- Capacities versus observed counts;
- Modelled delays versus observed delays; and
- Modelled flows versus observed flows.

Where issues with the initial networks were identified, the parameters defining the capacity of movements were reviewed. The loading of zone connectors were reviewed and refined accordingly to represent more accurate loading of the traffic on to the network and to avoid issues with delays at major junctions due to loading directly to junctions.

7.3.2 Signalised Junctions

The initial assignments were reviewed to check that the levels of delay at signalised nodes was reasonable and to find the worst converged nodes. For the problem areas, local signal optimisation was used as a proxy to represent varying signal timings under maximum / minimum green times. However, before being adopted into the networks the outturn timings were examined to assure the outturn was sensible for that particular junction and the hierarchy of routes into it.

7.4 Matrix Calibration – Prior Matrix Assignments

The derived matrices, as detailed in Chapter 6, were assigned to the networks and reviewed at a screenline level to determine how they performed against the model validation criteria. The high level statistics for screenline performance and link/turn flow performance are reported in Table 7-1 and Table 7-2 below.

Table 7-1 Screenline Performance Summary – Prior Matrices

Performance Measure	AM Peak	Inter Peak	PM Peak
All Screenlines and cordons within 10% of observed flows	62%	50%	38%
All Screenlines and cordons within GEH < 4 of observed flows	65%	47%	29%

Table 7-2 Link Flow Performance Summary – Prior Matrices

Performance Measure	AM Peak	Inter Peak	PM Peak
All Counts (853)			
Pass TAG Flow Criteria	82%	84%	82%
Pass TAG GEH Criteria	72%	73%	70%

The screenline summary by time period across the bypass screenlines – capturing the key strategic movements to and from the main urban area in the model – are presented in Table 7-3, Table 7-4 and Table 7-5 respectively. The inter-peak has a close adherence with all screenlines within GEH <4, with only one exception in the AM peak (which is within 10%) but a few screenlines showing low volumes of modelled trips compared to the observed counts in the PM peak.

Table 7-3 All Vehicles Prior Matrix Comparison – AM Peak

All Vehicles	Obs.	Mod.	Diff.	%Diff.	GEH
Inbound					
Northern Bypass	2,803	3,087	284	10%	5.2
Eastern Bypass	3,009	3,205	196	7%	3.5
Southern Bypass	3,134	2,951	-182	-6%	3.3
Western Bypass	1,063	982	-80	-8%	2.5
Total	**10,008**	**10,225**	**217**	**2%**	**2.2**
Outbound					
Northern Bypass	2,004	1,944	-60	-3%	1.4
Eastern Bypass	1,800	1,870	70	4%	1.6
Southern Bypass	2,610	2,792	182	7%	3.5
Western Bypass	1,039	1,153	114	11%	3.4
Total	**7,452**	**7,758**	**306**	**4%**	**3.5**

Table 7-4 All Vehicles Prior Matrix Comparison – Inter Peak

All Vehicles	Obs.	Mod.	Diff.	%Diff.	GEH
Inbound					
Northern Bypass	1,921	1,853	-68	-4%	1.6
Eastern Bypass	1,927	1,824	-103	-5%	2.4

Southern Bypass	2,088	2,189	102	5%	2.2
Western Bypass	744	698	-46	-6%	1.7
Total	**6,680**	**6,565**	**-116**	**-2%**	**1.4**
Outbound					
Northern Bypass	1,868	1,879	12	1%	0.3
Eastern Bypass	2,083	1,957	-126	-6%	2.8
Southern Bypass	2,052	2,222	169	8%	3.7
Western Bypass	706	684	-22	-3%	0.8
Total	**6,709**	**6,743**	**34**	**1%**	**0.4**

Table 7-5 All Vehicles Prior Matrix Comparison – PM Peak

All Vehicles	Obs.	Mod.	Diff.	%Diff.	GEH
Inbound					
Northern Bypass	2,271	1,962	-309	-14%	6.7
Eastern Bypass	1,975	1,637	-339	-17%	8.0
Southern Bypass	3,177	2,655	-523	-16%	9.7
Western Bypass	993	1,100	107	11%	3.3
Total	**8,416**	**7,353**	**-1063**	**-13%**	**12.0**
Outbound					
Northern Bypass	2,810	2,659	-151	-5%	2.9
Eastern Bypass	3,351	3,074	-276	-8%	4.9
Southern Bypass	2,794	2,450	-343	-12%	6.7
Western Bypass	1,125	847	-278	-25%	8.8
Total	**10,079**	**9,031**	**-1,048**	**-10%**	**10.7**

The prior matrix assignment results for cars only were discussed previously in Section 6.8. As referenced in that section, there was an overall under-representation of trips in the PM peak from the MPOD data, likely to be a result of more variable trip making and trip chaining in that period coupled with the dwell time used to identify a trip in the MPOD data. It was also referenced regarding the count on Whisby Road, relating to the specific issue of trips exiting the garden centre in the PM peak, which accounts for the further shortfall on the Western Bypass Outbound compared to the other screenlines.

7.5 Matrix Calibration – Matrix Estimation

The principle adopted for matrix estimation was that it should not excessively distort the prior demand but allow sufficient scope to reasonably improve the screenline validation.

7.5.1 Methodology for Matrix Estimation

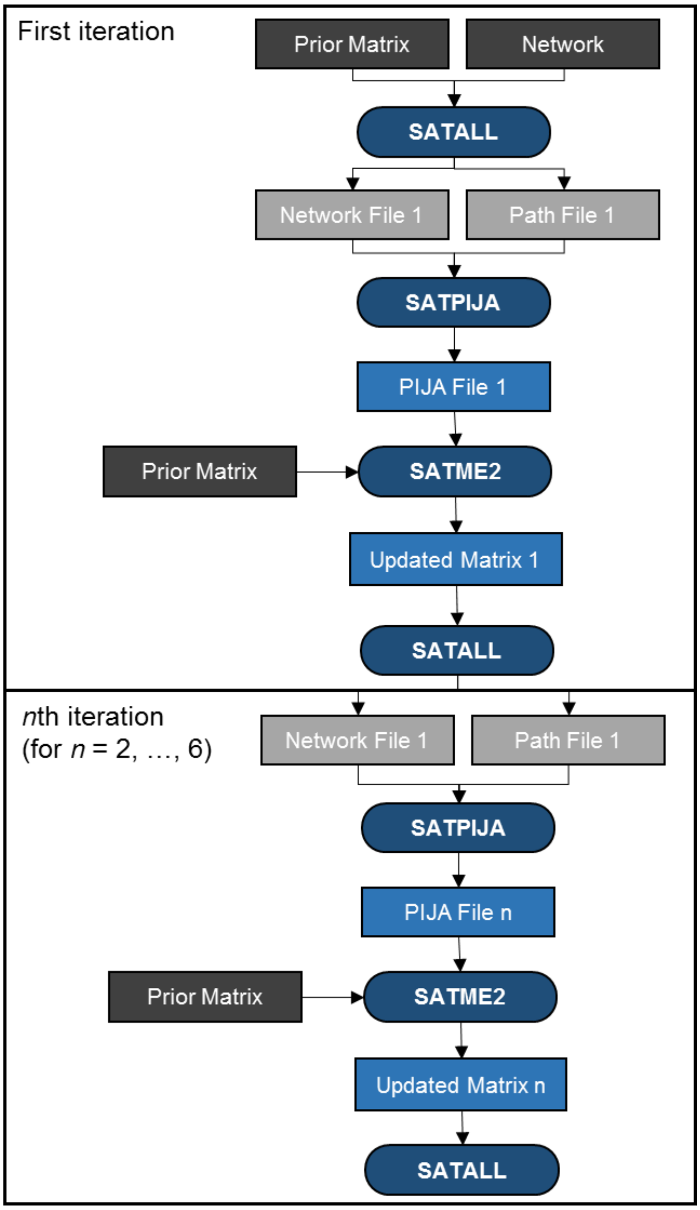
The matrix estimation process used an iterative approach to generate a matrix with improved calibration and validation in the model. Six iterations were used, whereby the PIJA factors were taken from the previous iteration but the original prior matrix was always used for the demand adjustment. This process is shown in Figure 7-2.

There are several parameters within SATURN that permit the user to control the extent of change that will be caused by the matrix estimation. The GLTM process has adopted the values which have been used successfully on previous studies by the modelling team including ones which utilised mobile phone data and similar matrix development techniques. The parameters are listed in Table 7-6.

Table 7-6 SATURN Constraints for Matrix Estimation

Parameter	Description	GLTM Value
XAMAX	The maximum balancing factor to be applied to avoid large changes to the prior matrix. (The minimum balancing factor is taken as the inverse)	Car: 2 LGV/HGV: 5
EPSILN	The convergence criteria for the difference between individual observed counts and their respective model flow.	0.001
ITERMX	The maximum number of iterations that will be run to achieve convergence.	199

Figure 7-2 Methodology for Matrix Estimation



A benefit of using mobile phone data is that it provides complete national coverage. Combined with the synthetic matrices infilling short distance trips there was no expectation of unobserved movements in the demand data. Therefore a SEED value was not used. The higher XAMAX value for the GV matrices reflects the lower confidence in the demand data used to derive those matrices.

7.5.2 *Impacts of Matrix Estimation – Zonal Cell Values*

The TAG criteria, reproduced in Table 3-2, provides the target criteria for regression analysis of zonal cell values, prior and post matrix estimation. The GLTM results are summarised in Table 7-7. The criteria were satisfied for each user class and period with one exception for HGV in the PM peak – the reasons for this are discussed further in Section 7.5.3.

Table 7-7 Impacts of Matrix Estimation – Zonal Cell Values Regression Statistics

Period	User Class	Aspect	Measure	Require	Value	Pass?
AM	Business	Zonal Cells	R^2	0.95	0.998	✓
			Slope	0.98 - 1.02	0.997	✓
			Intercept	Near zero	-0.005	✓
	Commute	Zonal Cells	R^2	0.95	1.000	✓
			Slope	0.98 - 1.02	1.000	✓
			Intercept	Near zero	-0.002	✓
	Other	Zonal Cells	R^2	0.95	1.000	✓
			Slope	0.98 - 1.02	1.000	✓
			Intercept	Near zero	-0.002	✓
	LGV	Zonal Cells	R^2	0.95	1.000	✓
			Slope	0.98 - 1.02	1.000	✓
			Intercept	Near zero	0.000	✓
	HGV	Zonal Cells	R^2	0.95	0.981	✓
			Slope	0.98 - 1.02	0.990	✓
			Intercept	Near zero	-0.001	✓
IP	Business	Zonal Cells	R^2	0.95	0.999	✓
			Slope	0.98 - 1.02	0.998	✓
			Intercept	Near zero	-0.002	✓
	Commute	Zonal Cells	R^2	0.95	1.000	✓
			Slope	0.98 - 1.02	1.000	✓
			Intercept	Near zero	0.000	✓
	Other	Zonal Cells	R^2	0.95	1.000	✓
			Slope	0.98 - 1.02	1.000	✓
			Intercept	Near zero	-0.002	✓
	LGV	Zonal Cells	R^2	0.95	1.000	✓
			Slope	0.98 - 1.02	1.000	✓
			Intercept	Near zero	0.002	✓
	HGV	Zonal Cells	R^2	0.95	0.978	✓
			Slope	0.98 - 1.02	0.993	✓
			Intercept	Near zero	0.000	✓
PM	Business	Zonal Cells	R^2	0.95	0.998	✓
			Slope	0.98 - 1.02	0.997	✓
			Intercept	Near zero	-0.002	✓
	Commute	Zonal Cells	R^2	0.95	1.000	✓
			Slope	0.98 - 1.02	1.000	✓
			Intercept	Near zero	-0.001	✓

	Other	Zonal Cells	R^2	0.95	1.000	✓
			Slope	0.98 - 1.02	1.000	✓
			Intercept	Near zero	0.000	✓
	LGV	Zonal Cells	R^2	0.95	1.000	✓
			Slope	0.98 - 1.02	1.000	✓
			Intercept	Near zero	0.003	✓
	HGV	Zonal Cells	R^2	0.95	0.887	×
			Slope	0.98 - 1.02	0.955	×
			Intercept	Near zero	0.001	✓

7.5.3 *Impacts of Matrix Estimation – Zonal Trip Ends*

The TAG criteria, reproduced in Table 3-2, provided the target criteria for regression analysis of zonal trip ends, prior and post matrix estimation. The GLTM results were summarised by period in Table 7-8,

Table 7-9 and Table 7-10 respectively below, with detailed reporting and graphs included in Appendix F.

For commute, other and LGVs, all criteria passed in all time periods. It is noted that for business, whilst the R^2 and intercept pass in all periods the slope did not. This is due to a reduction through the ME of long distance external trips on the A1, which is discussed in more detail under the trip length distribution checks in the next section. Although the HGV were developed using a similar methodology to the LGV, the LGV sample in TMOD was considered to be far higher due to the nature of vehicles tracked with the devices. The HGV were only very narrowly outside the criteria for R^2 and slope values, which, based on the sample, is not unreasonable.

