Lincolnshire County Council

NORTH HYKEHAM RELIEF ROAD

Traffic Forecasting Report

70038233
JANUARY 2019

CONFIDENTIAL

Lincolnshire County Council

NORTH HYKEHAM RELIEF ROAD

Traffic Forecasting Report

TYPE OF DOCUMENT (VERSION) CONFIDENTIAL

PROJECT NO. 70038233

OUR REF. NO. 70038233

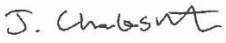
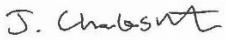
DATE: JANUARY 2019

WSP

Lincolnshire County Council
Crown House
Grantham Street
Lincoln
LN2 1BD

WSP.com

QUALITY CONTROL

Issue/revision	First issue	Revision 1	Revision 2	Revision 3
Remarks	Draft	Final		
Date	09 / 01 / 2019	21 / 02 / 2019		
Prepared by	BP / MB	BP / MB		
Signature				
Checked by	JC	JC		
Signature				
Authorised by	JP	JP		
Signature				
Project number	70038233	70038233		
Report number	70038233-WSP-EGN-XX-RP-TR-0003	70038233-WSP-EGN-XX-RP-TR-0003		
File reference	DRAFT	FINAL		

CONTENTS

TABLES

FIGURES

APPENDICES

NTM GOODS VEHICLE GROWTH

APPENDIX D

DEVELOPMENT TRIP DISTRIBUTION GRAVITY MODEL

APPENDIX E

FIXED SPEED FORECAST FACTORS

APPENDIX F

VDM SECTOR IMPACTS

APPENDIX G

HIGHWAY MODEL CONVERGENCE STATISTICS (ALL FORECASTS)

APPENDIX H

CORE SCENARIO FLOW DIFFERENCE PLOTS

APPENDIX I

CORE SCENARIO DELAY DIFFERENCE PLOTS

APPENDIX J

VDM CONVERGENCE STATISTICS (ALL FORECASTS)

APPENDIX K

ALTERNATIVE SCHEME OPTION FLOW DIFFERENCE PLOTS

APPENDIX L

ALTERNATIVE GROWTH SCENARIO FLOW DIFFERENCE PLOTS

1 INTRODUCTION

1.1 OVERVIEW

WSP have been commissioned by Lincolnshire County Council (LCC) to prepare an Outline Business Case (OBC) for the proposed North Hykeham Relief Road (NHRR).

A comprehensive options development process was concluded by the preparation of the NHRR Options Assessment Report (OAR) (September 2018). The outcome from this was that a preferred option was recommended to, and subsequently approved by, the local Highways Scrutiny and Executive in October 2018.

LCC is seeking funding to develop and construct the NHRR.

Traffic forecasting is a requirement to undertake the scheme appraisal which will form the basis of the Value for Money (VfM) conclusion in the OBC Economic Case. The OBC will submitted to the Department for Transport (DfT) in due course.

To support the Economic Case, traffic forecasting has been undertaken. The forecasting methodology and the technical considerations related to the approach that was undertaken were developed in line with the guidance provided in WebTAG (in particular Unit M4: Forecasting and Uncertainty, May 2018) which is referenced throughout this report.

The forecast model outputs have been taken forward to feed into the economic appraisal, environmental appraisal and distributional impacts assessment. The details and outcomes of those assessments are documented in their respective reports.

1.2 SCHEME DESCRIPTION

The proposed NHRR ("the scheme") will provide a new link through a predominately rural area situated to the south of the Lincoln urban area, which is an area encompassing the district of Lincoln plus the primarily residential areas of North Hykeham and Waddington which are situated in North Kesteven district.

The scheme will link the existing A46 Western Relief Road to the under-construction A15 Lincoln Eastern Bypass (LEB) forming a complete ring road around the Lincoln urban area.

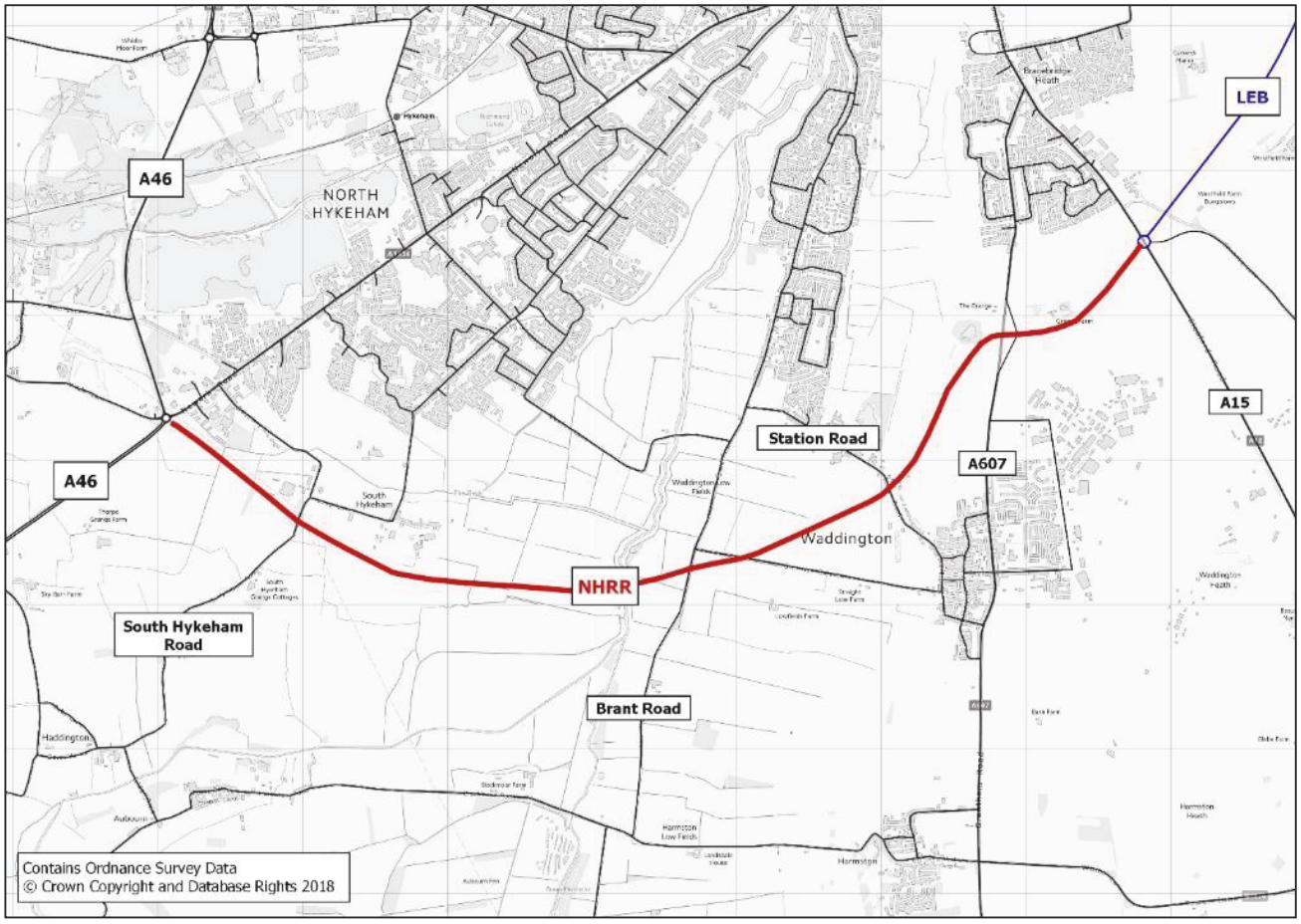
A dual carriageway standard road was determined as the preferred option based on the outputs and conclusions from the options development process, which is detailed in the NHRR Options Appraisal Report (OAR) (September 2018).

The key design features of the scheme are that it will:

- Tie into an upgraded Pennell's roundabout at the western end and tie into the under-construction LEB / A15 roundabout at the eastern end;
- Have at-grade roundabout junctions with South Hykeham Road, Brant Road and A607 Grantham Road; and
- Pass under Station Road which will cross the scheme with a new overbridge.

The preferred route alignment is shown in Figure 1-1.

Figure 1-1 Scheme Alignment



1.3 PURPOSE AND STRUCTURE OF THIS REPORT

This Traffic Forecasting Report (TFR) documents the forecasting assumptions, methodology and outcomes for the development of the forecast scenarios which will be used subsequently for the economic appraisal of the scheme.

The document is structured as follows:

- Chapter 2 summarises the specification and structure of the **Greater Lincoln Transport Model**;
- Chapter 3 sets out the **forecasting requirements** and **methodology** for this process;
- Chapter 4 defines the **future year scenarios** including forecast years, scenario definitions, and sources of uncertainty;
- Chapter 5 describes the development of the **Reference Case demand** including background growth, development trip generation and development trip distribution;
- Chapter 6 describes the **supply forecasting** to develop the future year networks including assumptions and coding for committed schemes;
- Chapter 7 details the methodology for applying **variable demand forecasting** and the impacts on the demand matrices;
- Chapter 8 describes the **Core Scenario assignment results** including convergence, network statistics and reassignment effects;

- Chapter 9 details the **alternative scenarios** including comparisons of the network statistics and reassignment effects against the Core; and
- Chapter 10 **concludes** the document.