Table 7-8 Impacts of Matrix Estimation –Trip End Regression Statistics AM

User Class	Aspect	Measure	Require	Value	Pass?
Business	Origins	R^2	>0.98	0.998	✓
		Slope	0.99 - 1.01	0.953	×
		Intercept	Near zero	-0.7	✓
	Destinations	R^2	>0.98	0.996	✓
		Slope	0.99 - 1.01	0.946	×
		Intercept	Near zero	-0.2	✓
Commute	Origins	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	0.998	✓
		Intercept	Near zero	-1.2	✓
	Destinations	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	0.997	✓
		Intercept	Near zero	-1.1	✓
Other	Origins	R^2	>0.98	0.999	✓

User Class	Aspect	Measure	Require	Value	Pass?
		Slope	0.99 - 1.01	0.991	✓
		Intercept	Near zero	-0.4	✓
	Destinations	R^2	>0.98	0.999	✓
		Slope	0.99 - 1.01	0.990	✓
		Intercept	Near zero	-0.2	✓
LGV	Origins	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	1.000	✓
		Intercept	Near zero	0.3	✓
	Destinations	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	0.999	✓
		Intercept	Near zero	0.4	✓
HGV	Origins	R^2	>0.98	0.973	×
		Slope	0.99 - 1.01	0.983	×
		Intercept	Near zero	-0.6	✓
	Destinations	R^2	>0.98	0.972	×
		Slope	0.99 - 1.01	0.985	×
		Intercept	Near zero	-0.6	✓

Table 7-9 Impacts of Matrix Estimation – Trip End Regression Statistics IP

User Class	Aspect	Measure	Require	Value	Pass?
Business	Origins	R^2	>0.98	0.997	✓
		Slope	0.99 - 1.01	0.957	×
		Intercept	Near zero	-0.2	✓
	Destinations	R^2	>0.98	0.998	✓
		Slope	0.99 - 1.01	0.956	×
		Intercept	Near zero	-0.2	✓
Commute	Origins	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	0.997	✓
		Intercept	Near zero	0.0	✓
	Destinations	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	0.997	✓
		Intercept	Near zero	0.0	✓
Other	Origins	R^2	>0.98	0.999	✓
		Slope	0.99 - 1.01	0.989	×
		Intercept	Near zero	0.3	✓
	Destinations	R^2	>0.98	0.999	✓
		Slope	0.99 - 1.01	0.989	×
		Intercept	Near zero	0.3	✓
LGV	Origins	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	1.001	✓
		Intercept	Near zero	1.8	✓
	Destinations	R^2	>0.98	1.000	✓

User Class	Aspect	Measure	Require	Value	Pass?
		Slope	0.99 - 1.01	1.001	✓
		Intercept	Near zero	1.8	✓
HGV	Origins	R^2	>0.98	0.967	×
		Slope	0.99 - 1.01	1.020	×
		Intercept	Near zero	-0.2	✓
	Destinations	R^2	>0.98	0.968	×
		Slope	0.99 - 1.01	1.021	×
		Intercept	Near zero	-0.2	✓

Table 7-10 Impacts of Matrix Estimation – Trip End Regression Statistics PM

User Class	Aspect	Measure	Require	Value	Pass?
Business	Origins	R^2	>0.98	0.996	✓
		Slope	0.99 - 1.01	0.954	×
		Intercept	Near zero	0.4	✓
	Destinations	R^2	>0.98	0.997	✓
		Slope	0.99 - 1.01	0.964	×
		Intercept	Near zero	-0.1	✓
Commute	Origins	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	0.998	✓
		Intercept	Near zero	-0.3	✓
	Destinations	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	0.998	✓
		Intercept	Near zero	-0.5	✓
Other	Origins	R^2	>0.98	0.999	✓
		Slope	0.99 - 1.01	0.992	✓
		Intercept	Near zero	1.3	✓
	Destinations	R^2	>0.98	0.999	✓
		Slope	0.99 - 1.01	0.993	✓
		Intercept	Near zero	1.0	✓
LGV	Origins	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	1.004	✓
		Intercept	Near zero	2.0	✓
	Destinations	R^2	>0.98	1.000	✓
		Slope	0.99 - 1.01	1.003	✓
		Intercept	Near zero	2.0	✓
HGV	Origins	R^2	>0.98	0.892	×
		Slope	0.99 - 1.01	1.061	×
		Intercept	Near zero	-0.1	✓
	Destinations	R^2	>0.98	0.931	×
		Slope	0.99 - 1.01	1.061	×
		Intercept	Near zero	-0.1	✓

7.5.4 *Impacts of Matrix Estimation – Trip Length Distribution*

The TAG criteria, reproduced in Table 3-2, advises that the change in average trip length and standard deviation are not in excess of 5% and any exceedance of this was investigated for its impact within the study area. The GLTM results are summarised in

Table 7-11 below, with detailed reporting and graphs included in Appendix F.

Table 7-11 Impacts of Matrix Estimation Summary - Trip Length Distribution

User Class	Measure	AM Peak		Inter Peak		PM Peak	
		Mean	St. Dev	Mean	St. Dev	Mean	St. Dev
Business	Prior ME	50.76	59.66	55.10	69.06	52.91	66.11
	Post ME	46.19	54.08	49.85	63.57	48.13	60.15
	Difference	*-9%*	*-9%*	*-10%*	*-8%*	*-9%*	*-9%*
Commute	Prior ME	22.97	26.19	18.04	22.72	22.67	23.94
	Post ME	22.20	23.65	17.62	21.59	22.22	22.33
	Difference	*-3%*	*-10%*	*-2%*	*-5%*	*-2%*	*-7%*
Other	Prior ME	21.16	19.95	23.30	38.61	22.30	32.69
	Post ME	30.05	27.21	21.64	35.24	21.23	30.11
	Difference	*-6%*	*-9%*	*-7%*	*-9%*	*-5%*	*-8%*
LGV	Prior ME	40.06	38.38	40.63	38.06	39.73	37.55
	Post ME	39.54	38.39	40.27	38.95	40.12	39.32
	Difference	*-1%*	*0%*	*-1%*	*-2%*	*1%*	*5%*
HGV	Prior ME	38.36	48.41	37.28	47.97	39.11	50.78
	Post ME	41.10	51.29	42.38	53.72	49.94	60.02
	Difference	*7%*	*6%*	*14%*	*12%*	*28%*	*18%*

It was examined why some changes exceeding 5% occurred. For cars, it was established through comparison of the model flows prior and post ME that a main reason for this was due to a reduction in longer distance external-external trips on the A1 – this route follows closely the East Coast Mainline for large sections so this may be an issue with the original identification of rail and highway in the MPOD data raised in Chapter 6. It was therefore not surprising that this issue has had a greater impact on business trips, and to a lesser extent other trips. The trip length distribution plots are largely identical up to around 100km supporting this as shown by the graphs in Appendix F.

For the GVs, the prior matrices were derived from TMOD sample data expanded to population. However, as noted within Chapter 6, the sample for HGV is considerably lower than for LGV (which is actually the most represented vehicle type in the dataset due to the make-up of the sample population). This explains why the changes for LGV are minimal whereas there are greater adjustment to HGVs.

7.5.5 *Impacts of Matrix Estimation – Sector to Sector Movements*

The TAG criterion is for sector to sector changes to be within 5%. However, since some of the sector movements are low (specifically to/from sectors three and four), the GEH has been reported too. These are tabulated in Table 7-12, Table 7-13 and Table 7-14 below.

The overall matrix change is within 5% for all user classes in all periods, with the exception of business, in the AM peak, which is 6%. This shows that the overall magnitude of change is within the guidance however there are some more significant changes at sector to sector level.

Firstly, the intra-sector one trips have a considerable increase for car user classes across all periods. The majority of these trips are less than 10km so they come from the synthetic matrices. The synthetic matrix compares well against the bypass screenlines capturing trip ends to and from sector one but there was a shortage of trips in the prior matrix for intra sector one trips within the urban areas of Lincoln and North Hykeham. The trip ends in the synthetic matrix were derived from TEMPRO which only models end-to-end trip making where in reality, short distance trip making (such as shopping etc.) can travel around the network and will be captured at multiple count locations.

Secondly, there are some changes greater than the criteria for movements to/from sectors one and two. When using traditional data sources such as Roadside Interview Surveys (RSIs), the sample of observed vehicle trips (with occupancy) are expanded to the traffic counts thus creating a close initial adherence to the count data at RSI locations. However, mobile phone data is processed as person trips which were expanded at a device level based on known data around population and market share. As referenced in Chapter 6, there is a good adherence to overall trip end totals but some discrepancy with the geographical distribution which could be caused through the localised expansion for specific movements. It would therefore be expected that the sector changes based on mobile phone data demand may be greater in some instances than the guidance.

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Table 7-12 Impacts of Matrix Estimation Summary - Sector Changes AM Peak

Percentage Difference

	Business	1	2	3	4	Total
1	Within Bypass Cordon	21%	7%	8%	-18%	5%
2	Within Outer Cordon	16%	-21%	-15%	-34%	-10%
3	Within Geofence	-1%	-13%	-6%	-7%	-6%
4	External	-27%	-39%	-9%	-4%	-6%
	Total	4%	-13%	-7%	-6%	-6%

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	16%	9%	10%	-18%	14%
2	Within Outer Cordon	15%	-8%	-11%	-35%	6%
3	Within Geofence	3%	-6%	-3%	-3%	-3%
4	External	-33%	-33%	-4%	0%	-1%
	Total	12%	0%	-3%	-1%	-1%

	Other	1	2	3	4	Total
1	Within Bypass Cordon	19%	11%	8%	-24%	16%
2	Within Outer Cordon	14%	-11%	-11%	-37%	2%
3	Within Geofence	3%	-14%	-3%	-3%	-3%
4	External	-31%	-41%	-4%	-1%	-2%
	Total	15%	-4%	-3%	-2%	-1%

	LGV	1	2	3	4	Total
1	Within Bypass Cordon	33%	33%	2%	-2%	25%
2	Within Outer Cordon	2%	6%	-25%	-33%	-7%
3	Within Geofence	-8%	1%	-1%	-1%	-1%
4	External	-14%	-10%	1%	0%	0%
	Total	17%	13%	-1%	0%	1%

	HGV	1	2	3	4	Total
1	Within Bypass Cordon	-28%	-39%	-17%	-29%	-27%
2	Within Outer Cordon	-23%	-10%	-53%	-32%	-30%
3	Within Geofence	-28%	-45%	-4%	3%	-4%
4	External	-8%	-34%	10%	0%	5%
	Total	-26%	-32%	-3%	1%	-5%

GEH

	Business	1	2	3	4	Total
1	Within Bypass Cordon	5.4	0.8	1.7	4.5	2.3
2	Within Outer Cordon	2.6	2.0	2.8	5.3	3.1
3	Within Geofence	0.3	2.2	6.3	6.4	9.0
4	External	5.7	4.4	7.7	5.2	9.5
	Total	1.9	3.5	9.6	8.9	12.7

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	9.8	2.0	2.4	2.0	9.8
2	Within Outer Cordon	5.3	1.4	2.0	2.8	2.7
3	Within Geofence	0.9	1.0	5.9	2.5	6.3
4	External	4.3	1.7	3.4	0.8	2.0
	Total	10.0	0.0	6.6	1.7	3.1

	Other	1	2	3	4	Total
1	Within Bypass Cordon	13.4	2.8	1.9	3.0	13.1
2	Within Outer Cordon	5.2	2.8	2.6	3.2	1.3
3	Within Geofence	1.0	3.5	6.9	2.6	7.5
4	External	4.0	2.8	3.3	1.5	3.4
	Total	13.2	1.9	7.6	3.0	3.8

	LGV	1	2	3	4	Total
1	Within Bypass Cordon	10.6	4.7	0.4	0.2	10.4
2	Within Outer Cordon	0.4	0.8	4.4	2.7	2.2
3	Within Geofence	1.6	0.1	1.4	0.6	1.7
4	External	1.5	0.6	0.4	0.0	0.0
	Total	7.5	3.3	1.5	0.3	1.1

	HGV	1	2	3	4	Total
1	Within Bypass Cordon	6.9	5.3	2.8	2.4	9.0
2	Within Outer Cordon	3.1	1.1	7.2	2.0	6.8
3	Within Geofence	4.9	5.5	3.6	1.2	4.0
4	External	0.6	1.6	3.5	0.2	2.5
	Total	8.8	7.0	3.0	0.5	5.7

Table 7-13 Impacts of Matrix Estimation Summary - Sector Changes Inter Peak

Percentage Difference

	Business	1	2	3	4	Total
1	Within Bypass Cordon	23%	23%	2%	-17%	**11%**
2	Within Outer Cordon	20%	-21%	-12%	-31%	**-6%**
3	Within Geofence	9%	-19%	-5%	-7%	**-5%**
4	External	-18%	-38%	-8%	-4%	**-6%**
	Total	**13%**	**-10%**	**-6%**	**-6%**	**-5%**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	17%	25%	23%	-5%	**19%**
2	Within Outer Cordon	20%	-19%	-12%	-32%	**2%**
3	Within Geofence	29%	-17%	-2%	-2%	**-2%**
4	External	-8%	-40%	-2%	0%	**0%**
	Total	**18%**	**4%**	**-2%**	**0%**	**0%**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	18%	23%	6%	-22%	**16%**
2	Within Outer Cordon	16%	-18%	-12%	-32%	**1%**
3	Within Geofence	7%	-18%	-3%	-3%	**-3%**
4	External	-21%	-38%	-4%	-2%	**-3%**
	Total	**15%**	**4%**	**-3%**	**-3%**	**-1%**

	LGV	1	2	3	4	Total
1	Within Bypass Cordon	74%	57%	24%	11%	**60%**
2	Within Outer Cordon	68%	10%	4%	5%	**29%**
3	Within Geofence	26%	-8%	1%	6%	**2%**
4	External	26%	10%	8%	0%	**1%**
	Total	**63%**	**23%**	**3%**	**0%**	**4%**

	HGV	1	2	3	4	Total
1	Within Bypass Cordon	0%	-60%	3%	-17%	**-15%**
2	Within Outer Cordon	-41%	-10%	-35%	-4%	**-33%**
3	Within Geofence	-9%	-35%	-1%	15%	**0%**
4	External	7%	-7%	18%	1%	**9%**
	Total	**-10%**	**-42%**	**1%**	**7%**	**0%**

GEH

	Business	1	2	3	4	Total
1	Within Bypass Cordon	5.1	1.3	-0.6	2.0	**3.1**
2	Within Outer Cordon	1.0	0.2	0.3	1.8	**0.1**
3	Within Geofence	0.5	1.2	3.1	3.8	**5.0**
4	External	2.0	2.7	4.5	3.4	**6.3**
	Total	**3.6**	**0.8**	**5.6**	**5.8**	**7.3**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	5.3	2.8	2.1	-0.8	**6.8**
2	Within Outer Cordon	2.0	1.3	0.2	-0.2	**-0.6**
3	Within Geofence	2.7	0.8	2.3	-0.2	**2.1**
4	External	-0.5	-0.1	-0.1	-0.8	**-0.5**
	Total	**6.7**	**-0.1**	**2.2**	**-0.5**	**-0.2**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	14.1	7.1	0.7	2.5	**15.2**
2	Within Outer Cordon	4.4	3.3	1.9	1.8	**-0.6**
3	Within Geofence	1.0	3.2	5.5	2.4	**6.3**
4	External	2.7	2.9	3.2	1.7	**4.2**
	Total	**14.1**	**0.9**	**6.6**	**3.5**	**2.3**

	LGV	1	2	3	4	Total
1	Within Bypass Cordon	18.3	5.8	2.4	-0.1	19.0
2	Within Outer Cordon	6.5	0.2	-0.5	-0.8	**4.8**
3	Within Geofence	2.6	-0.1	-0.3	1.1	**1.0**
4	External	1.0	-0.5	2.0	-0.9	**0.0**
	Total	**19.5**	**3.8**	**1.5**	**-0.3**	**5.9**

	HGV	1	2	3	4	Total
1	Within Bypass Cordon	-1.0	8.5	-0.6	0.2	**3.2**
2	Within Outer Cordon	4.3	-0.3	2.4	-0.9	**4.8**
3	Within Geofence	0.1	3.2	0.0	3.6	**-0.7**
4	External	-0.6	-0.6	4.5	-0.7	**3.1**
	Total	**1.6**	**7.9**	**0.1**	**2.3**	**-0.8**

Lincolnshire COUNTY COUNCIL HIGHWAYS ALLIANCE

Table 7-14 Impacts of Matrix Estimation Summary - Sector Changes PM Peak

Percentage Difference

	Business	1	2	3	4	Total
1	Within Bypass Cordon	17%	12%	6%	-1%	**11%**
2	Within Outer Cordon	21%	-14%	-2%	-19%	**1%**
3	Within Geofence	44%	3%	-4%	-5%	**-3%**
4	External	4%	-15%	-8%	-5%	**-6%**
	Total	**21%**	**0%**	**-5%**	**-5%**	**-4%**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	14%	15%	5%	-2%	**12%**
2	Within Outer Cordon	21%	-8%	-2%	-12%	**6%**
3	Within Geofence	34%	-1%	-2%	-2%	**-2%**
4	External	3%	-14%	-3%	0%	**0%**
	Total	**16%**	**7%**	**-2%**	**0%**	**0%**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	18%	22%	11%	6%	**17%**
2	Within Outer Cordon	23%	-9%	0%	-20%	**7%**
3	Within Geofence	27%	3%	-2%	-2%	**-2%**
4	External	-4%	-14%	-3%	-1%	**-2%**
	Total	**19%**	**11%**	**-2%**	**-1%**	**0%**

	LGV	1	2	3	4	Total
1	Within Bypass Cordon	43%	42%	39%	32%	**42%**
2	Within Outer Cordon	78%	20%	28%	63%	**44%**
3	Within Geofence	42%	16%	3%	13%	**6%**
4	External	53%	28%	11%	0%	**1%**
	Total	**48%**	**28%**	**6%**	**1%**	**5%**

	HGV	1	2	3	4	Total
1	Within Bypass Cordon	-32%	-55%	-54%	73%	**-36%**
2	Within Outer Cordon	-61%	-8%	-16%	-22%	**-38%**
3	Within Geofence	-12%	-32%	0%	38%	**5%**
4	External	17%	3%	38%	3%	**25%**
	Total	**-30%**	**-32%**	**5%**	**25%**	**5%**

GEH

	Business	1	2	3	4	Total
1	Within Bypass Cordon	3.0	0.4	0.0	-0.9	**2.7**
2	Within Outer Cordon	1.0	0.0	-0.8	0.4	**-0.9**
3	Within Geofence	6.1	-0.7	2.1	2.3	**2.0**
4	External	-0.2	0.5	4.8	3.9	**6.2**
	Total	**6.2**	**-1.0**	**4.9**	**4.9**	**5.5**

	Commute	1	2	3	4	Total
1	Within Bypass Cordon	7.1	3.8	0.5	-0.8	**8.1**
2	Within Outer Cordon	3.4	0.5	-0.7	-0.4	**1.0**
3	Within Geofence	6.6	-0.9	3.6	0.5	**3.0**
4	External	-0.7	0.0	1.8	-0.4	**0.4**
	Total	**10.1**	**2.1**	**4.1**	**0.0**	**0.4**

	Other	1	2	3	4	Total
1	Within Bypass Cordon	13.5	7.9	3.3	0.0	**16.3**
2	Within Outer Cordon	5.8	1.4	-0.9	0.4	**2.1**
3	Within Geofence	6.7	-0.2	5.0	1.1	**4.3**
4	External	-0.5	0.2	2.7	0.7	**2.5**
	Total	**16.3**	**5.1**	**5.3**	**1.5**	**-0.7**

	LGV	1	2	3	4	Total
1	Within Bypass Cordon	10.5	4.6	4.7	1.3	13.2
2	Within Outer Cordon	7.6	1.4	2.2	1.8	**8.0**
3	Within Geofence	4.8	0.9	1.5	3.6	**4.4**
4	External	2.9	0.5	3.4	-0.9	**0.7**
	Total	**14.7**	**5.2**	**4.6**	**0.6**	**7.8**

	HGV	1	2	3	4	Total
1	Within Bypass Cordon	4.0	3.6	6.4	2.2	**7.1**
2	Within Outer Cordon	5.9	-0.6	0.3	-0.4	**4.6**
3	Within Geofence	0.3	2.2	-0.8	7.5	**2.2**
4	External	-0.2	-0.9	8.4	-0.5	**7.1**
	Total	**5.8**	**3.6**	**2.2**	**6.5**	**2.6**

8 Highway Model Validation

8.1 Introduction

This chapter reports the GLTM base year model performance and validation summary with respect to:

- Trip matrix validation;
- Link and turn flow validation; and
- Journey time validation.

The validation of the base year models utilised two sources of data:

- Traffic count data – an independent subset of the traffic counts identified for validation against those used in matrix estimation, see Section 4.3; and
- Journey time data – link based travel time data from TrafficMaster data aggregated into key routes in the model, see Section 4.4.

8.2 Assignment Convergence

Three parameters in SATURN correspond to the highway model convergence criteria in TAG Unit M3.1. The values adopted for SATURN stopping criteria in GLTM are reported in Table 8-1 below.

The value of 99 for RSTOP is stricter than the TAG acceptance criteria, which were listed in Table 3-1.**Error! Reference source not found.** The values for PCNEAR and NISTOP follow the acceptability guidelines in TAG.

Table 8-1 SATURN Constraints for Convergence

Parameter	Description	GLTM Value
RSTOP	The percentage of links which change by less that the values defined by PCNEAR	99
PCNEAR	Defines the threshold maximum percentage flow change (for ISTOP% of links)	1.00
NISTOP	Number of successive loops for the criteria to be met	4

The base models are well converged as reported by the convergence statistics for the prior and calibrated assignments in Table 8-2 and Table 8-3 respectively.

Table 8-2 Prior Assignment Statistics

AM Peak			Inter Peak			PM Peak		
Loop	%Flow	%GAP	Loop	%Flow	%GAP	Loop	%Flow	%GAP
22	99.1	0.0003	19	99.2	0.0000	19	99.5	0.0000
23	99.3	0.0004	20	99.1	0.0000	20	99.5	0.0000
24	99.4	0.0002	21	99.3	0.0000	21	99.5	0.0000
25	99.4	0.0002	22	99.4	0.0000	22	99.6	0.0000

Table 8-3 Calibrated Assignment Statistics

AM Peak			Inter Peak			PM Peak		
Loop	%Flow	%GAP	Loop	%Flow	%GAP	Loop	%Flow	%GAP
26	99.1	0.0003	23	99.5	0.0002	18	99.2	0.0007
27	99.8	0.0001	24	99.2	0.0009	19	99.3	0.0003
28	99.2	0.0005	25	99.2	0.0007	20	99.5	0.0007
29	99.7	0.0001	26	99.1	0.0005	21	99.5	0.0001

8.3 Trip Matrix Validation

The trip matrix validation has been reported for 18 bi-directional screenlines which were mapped in Figure 4-13 and Figure 4-14. TAG guidance, reproduced in Table 3-3, advises that modelled flow should be within 5% of the observed counts for “all or nearly all” screenlines.

The GLTM high level results are presented in Table 8-4 below with the detailed breakdown in Table 8-5; they are also presented as thematic maps in Figure 8-1, Figure 8-2 and Figure 8-3 by period respectively.

The GEH has also been reported since the total flow for several screenlines are within the second interval for link flow validation in TAG of 700 to 2,700 veh/hr interval – whilst this is not specified for screenline validation the same implication of a ‘larger’ percentage change masking a ‘small’ absolute trip change relative to the actual trip total applies.

The screenlines which do not meet the 5% threshold are all within GEH < 4 with the exception of the two in the PM peak – Western Bypass outbound and North West Inner Cordon inbound. However, the latter is within 10% and its GEH value 4.4 is only narrowly greater than the threshold tested.

A complete set of reporting of the trip matrix validation for the calibrated models is included in Appendix G. This includes summary tabulations of the screenline performance by time period by vehicle class and larger versions of the maps presented below.

Table 8-4 Calibrated Matrices Screenline Validation

Performance Measure	AM Peak	Inter Peak	PM Peak
All screenlines and cordons within 5% of observed flows	85%	82%	82%
All Screenlines and cordons within 10% of observed flows	100%	100%	97%
All Screenlines and cordons within GEH < 4	100%	100%	94%

Table 8-5 Detailed Summary of Screenline Validation Performance

Screenline	Direction	Cal/Val	AM Peak		Inter Peak		PM Peak	
			Flow <|5|%	GEH <4	Flow <|5|%	GEH <4	Flow <|5|%	GEH <4
Inner East-west 1	Eastbound	Val	✓	✓	×	✓	✓	✓
Inner East-west 1	Westbound	Val	✓	✓	✓	✓	✓	✓
Inner East-west 2	Eastbound	Val	×	✓	✓	✓	✓	✓
Inner East-west 2	Westbound	Val	✓	✓	✓	✓	✓	✓
Inner East-west 3	Eastbound	Val	✓	✓	✓	✓	✓	✓
Inner East-west 3	Westbound	Val	✓	✓	✓	✓	✓	✓
Inner Ne Screenline	Inbound	Val	✓	✓	✓	✓	×	✓
Inner Ne Screenline	Outbound	Val	✓	✓	×	✓	✓	✓
Inner Nw Screenline	Inbound	Val	✓	✓	×	✓	×	×
Inner Nw Screenline	Outbound	Val	×	✓	×	✓	×	✓
Inner Se Screenline	Inbound	Val	✓	✓	✓	✓	✓	✓
Inner Se Screenline	Outbound	Val	×	✓	✓	✓	×	✓
Inner Sw Screenline	Inbound	Val	✓	✓	✓	✓	✓	✓
Inner Sw Screenline	Outbound	Val	✓	✓	✓	✓	✓	✓
Leb Screenline	Inbound	Val	✓	✓	✓	✓	✓	✓
Leb Screenline	Outbound	Val	✓	✓	✓	✓	✓	✓
Lnb Screenline	Inbound	Cal	✓	✓	✓	✓	✓	✓
Lnb Screenline	Outbound	Cal	✓	✓	✓	✓	✓	✓
Lsb Screenline	Inbound	Cal	✓	✓	✓	✓	✓	✓
Lsb Screenline	Outbound	Cal	✓	✓	✓	✓	✓	✓
Ltp Cordon	Inbound	Cal	✓	✓	✓	✓	✓	✓
Ltp Cordon	Outbound	Cal	✓	✓	✓	✓	✓	✓
Lwb Screenline	Inbound	Cal	×	✓	×	✓	✓	✓
Lwb Screenline	Outbound	Cal	×	✓	×	✓	×	×
Outer East Screenline	Inbound	Cal	✓	✓	✓	✓	✓	✓
Outer East Screenline	Outbound	Cal	✓	✓	✓	✓	✓	✓
Outer North Screenline	Inbound	Cal	✓	✓	✓	✓	✓	✓

Outer North Screenline	Outbound	Cal	✓	✓	✓	✓	✓	✓
Outer South Screenline	Inbound	Cal	✓	✓	✓	✓	×	✓
Outer South Screenline	Outbound	Cal	✓	✓	✓	✓	✓	✓
Outer West Screenline	Inbound	Cal	✓	✓	✓	✓	✓	✓
Outer West Screenline	Outbound	Cal	✓	✓	✓	✓	✓	✓
Railway Screenline	Northbound	Val	✓	✓	✓	✓	✓	✓
Railway Screenline	Southbound	Val	✓	✓	✓	✓	✓	✓
Suburban South Screenline	Inbound	Val	✓	✓	✓	✓	✓	✓
Suburban South Screenline	Outbound	Val	✓	✓	✓	✓	✓	✓