2 GREATER LINCOLN TRANSPORT MODEL

2.1 INTRODUCTION

It was established in 2016 that an updated Greater Lincoln Transport Model (GLTM) would be developed to enable modelling and appraisal for new projects being developed by Lincolnshire County Council (LCC) and its partners. The updated GLTM was developed in 2017 and validated for a 2016 base year in an average neutral month.

Traffic modelling and forecasting for the scheme has been undertaken using the GLTM.

This chapter describes the GLTM including:

- Model structure;
- Segmentation; and
- Fitness for purpose.

The model development is detailed in the GLTM Local Model Validation Report (LMVR) (April 2017).

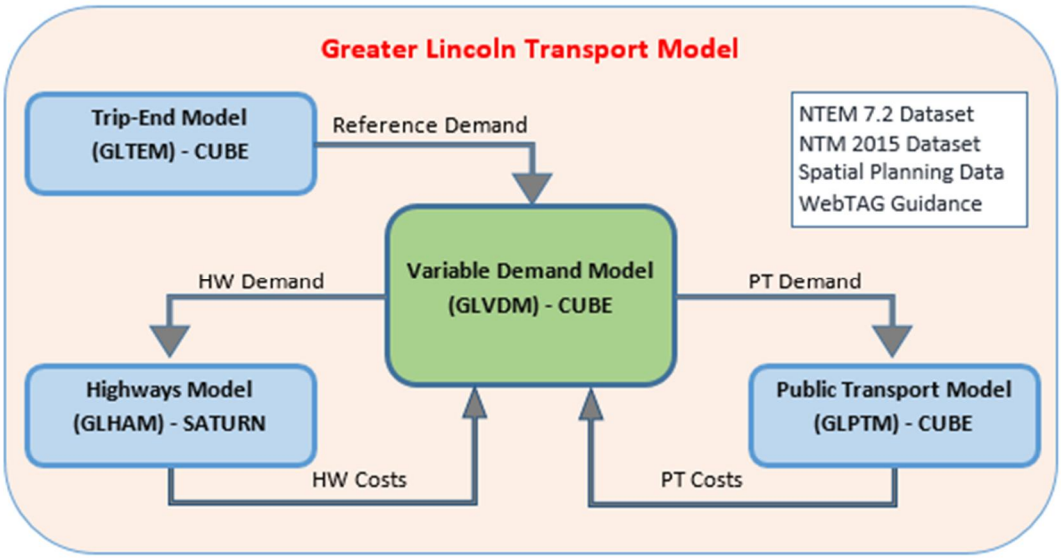
2.2 MODEL STRUCTURE

There are four primary components to the 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. The model was developed in SATURN version 11.3.12W.
- **Greater Lincoln Public Transport Model (GLPTM)**: A public transport assignment model developed within CUBE Voyager to reflect journeys travelling on public transport routes, including route choice, service patronage and travel costs. The model was developed in CUBE version 6.4.
- **Greater Lincoln Trip End Model (GLTEM)**: A trip end model developed within CUBE Voyager to consider the 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 of cost change impacts on distribution and mode split. GLVDM facilitates mode choice between private highway and public transport assignments.

This model structure is illustrated in Figure 2-1.

Figure 2-1 GLTM Structure



The GLTM provides detailed coverage of the Lincoln urban area including North Hykeham and Waddington. The highway model simulation area, referred to by WebTAG as the Fully Modelled Area (FMA) is defined by approximately a 10km cordon around the A46 and under-construction LEB. Speed flow curves are applied in the buffer area which extends to the towns of Gainsborough, Newark, Sleaford and Market Rasen.

The base year highway network coverage is illustrated in Figures 2-2 and 2-3. The images illustrate the extent of the FMA and the network coverage in the external area.

There are 733 zones in the base model with roughly 490 in the FMA.