Figure 8-1 Screenline Flow % Difference - AM Peak

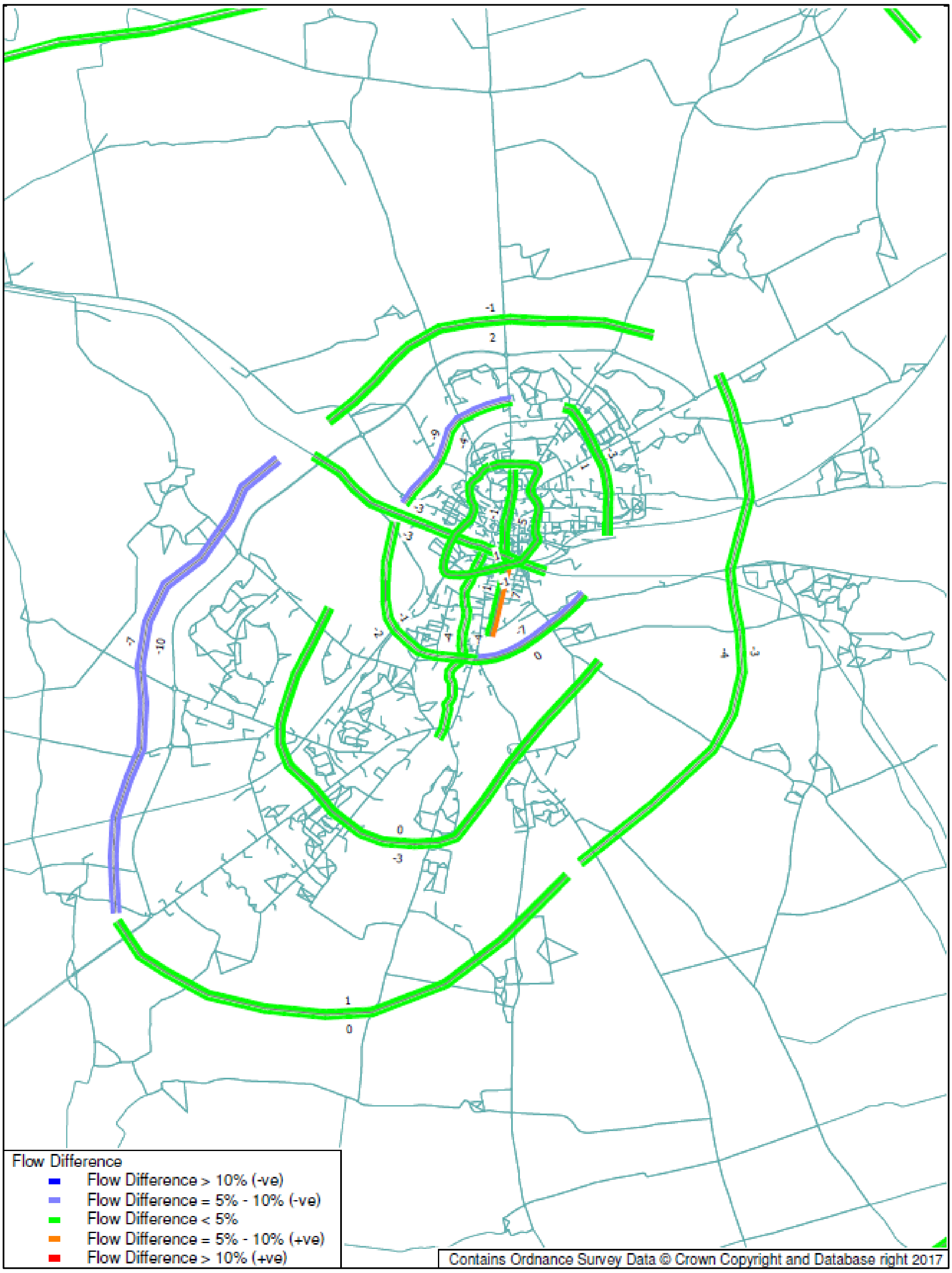


Figure 8-2 Screenline Flow % Difference - Inter Peak

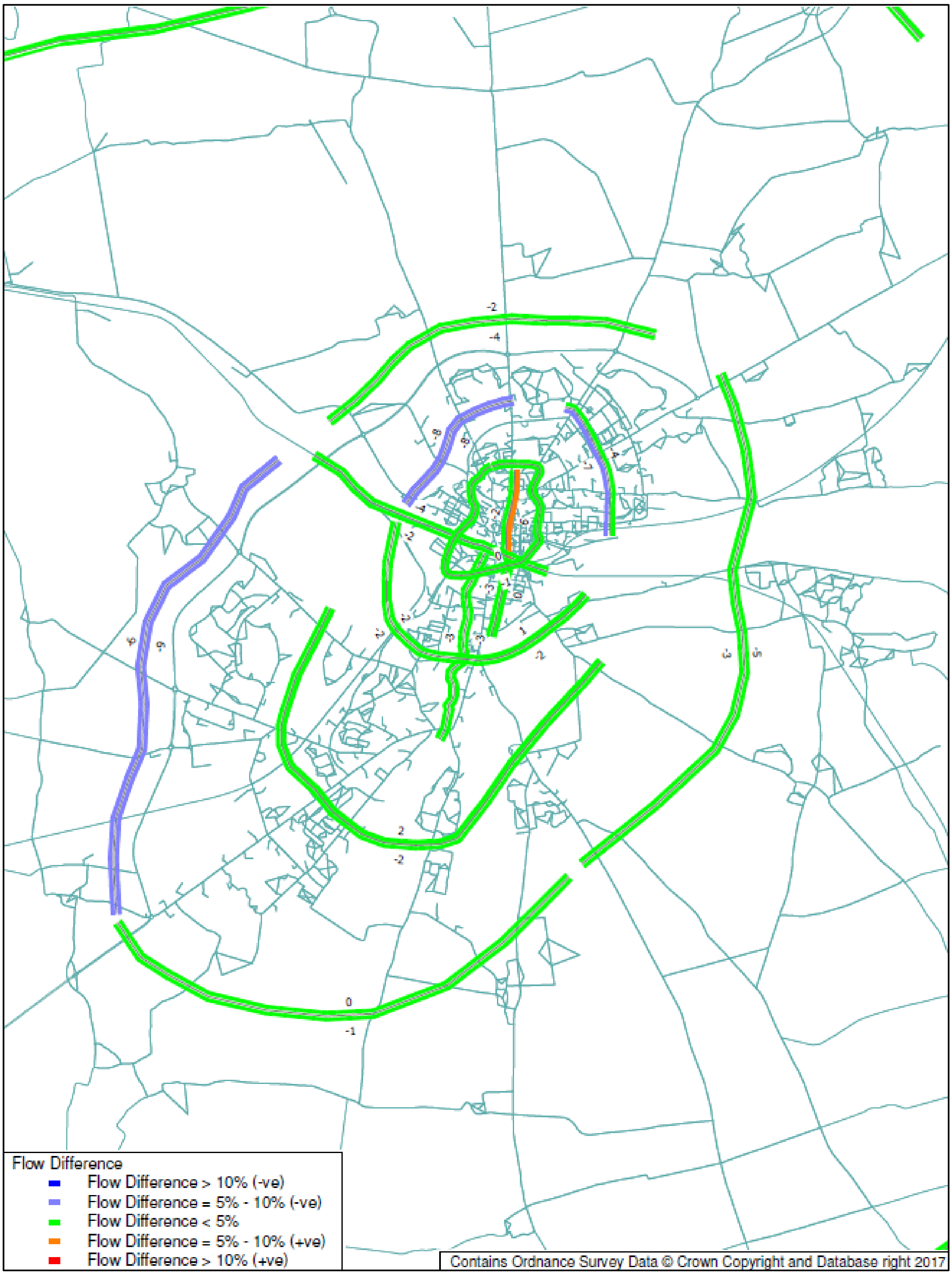
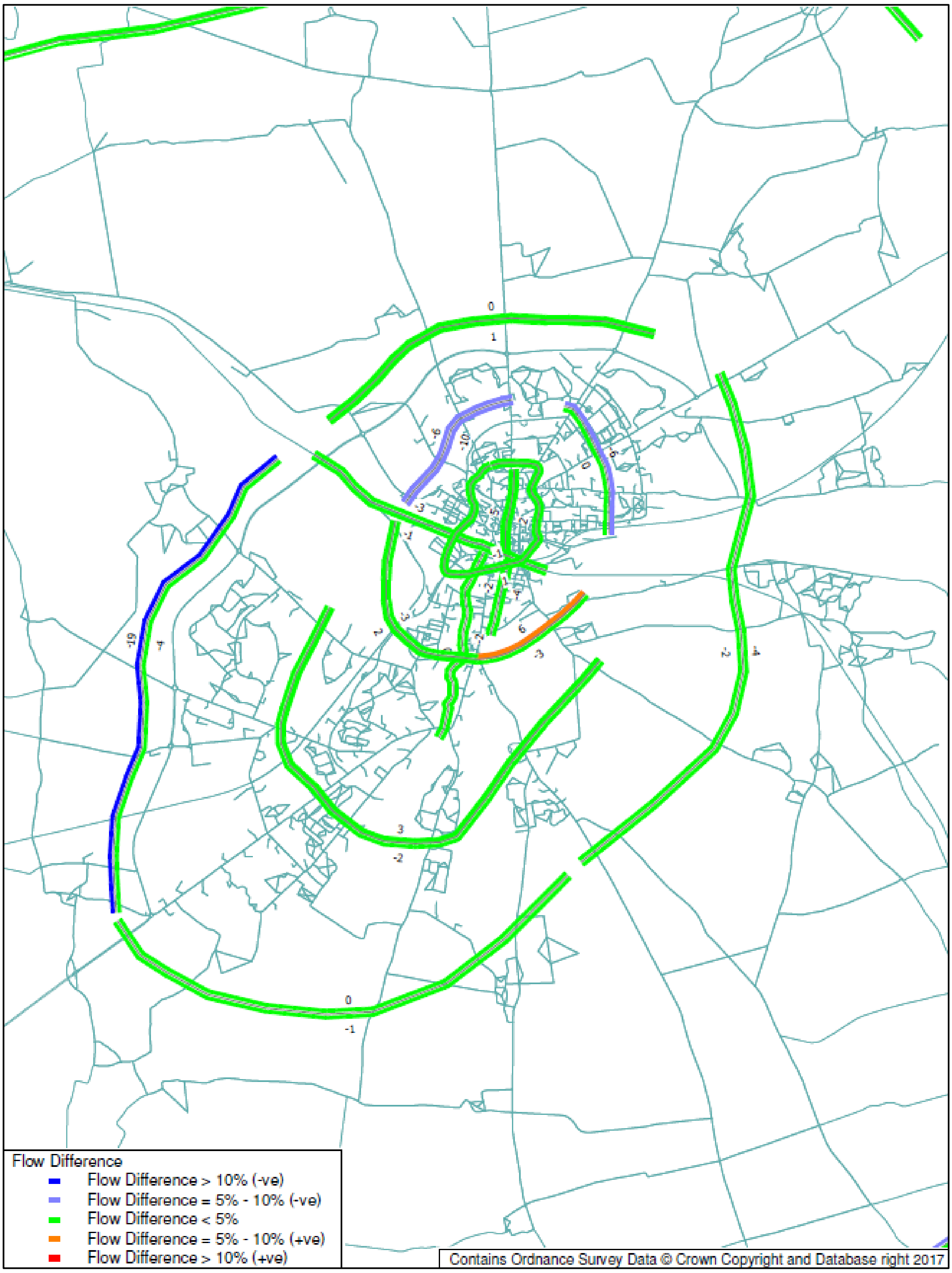


Figure 8-3 Screenline Flow % Difference - PM Peak



8.4 Link Flow Validation

The summary statistics for the link and turning flow validation in the calibrated models are reported in Table 8-6 and illustrated in Figure 8-4 to Figure 8-9 below. The flow validation is excellent with the criteria from TAG, reproduced in Table 3-5, comfortably exceeded in all time periods with upwards of 98% of flows meeting the flow criteria

Table 8-6 Link Flow Validation Summary – Calibrated Matrices

Performance Measure	AM Peak	Inter Peak	PM Peak
All Counts (853)			
Pass TAG Flow Criteria	99%	100%	99%
Pass TAG GEH Criteria	96%	96%	94%
Calibration Counts (614, 72%)			
Pass TAG Flow Criteria	100%	100%	100%
Pass TAG GEH Criteria	97%	97%	95%
Validation Counts (239, 28%)			
Pass TAG Flow Criteria	98%	100%	99%
Pass TAG GEH Criteria	91%	94%	93%

A complete set of reporting of the link and turning flow validation for the calibrated models is included in Appendix H. This includes summary tabulations by time period by vehicle class for each link plus larger versions of the maps presented below.

Figure 8-4 Link Validation (GEH) – AM Peak

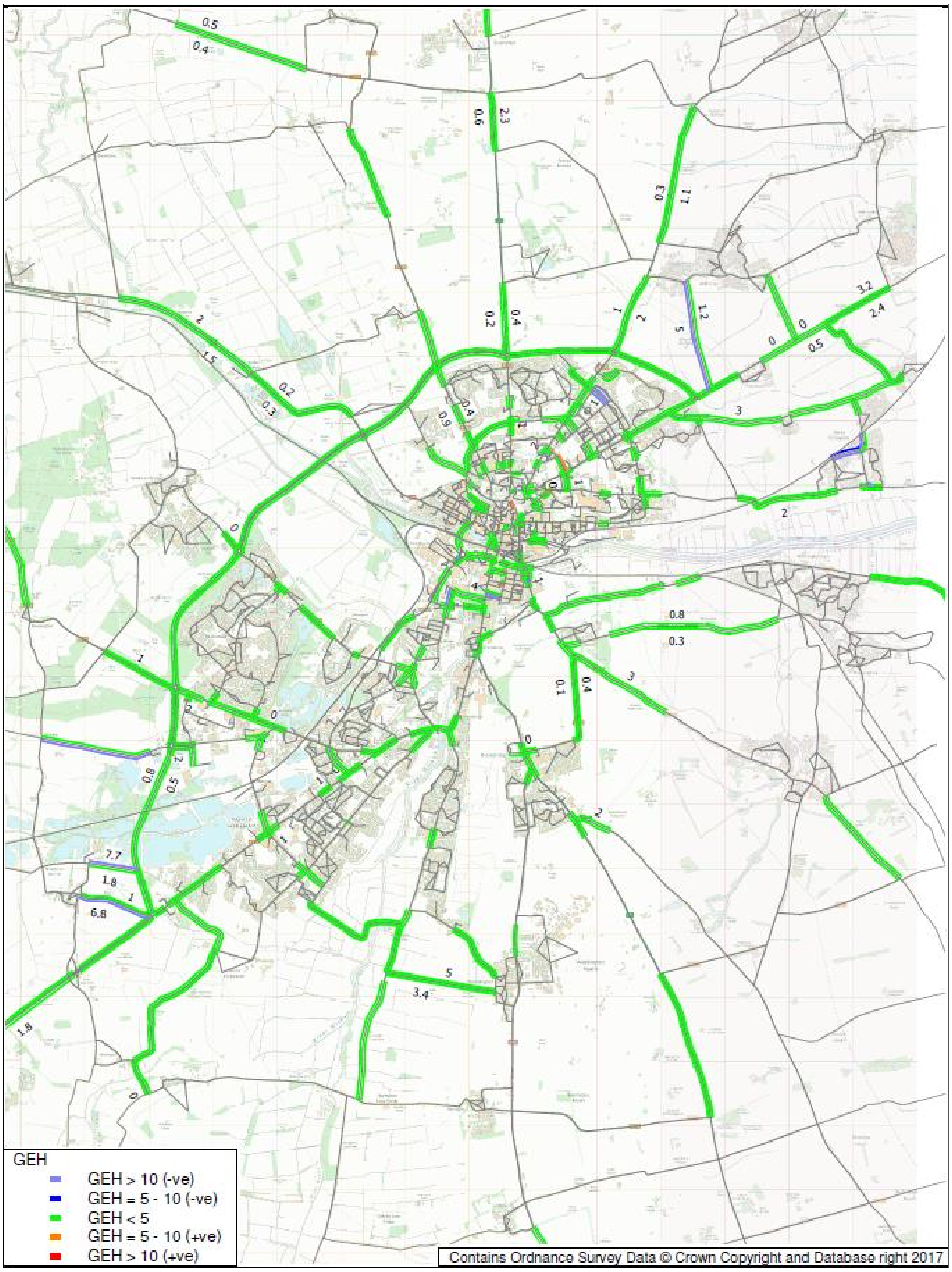


Figure 8-5 Flow Difference (Modelled - Observed) – AM Peak

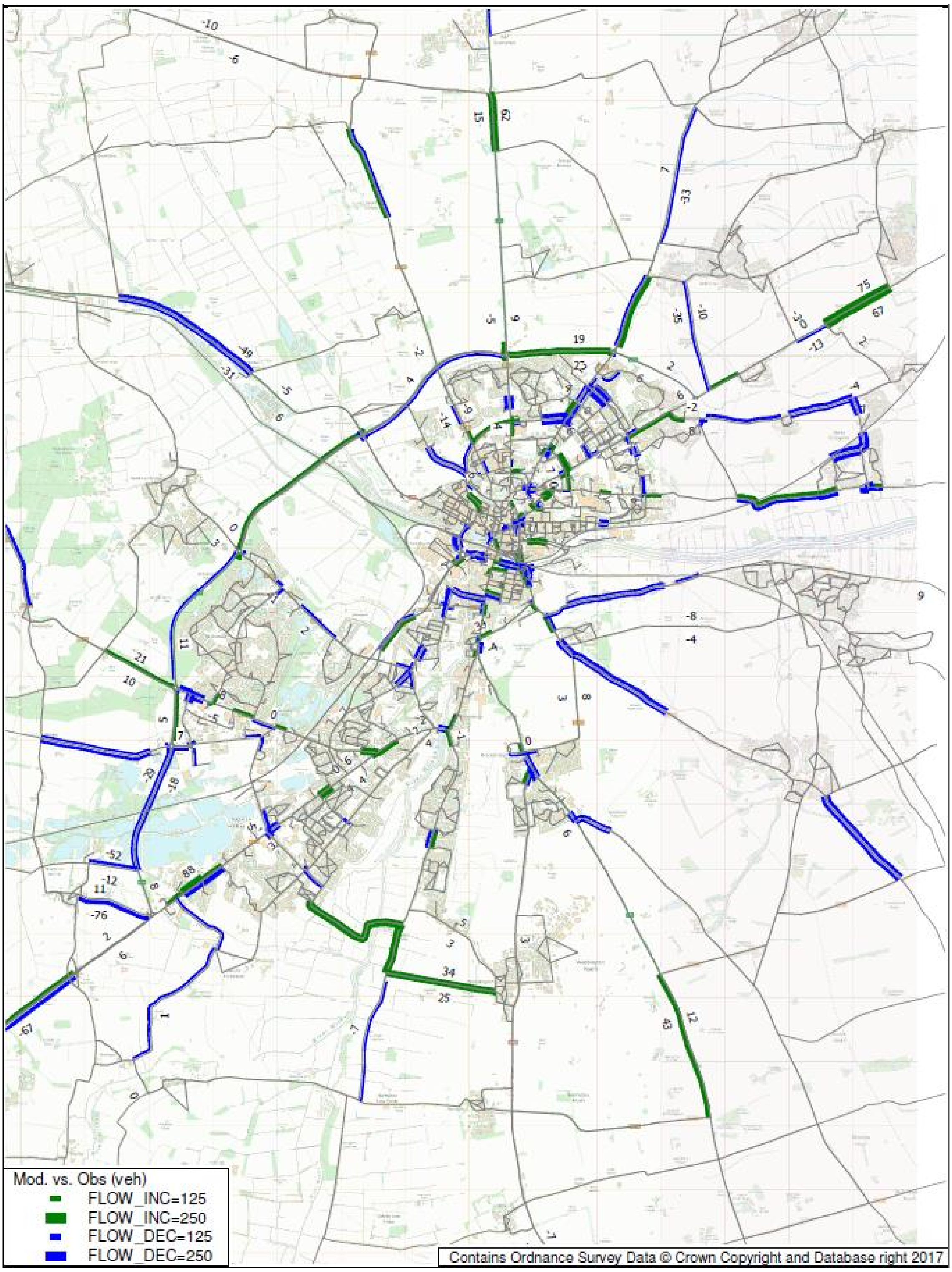


Figure 8-6 Link Validation (GEH) – Inter Peak

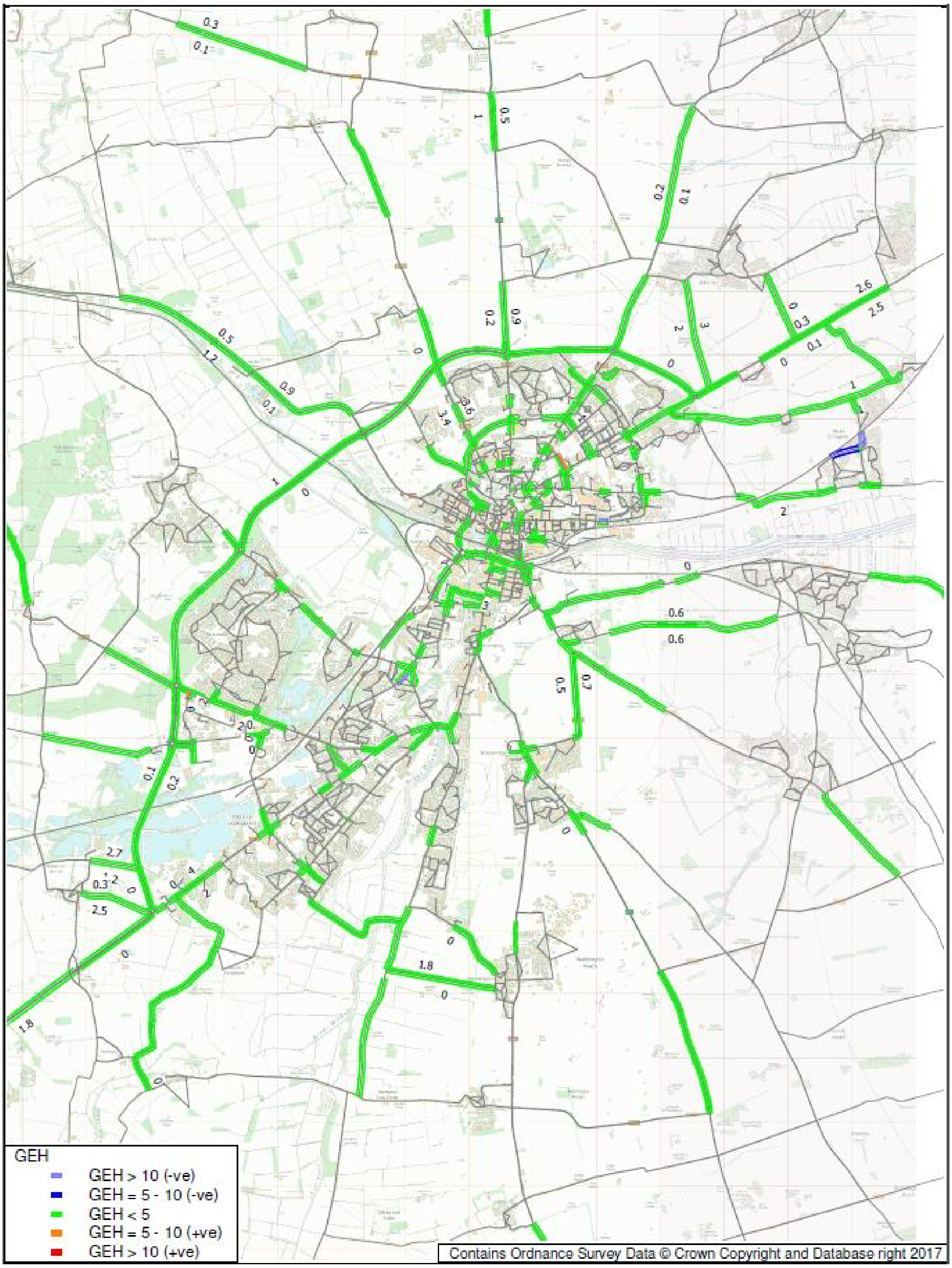


Figure 8-7 Flow Difference (Modelled - Observed) –Inter Peak

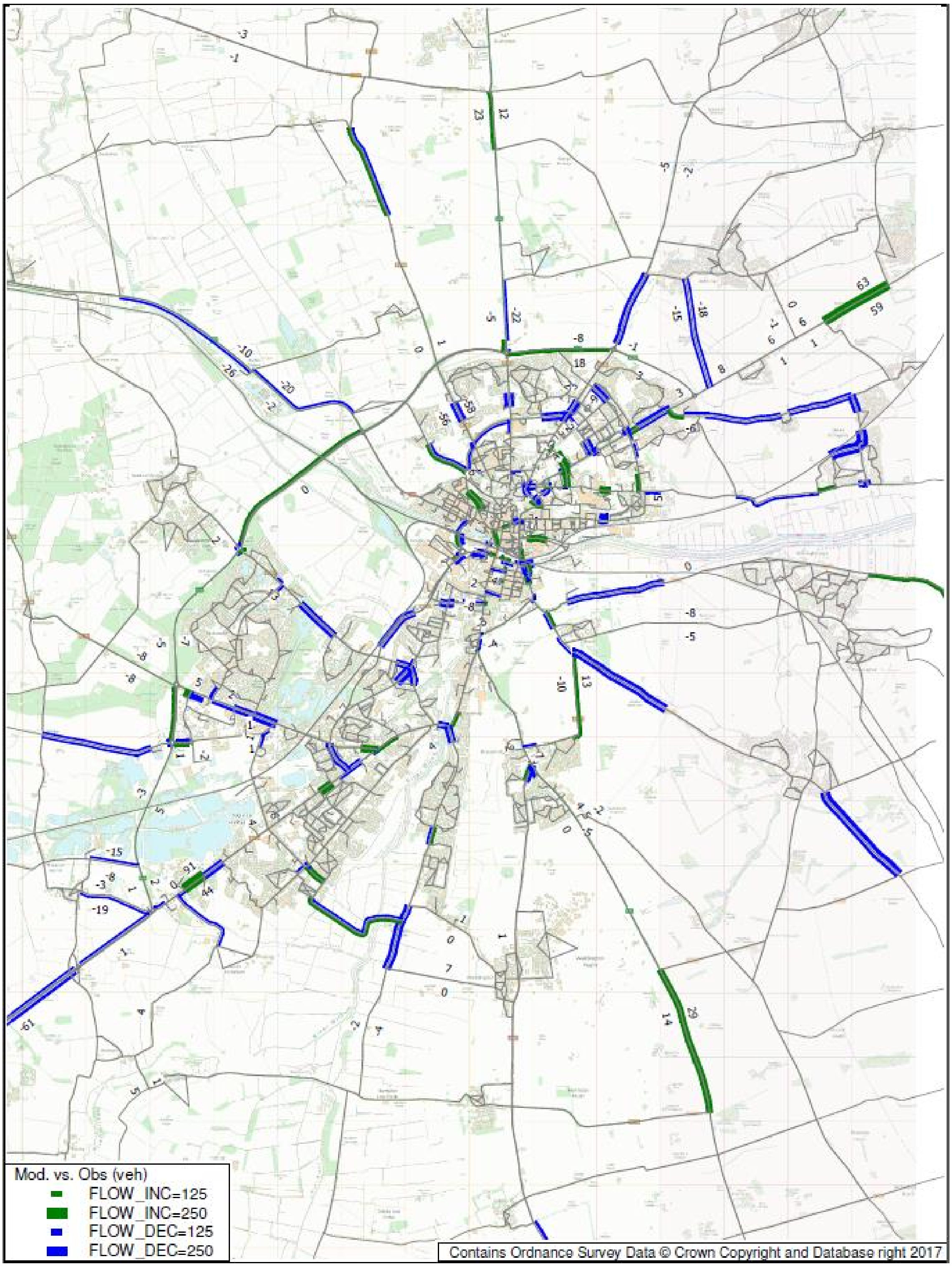


Figure 8-8 Link Validation (GEH) – PM Peak

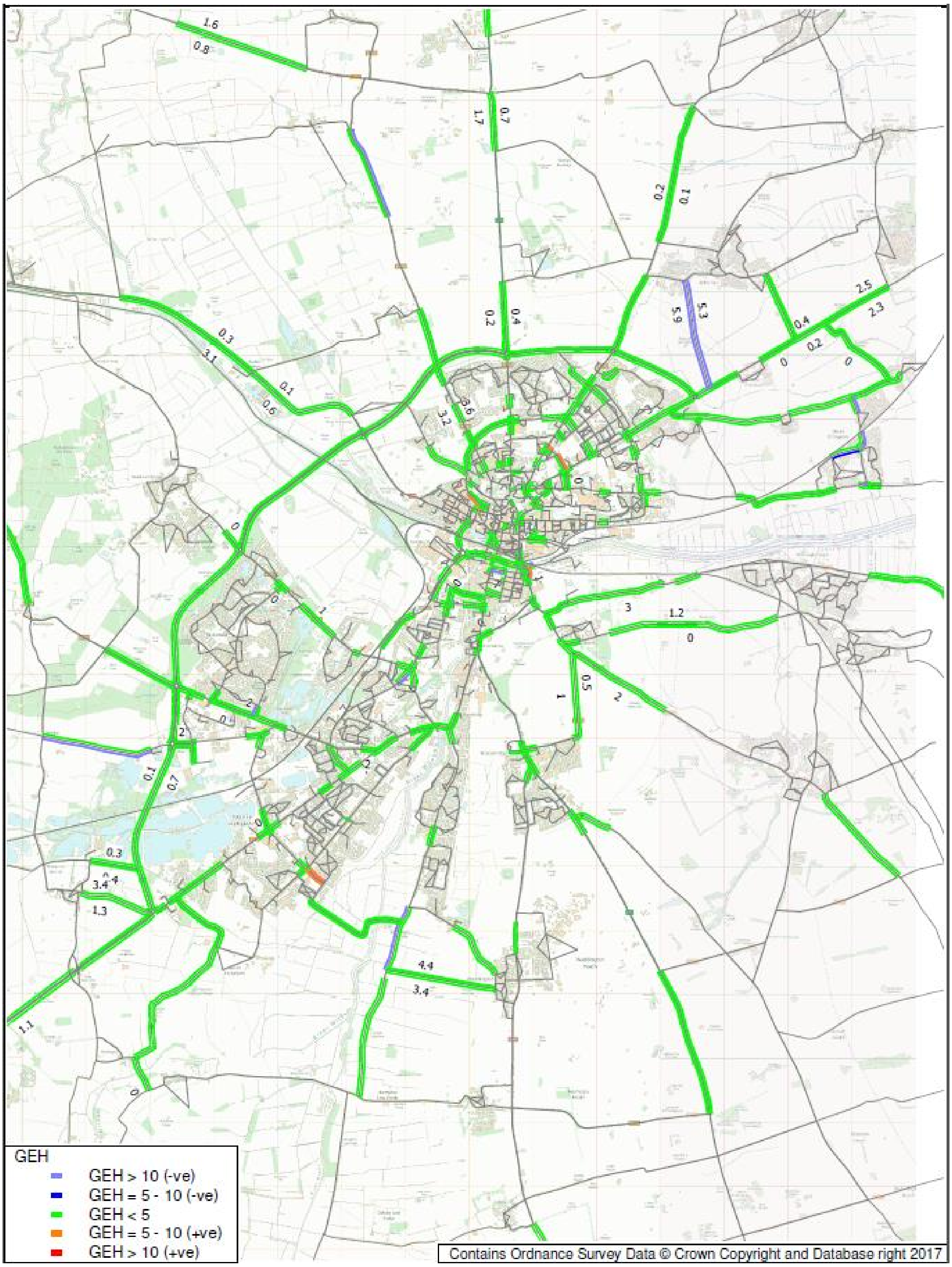
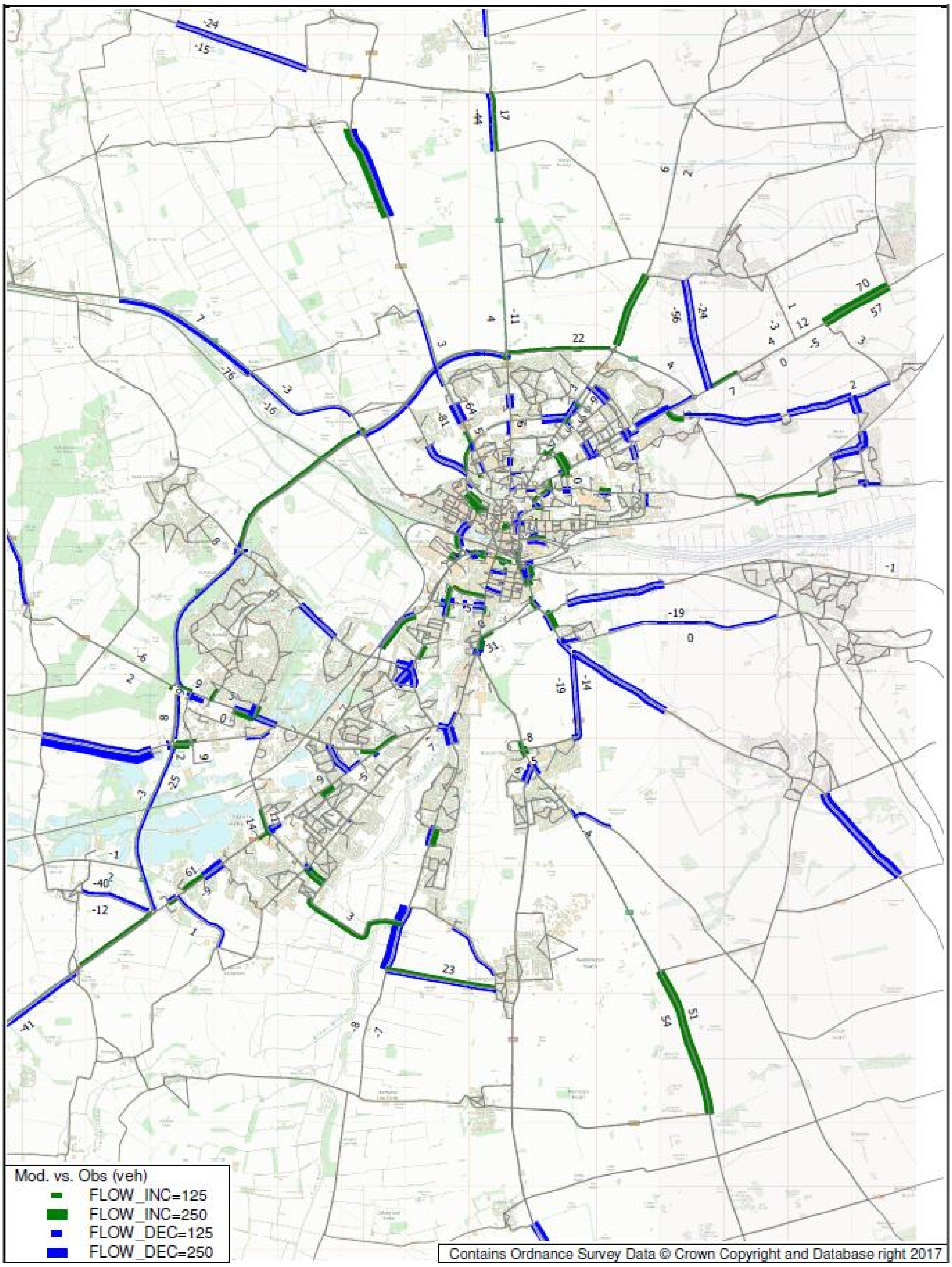


Figure 8-9 Flow Difference (Modelled - Observed) – PM Peak



8.5 Journey Time Validation

The summary statistics for the journey time validation in the calibrated models are reported in Table 8-7 and illustrated in Figure 8-13, Figure 8-14 and Figure 8-15 below. The detailed breakdown by route are tabulated in Table 8-8 and plotted in Figure 8-10, Figure 8-11 and Figure 8-12. The criteria set out in TAG, reproduced in Table 3-4, has been exceeded in all periods with particularly high validation in the AM peak and inter peak.

Table 8-7 Journey Time Validation Summary

Performance Measure	AM Peak	Inter Peak	PM Peak
Routes within 15% or 1 min of Observed Times	97%	99%	90%

A complete set of reporting of the journey time validation for the calibrated models is included in Appendix I. This includes summary tabulations of the journey time validation by time period by route, larger versions of the maps presented below.

Table 8-8 Journey Time Validation by Route

Route	AM	IP	PM
	Pass TAG?	Pass TAG?	Pass TAG?
Route 1: A15_Caenby NB	✓	✓	✓
Route 1: A15_Caenby SB	✓	✓	✓
Route 2: A46_Middle_Rasen NB	✓	✓	✓
Route 2: A46_Middle_Rasen SB	✓	✓	✓
Route 3: A158_Horncastle EB	✓	✓	✓
Route 3: A158_Horncastle WB	✓	✓	✓
Route 4: A15_Sleaford NB	✓	✓	✓
Route 4: A15_Sleaford SB	✓	✓	✓
Route 5: A46_Newark NB	✓	✓	✓
Route 5: A46_Newark SB	✓	✓	✓
Route 6: A57_East_Markham EB	✓	✓	✓
Route 6: A57_East_Markham WB	✓	✓	✓
Route 7: A57_A156_Gainsborough NB	✓	✓	✓
Route 7: A57_A156_Gainsborough SB	✓	✓	✓
Route 8: A46_Orbital_NW NB	✓	✓	×
Route 8: A46_Orbital_NW SB	✓	×	✓
Route 9: B1003_Boultham NB	✓	✓	✓
Route 9: B1003_Boultham SB	✓	✓	✓