Figure 2-2 FMA Network Coverage – Lincoln Urban Area

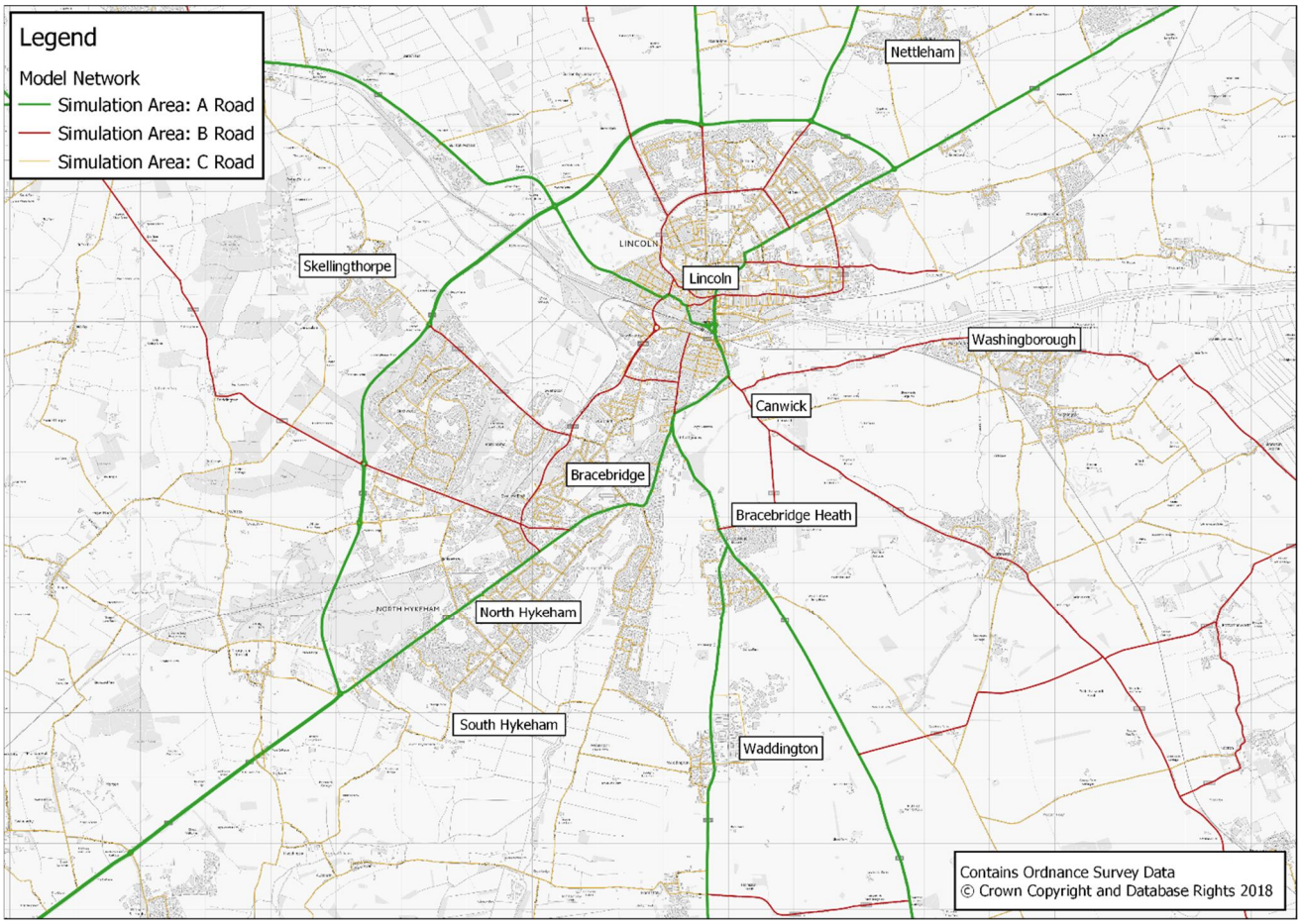
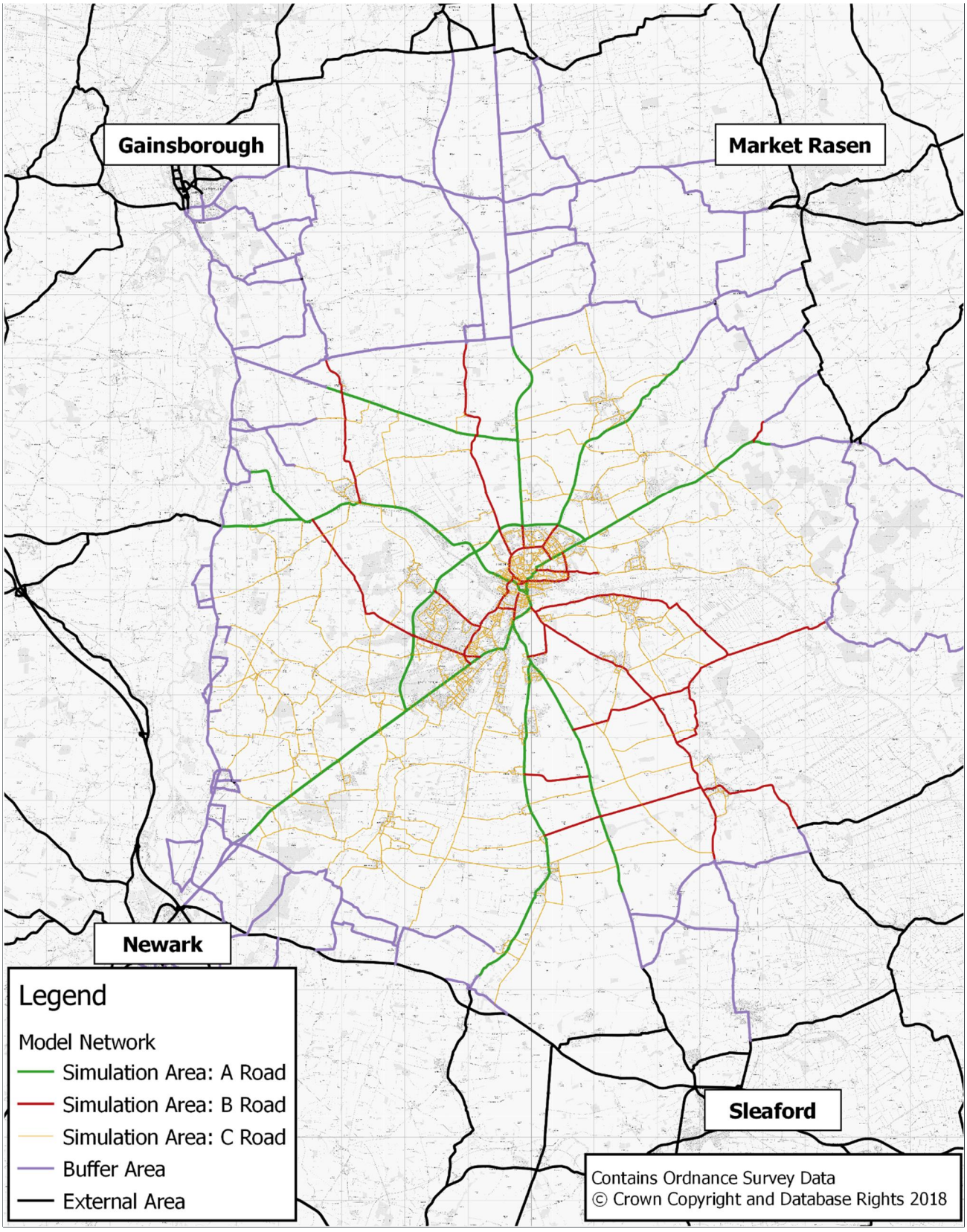