Route 10: W_Parade_Monks_Road EB	✓	✓	×
Route 10: W_Parade_Monks_Road WB	✓	✓	×
Route 11: A607_Leadenham NB	✓	✓	✓
Route 11: A607_Leadenham SB	✓	✓	✓
Route 12: B1190_Bardney EB	✓	✓	✓
Route 12: B1190_Bardney WB	✓	✓	✓
Route 13: Outer_Circle_Drive NB	✓	✓	✓
Route 13: Outer_Circle_Drive SB	✓	✓	✓

Route	AM Pass TAG?	IP Pass TAG?	PM Pass TAG?
Route 14: B1273_Langdales_Road NB	×	✓	×
Route 14: B1273_Langdales_Road SB	✓	✓	✓
Route 15: B1262_High_Street NB	✓	✓	✓
Route 15: B1262_High_Street SB	✓	✓	✓
Route 16: Skellingthorpe_Road EB	×	✓	×
Route 16: Skellingthorpe_Road WB	✓	✓	✓
Route 17: B1190_Doddington_Road EB	✓	✓	×
Route 17: B1190_Doddington_Road WB	✓	✓	✓
Route 18: Hykeham_Road_Mill_Lane NB	✓	✓	✓
Route 18: Hykeham_Road_Mill_Lane SB	✓	✓	✓
Route 19: HykehamStation_Waddington EB	✓	✓	×
Route 19: HykehamStation_Waddington WB	✓	✓	✓
Route 20: B1178_Potterhanworth EB	✓	✓	✓
Route 20: B1178_Potterhanworth WB	✓	✓	✓
Route 21: B1188_Scopwick NB	✓	✓	✓
Route 21: B1188_Scopwick SB	✓	✓	✓
Route 22: Whisby_Road_Eagle_Moor EB	✓	✓	✓
Route 22: Whisby_Road_Eagle_Moor WB	✓	✓	✓
Route 23: B1202_Metheringham EB	✓	✓	✓
Route 23: B1202_Metheringham WB	✓	✓	✓
Route 24: Till_Bridge_Lane EB	✓	✓	✓
Route 24: Till_Bridge_Lane WB	✓	✓	✓
Route 25: Brant_Road NB	✓	✓	✓
Route 25: Brant_Road SB	✓	✓	✓
Route 26: Greetwell_Road_Fiskerton_Road EB	✓	✓	✓
Route 26: Greetwell_Road_Fiskerton_Road WB	✓	✓	✓
Route 27: B1131 NB	✓	✓	✓
Route 27: B1131 SB	✓	✓	✓
Route 28: B1398_North_Carlton SB	✓	✓	✓
Route 28: B1398_North_Carlton NB	✓	✓	✓
Route 29: B1202_Potterhanworth NB	✓	✓	✓
Route 29: B1202_Potterhanworth SB	✓	✓	✓
Route 30: Sutton_Road_Saxilby_Road NB	✓	✓	✓
Route 30: Sutton_Road_Saxilby_Road SB	✓	✓	✓
Route 31: B1360_New_Boultham EB	✓	✓	✓
Route 31: B1360_New_Boultham WB	✓	✓	✓
Route 32: Nettleham_Road_Eastgate NB	✓	✓	✓
Route 32: Nettleham_Road_Eastgate SB	✓	✓	✓
Route 33: Burton_Road_Union_Road NB	✓	✓	✓
Route 33: Burton_Road_Union_Road SB	✓	✓	✓
Route 34: Rasen_Lane_Newport NB	✓	✓	✓
Route 34: Rasen_Lane_Newport SB	✓	✓	✓
Route 35: Boultham_Park_Road_Moorland_Avenue NB	✓	✓	✓
Route 35: Boultham_Park_Road_Moorland_Avenue SB	✓	✓	✓
Route 36: B1178_Tower_Lane EB	✓	✓	✓
Route 36: B1178_Tower_Lane WB	✓	✓	✓