Figure 2-3 FMA Network Coverage – Wider Area



2.3 SEGMENTATION

The base year modelled time periods are defined in Table 2-1.

The peak hours had been determined through analysis of the daily traffic profile from survey data. Average hour was defined for the AM and PM periods in GLPTM based on variation within periods in the PT passenger flow profile due to trip start times being constrained by the timetables.

Table 2-1 GLTM Modelled User Classes

Period	GLHAM	GLPTM
AM Peak	Peak Hour (08:00-09:00)	Average Hour (07:00-10:00)
Inter Peak	Average Hour (10:00-16:00)	Average Hour (10:00-16:00)
PM Peak	Peak Hour (17:00-18:00)	Average Hour (16:00-19:00)

The base year modelled user classes are defined in Table 3-2.

Table 2-2 GLTM Modelled User Classes

User Class	GLHAM	GLPTM
1	Employers Business	Employers Business
2	Commuting	Commuting
3	Other	Other
4	Light Goods Vehicles (LGVs)	
5	Heavy Goods Vehicles (HGVs)	

The period and user class segmentation meet the requirements for this forecasting with the appropriate level of detail to undertake scheme appraisal for a scheme of this type including the disaggregation of benefits between business and non-business and conversion of forecast year benefits by time period into annualised totals.

2.4 FITNESS FOR PURPOSE

The GLTM was reviewed prior to be being used for this forecasting.

The scheme is expected to impact on traffic across a wide area which is captured in two of the specific objectives for the scheme, arising from the NHRR Options Appraisal Report:

- Reduce traffic levels on local and rural roads in the South of Lincoln through the transfer of strategic traffic to more appropriate routes; and
- Reduce traffic levels and congestion on the existing orbital network around Lincoln and on key routes through the city.

To give confidence in the outcomes from traffic forecasting and appraisal to support analysis of these impacts, the model must be well specified and validated in those areas. In particular, that includes:

- The local area and roads in the south of the Lincoln urban area to the north of the scheme;
- The rural villages and roads to the south of the scheme; and
- The existing A46 orbital network.

The GLTM LMVR Addendum (December 2018) details the review of the model and fitness for purpose for this application. This included the model coverage plus the network and zone density in the impact area, in addition to specific consideration for the validation at a localised level to the scheme.

3 FORECASTING APPROACH AND REQUIREMENTS

3.1 INTRODUCTION

Forecasting the usage and performance of transport networks is a critical component in any transport appraisal. The principal purpose for the development of the future year traffic forecasts is to support the LCC funding bid for the NHRR.

This chapter describes the forecasting requirements including:

- Approach to forecasting;
- Base model specification; and
- Forecasting requirements.

This has been prepared with reference to the guidance set out in WebTAG Unit M4 Forecasting and Uncertainty (May 2018).

3.2 APPROACH TO FORECASTING

The approach to forecasting is summarised in Figure 3-1 (extracted from WebTAG M4).

The starting point is the validated base year model – the specification is summarised in Chapter 2.

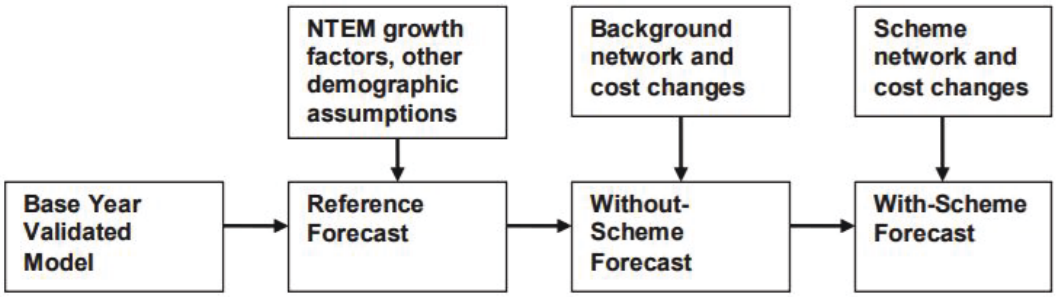
The Reference Case forecasts incorporate changes in travel demand incurred through demographic changes but not changes related to travel costs (including congestion and fares) or other parameters (e.g. value of time).

Development of the Reference Case demand is detailed in Chapter 5.

Background network changes (i.e. committed schemes) and changes to travel costs were used to develop fixed and variable demand 'without scheme' forecasts. This is detailed in Chapter 7.

Scheme network changes and the associated changes to travel costs were used to develop fixed and variable demand 'with scheme' forecasts. This is also detailed in Chapter 7.

Figure 3-1 Approach to Forecasting



Source: WebTAG M4 Figure 1

3.3 FORECASTING REQUIREMENTS

The forecasting requirements are split into four areas:

- Future year travel demand;
- Future year networks;
- Variable demand modelling; and
- Application to scheme appraisal.

The former two areas are underpinned by the requirement, set out in WebTAG M4, to develop an Uncertainty Log which is a record of development and infrastructure assumptions which have been applied in the forecasting. The Uncertainty Log is described in Section 4.4.

3.3.1 FUTURE YEAR TRAVEL DEMAND

Future year travel demands for the modelled forecast years take into the account the existing base year traffic demand together with the effects of traffic growth including additional traffic due to new developments.

Projected traffic growth is largely driven by an increasing population as people are expected to live longer, changes to vehicle operating costs and increasing car ownership with is linked to greater affluence and wealth from increased economic activity. Wealth enhances economic activity and also underpins new household formation; this links to two strategic outcomes of the scheme which are set out in the Strategic Case. There is a strong link, reported in various sources, between infrastructure investment and delivering sustainable household and economic growth. Travel demand forecasting is required to assess the impact of the scheme in supporting the delivery of those outcomes.

Two sensitivity tests have been modelled – high growth and low growth – using the methodology and parameters defined in WebTAG M4.

The assumptions used to derive the future year travel demands are documented in Section 5.5.

3.3.2 FUTURE YEAR NETWORKS

Future year forecasts of network conditions with and without the scheme are required to assess the scheme impacts.

The without scheme forecast must take into account the effects of other schemes that are likely to be in place by the scheme's opening and design years. Most significant is the LEB which is a major infrastructure project that is currently under-construction and will tie into the proposed NHRR (see Figure 1-1) at the A15 junction. The construction is expected to be completed in 2020 and so this will represent a step change from the base year networks to the 'without scheme' networks. They also include smaller schemes plus the infrastructure to support large development sites which have been included in the modelling.

Two alternative scheme configurations have been modelled – a 'next best alternative' and 'low cost option' – which are single carriageway schemes to the same alignment described in Section 1.2.

The assumptions used to derive the future year highway configurations are documented in Section 4.6.

3.3.3 VARIABLE DEMAND MODELLING

The primary purpose of variable demand modelling is to predict the changes in demand that will occur as a result of changes in transport conditions.

It is recommended in WebTAG M2 that variable demand modelling should be included in the model process if one (or more) of the following conditions are satisfied.

- The scheme has capital cost greater than £5million;
- There is significant congestion on the network in the forecast years without the scheme; or
- The scheme would be expected to have an appreciable impact on travel choice (e.g. mode share or distribution) in the scheme corridor.

The NHRR is a major local scheme costing far in excess of £5million with a primary objective to relieve congestion on the existing strategic and local road networks therefore variable demand modelling was required.

3.3.4 APPLICATION TO SCHEME APPRAISAL

The requirements of this forecasting are determined by the requirements for scheme appraisal.