Figure 8-10 Journey Time Validation by Route - AM Peak

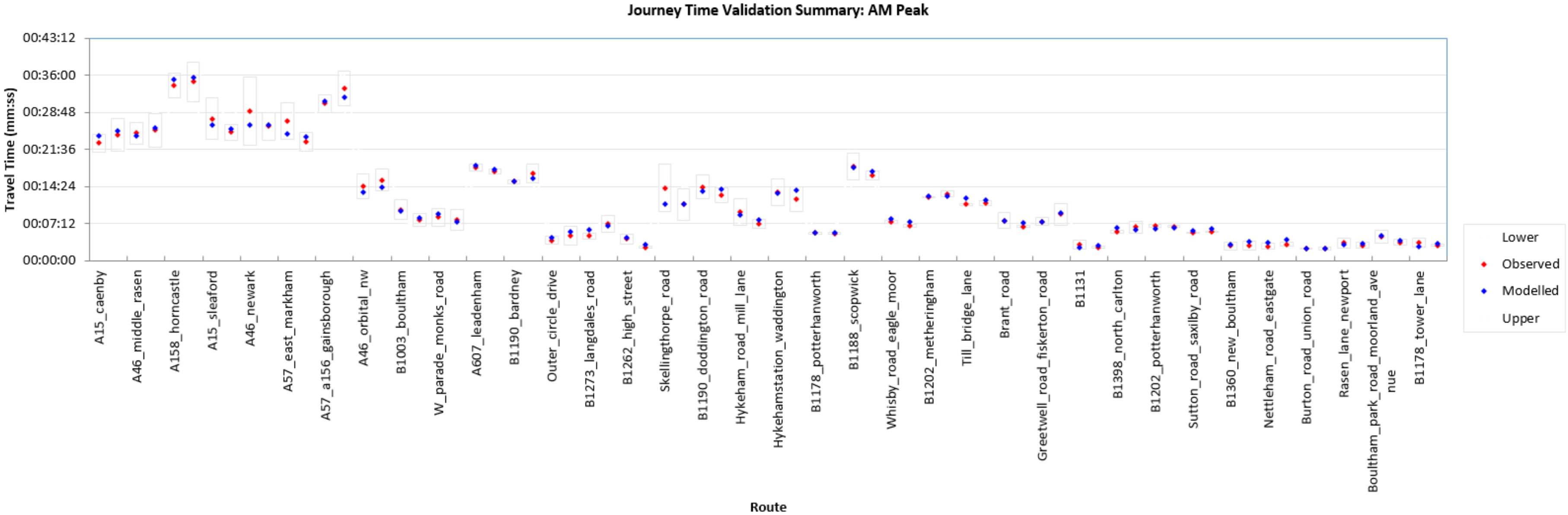


Figure 8-11 Journey Time Validation by Route - Inter Peak

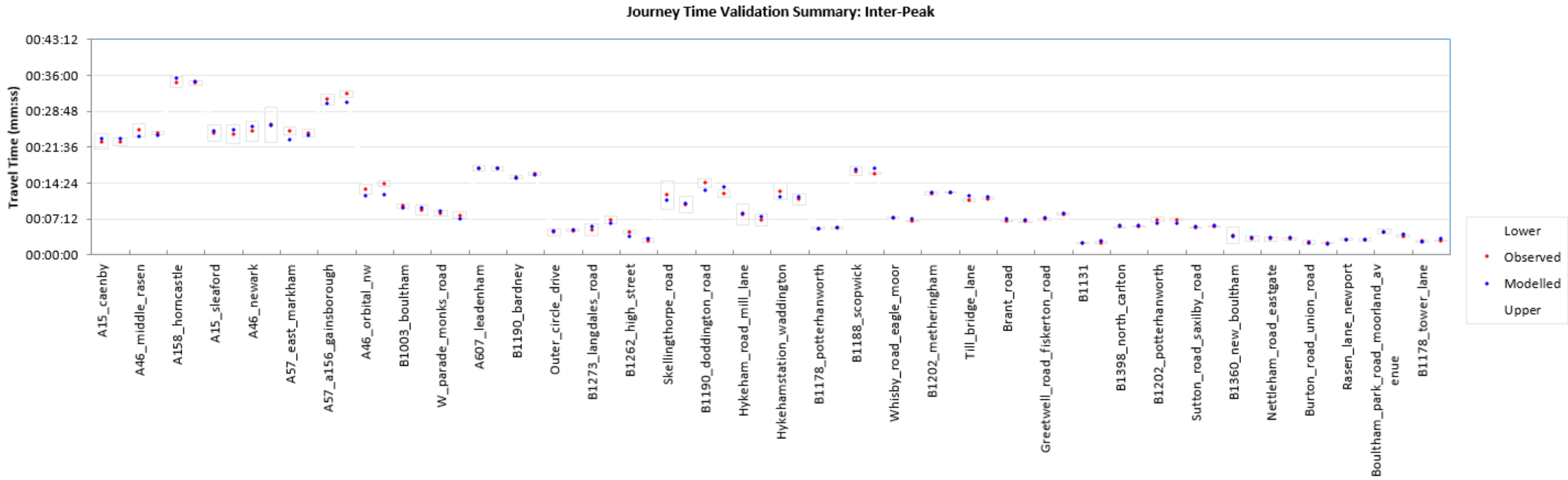


Figure 8-12 Journey Time Validation by Route - PM Peak

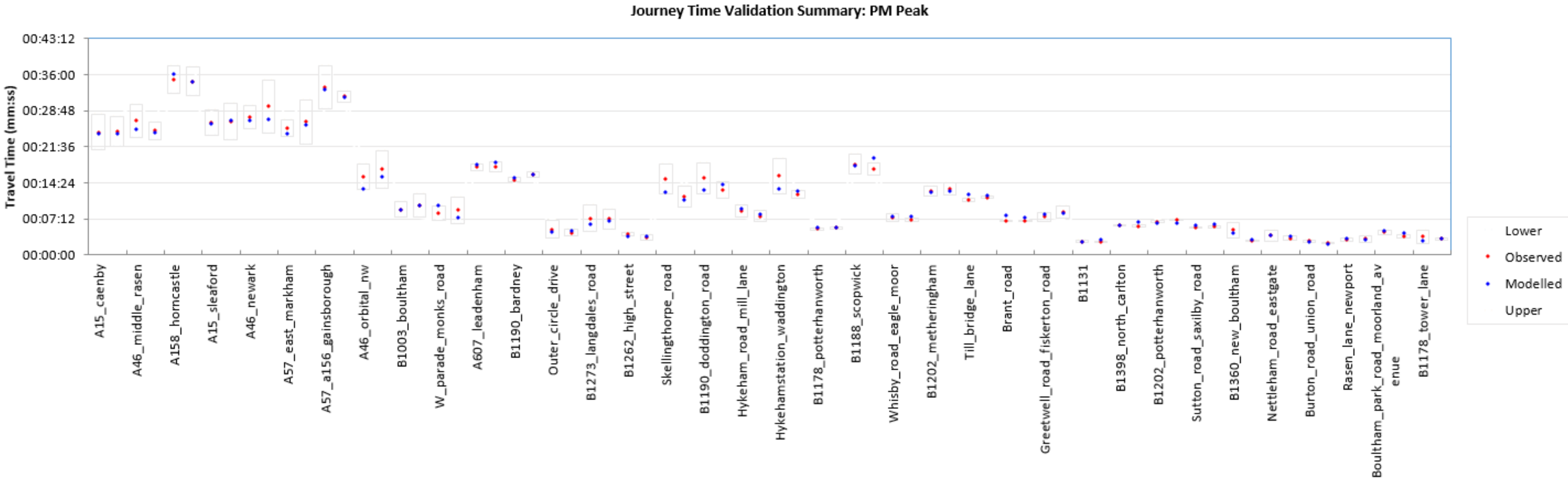


Figure 8-13 Journey Time Validation - AM Peak

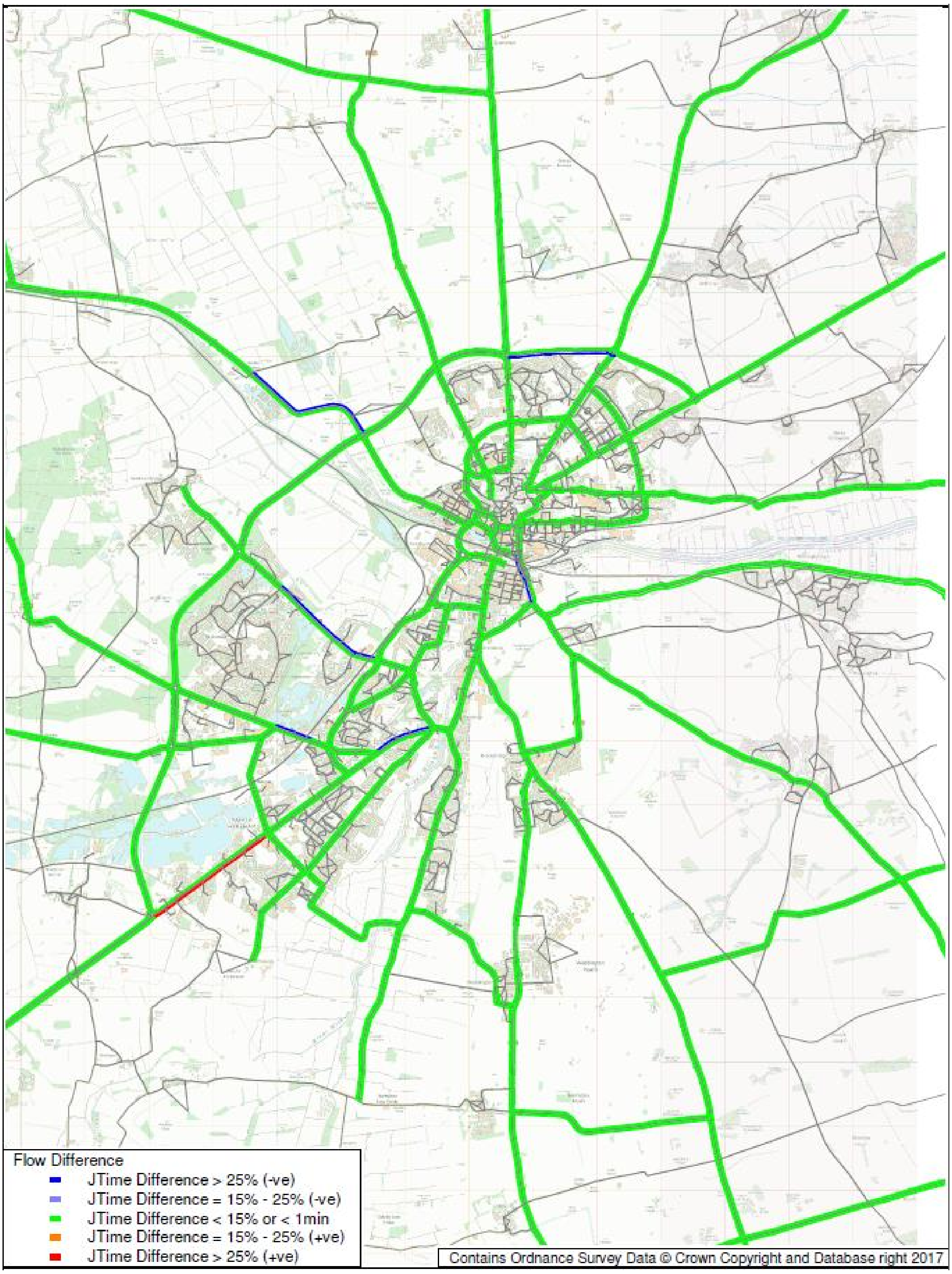


Figure 8-14 Journey Time Validation - Inter Peak

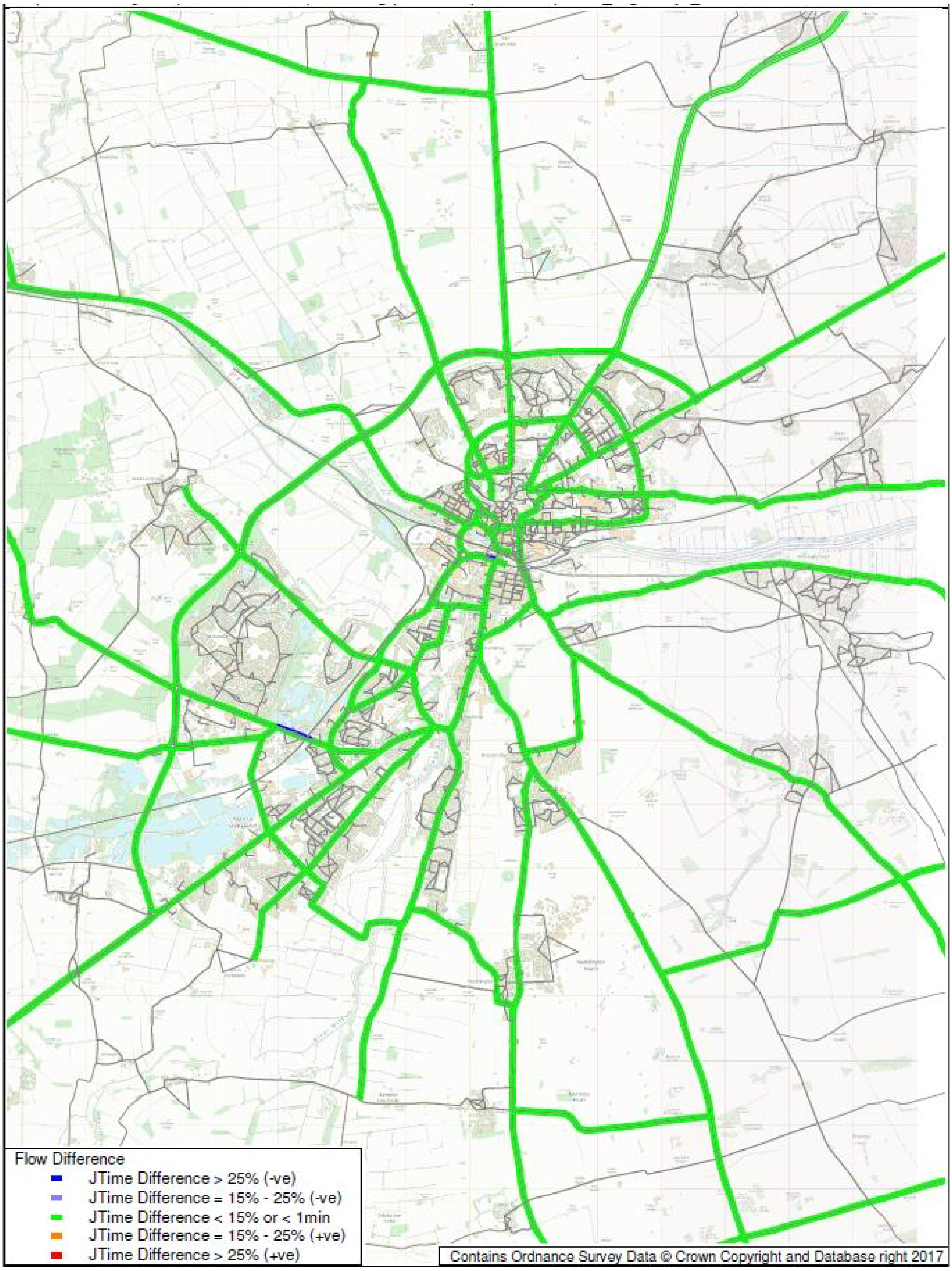
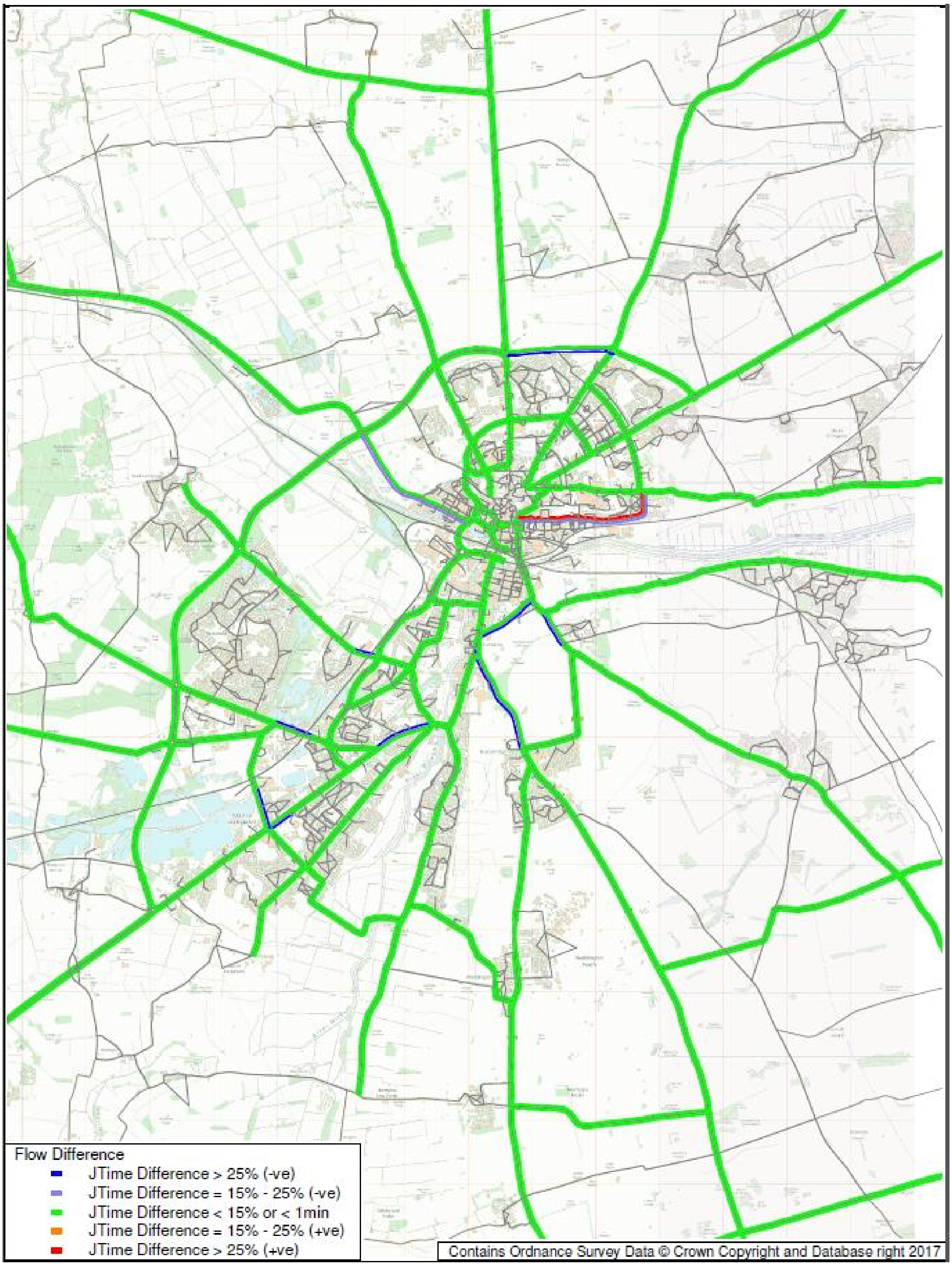