The Economic Case forms one component of the five-case model approach for developing transport business cases and it is written to demonstrate the value for money of a scheme, which is set out in the DfT's 'Transport Business Cases' guidance (January 2013). This is primarily based on the outcomes of cost-benefit analysis but supplemented by qualitative assessment of impacts which are not considered to be significant for the scheme or impacts with a low or emerging evidence base.

Appraisal impacts are split into four groups which rely on traffic forecasting outputs:

- Economy and Social impacts include transport efficiency and reliability for Business and Commuting and Other users respectively. The assessments will require forecast demand and skims at model zone OD level.
- Economy impacts also include dependent development which requires various forecast scenarios to be modelled and compared for the traffic impact of development.
- Public Account impacts include indirect tax revenue which is derived alongside the transport efficiency benefits.
- Environmental impacts include noise and air quality which require forecast traffic flows to inform the respective assessments.

To achieve this, the forecast models were required to:

- Model traffic impacts across the area for which the scheme is expected to have a significant impact in order to fully quantify scheme impacts in the forecasting outputs and subsequent economic appraisal;
- Have a simulated highway network with junction delay within that area so that the impacts of congestion on route choice and traffic flows are appropriately modelled – including blocking back and downstream flow metering – and the outturn derived calculations of junction and link delay are accurate; and
- Achieve a strong level of convergence in the assignment models to ensure that the traffic flow and delay outputs, among others, from the model are based on stable assignments and robust for economic appraisal calculations.

As stated in Section 1.1 the use of forecast outputs for appraisal applications are documented in the respective reports.

3.4 SUMMARY OF FORECAST MODEL OVERVIEW AND STAGES

The forecasting process comprised the following main stages:

- Defining future year travel scenarios;
- Preparing future year Reference Case demand;
- Preparing future year networks;
- Undertaking variable demand matrix forecasting; and
- Reporting of model outputs.

Each of these stages is described in the subsequent chapters.

These achieve each of the requirements set out in Section 3.4 through defining travel scenarios to predict future year travel demand, defining future year networks and applying variable demand forecasting to facilitate changes to the future year demand as a response to changes in travel costs.

4 FUTURE YEAR SCENARIOS

4.1 INTRODUCTION

This chapter defines the parameters and sources of uncertainty for the future year scenarios including:

- Forecast years;
- Scenario definitions;
- Uncertainty;
- Development sites; and
- Highway infrastructure.

This has been prepared with reference to the guidance set out in WebTAG Unit M4 Forecasting and Uncertainty (May 2018).

4.2 FORECAST YEARS

It is a requirement in WebTAG M4 that forecasts of economic benefits need to be derived for the scheme opening year and at least one other forecast year.

The forecast years are:

- **2026**: scheme opening year; and
- **2041**: design year (fifteen years after opening).

4.3 SCENARIO DEFINITIONS

The terminology used in this section is based on the definitions in WebTAG M4.

- A **forecast** is a single run of a transport model for a single year, under a set of forecasting assumptions that may or may not include the scheme.
- A **scenario** is a set of forecasts under a single set of assumptions.

4.3.1 CORE SCENARIO

WebTAG M4 describes the Core Scenario as representing the best basis for decision-making given current evidence. It should be based on more certain, unbiased assumptions although this necessitates consideration of some sources uncertainty. It is also the central case to be presented in the Appraisal Summary Table as part of Economic Case.

There are two forecasts in the Core Scenario:

- Without scheme forecast referred to herein as **Do Minimum (DM)**.
- With scheme forecast referred to herein as **Do Something (DS)**. This consists of the Do Minimum assumptions plus the dual carriageway NHRR as the preferred option.

The assumptions for the Do Minimum networks are detailed in Section 6.3.

The assumptions for Do Something scheme coding are detailed in Section 6.4.

4.3.2 ALTERNATIVE NETWORK CONFIGURATIONS

Two alternative network configurations have been modelled.

- With scheme forecast referred to herein as **Next Best Alternative (NB)**. This consists of the Do Minimum assumptions plus a single carriageway NHRR with future proofed junctions.
- With scheme forecast referred to herein as **Low Cost Option (LC)**. This consists of the Do Minimum assumptions plus a single carriageway NHRR.

The assumptions for scheme coding are detailed in Section 6.4.

4.3.3 ALTERNATIVE GROWTH SCENARIOS

Two alternative growth scenarios have been modelled.

- **High Growth**: Referred to herein as 'High', this forms one of the sensitivity tests recommended by WebTAG M4.
- **Low Growth**: Referred to herein as 'Low', this forms a second sensitivity test recommended by WebTAG M4.

The High and Low are defined to test the impact of the scheme under higher and lower background growth assumptions. In particular, whether the scheme is still effective with higher growth and whether the scheme is still economically viable with lower growth. This was only undertaken for the preferred option.