Figure 8-15 Journey Time Validation - PM Peak



8.6 GLHAM Base Year Model Outputs

This section provides the base year model outputs in terms of traffic volume and travel speed on the network by time period. Presentation of link flows and speed are provided from Figure 8-16 to Figure 8-21 below.

Figure 8-16 Link Flow Plot (veh) – AM Peak

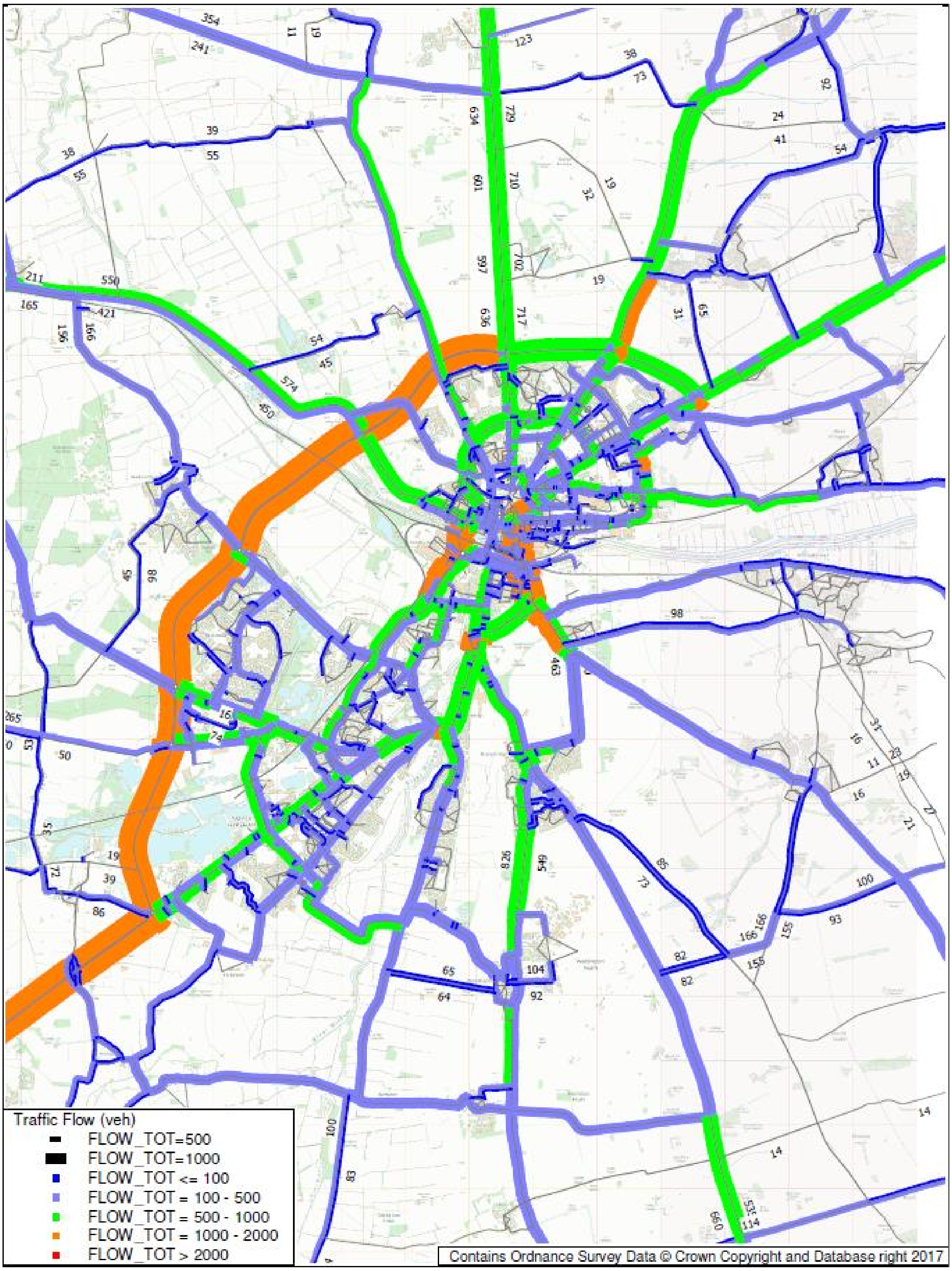


Figure 8-17 Link Flow Plot (veh) – Inter-Peak

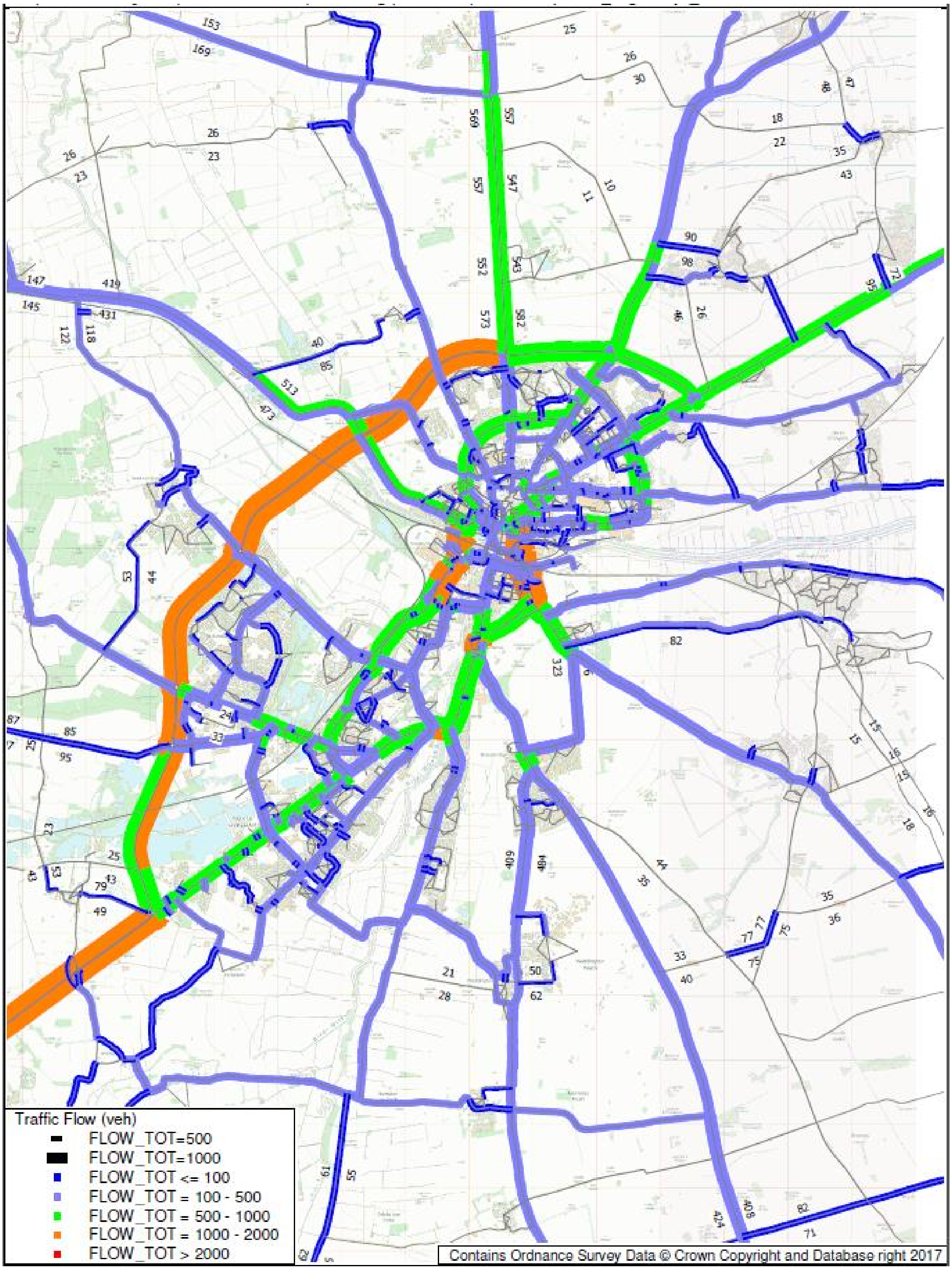


Figure 8-18 Link Flow Plot (veh) – PM Peak