4.3.4 DEPENDENT DEVELOPMENT SCENARIOS

A dependent development assessment has been undertaken for South West Quadrant development site in line with the guidance in WebTAG Unit A2-2 'Induced Investment' (May 2018). This requires additional forecasts to be developed, including:

- With the development but without the scheme; and
- With the development and with the scheme.

The dependent development assessment is detailed in the Economic Impacts Reports (December 2018).

4.3.5 SUMMARY OF SCENARIOS

The permutations of modelled scenarios are summarised in Table 4-1.

Table 4-1 Scenario Permutations

Scenarios	Name	Demand			Networks	
		Core	High	Low	Without scheme	With scheme
Core	Preferred option	• •	•	•	• (Core DM)	Inc. Preferred option (Core DS)
Alternatives	Next best option	• •	•	•	• •	Inc. Next best alternative
	Low cost option	• •	•	•	• •	Inc. Low cost option
	High growth	•	• •	•	• •	Inc. Preferred option
	Low growth	•	•	• •	• •	Inc. Preferred option

4.4 UNCERTAINTY

WebTAG M4 defines an Uncertainty Log as a record of assumptions in the model that will affect travel demand and supply. This is for the purpose of recording the central forecasting assumptions that underpin the Core scenario and the level of uncertainty around these assumptions.

The sources of uncertainty were considered at a national and local level.

- **National uncertainty** refers to national projections such as demographic changes, GDP growth and fuel price trends. This forms part of the background growth and is reflected in the data obtained from national models such as NTEM and NTM – see Section 5.4.
- **Local uncertainty** considers whether developments or other planned transport schemes will go ahead in the vicinity of the scheme. This information is documented in the Uncertainty Log.

The classifications of uncertainty are presented in Table 4-2.

Table 4-2 Classifications of Uncertainty

Classification	Status
Near Certain (NC) The outcome will happen or there is a high probability that it will happen.	Intent announced by proponent to regulatory agencies. Approved development proposals. Projects under construction.
More than Likely (MTL) The outcome is likely to happen but there is some uncertainty.	Submission of planning or consent application imminent. Development application within the consent process.
Reasonably Foreseeable (RF) The outcome may happen but there is significant uncertainty.	Identified within a development plan. Not directly associated with the transport scheme but may occur if the scheme is implemented. Development conditional upon the transport scheme proceeding. A committed policy goal, subject to tests (e.g. of deliverability) whose outcomes are subject to significant uncertainty.
Hypothetical (H) There is considerable uncertainty whether the outcome will ever happen.	Conjecture based upon currently available information. Discussed on a conceptual basis, One of a number of possible inputs in an initial consultation process. A policy aspiration.

Source: WebTAG Unit M4 Table A2

An Uncertainty Log was prepared as part of the GLTM project which documents all potential developments, highway schemes and public transport interventions within the three districts of Lincoln, North Kesteven and West Lindsey. This work was based on the content of the Central Lincolnshire Local Plan, adopted in April 2017 by the aforementioned districts and verified after discussion with Lincolnshire County Council. It covers the period up to 2036.

The Uncertainty Log was reviewed by LCC at the uncertainty log 'design freeze', which took place prior to model forecasting in September 2018. The uncertainty classification for each development site is based on the best available information at that time.

4.5 DEVELOPMENT SITES

All residential development sites within the FMA with at least twenty-five dwellings are included in the Uncertainty Log and modelled (subject to their uncertainty classification). Smaller developments (<25 dwellings) are assumed to be included in the background growth (see Section 5.4). All employment sites are categorised as 'strategic' or 'established' in the Local Plan document and are modelled (subject to their uncertainty classification).

Development classified as NC or MTL was included in the Core, in accordance with WebTAG M4 guidance.

4.5.1 MAJOR DEVELOPMENT

A sustainable urban extension (SUE) involves the planned expansion of an existing area through mixed use development supported by the necessary facilities and infrastructure to contribute to creating sustainable patterns of development. There are four such locations in the FMA which are mapped in Figure 4-1.

- **North East Quadrant (NEQ):** Land at Greetwell north east of Lincoln City Centre to deliver 1,400 homes and up to 5ha of employment land plus community facilities and green space.
- **South East Quadrant (SEQ):** Land at Canwick Heath south east of Lincoln City Centre to deliver 6,000 homes and up to 7ha of land for employment, community facilities and open space.
- **South West Quadrant (SWQ):** Land at Grange Farm south west of Lincoln City Centre to deliver 2,000 homes and up to 5ha of land for employment, community facilities and open space.
- **Western Growth Corridor (WGC):** Land to the west of Lincoln City Centre to deliver 3,200 homes during the Plan Period and up to 20ha of land for mixed-use development including commercial, leisure, retail, community facilities and open space.

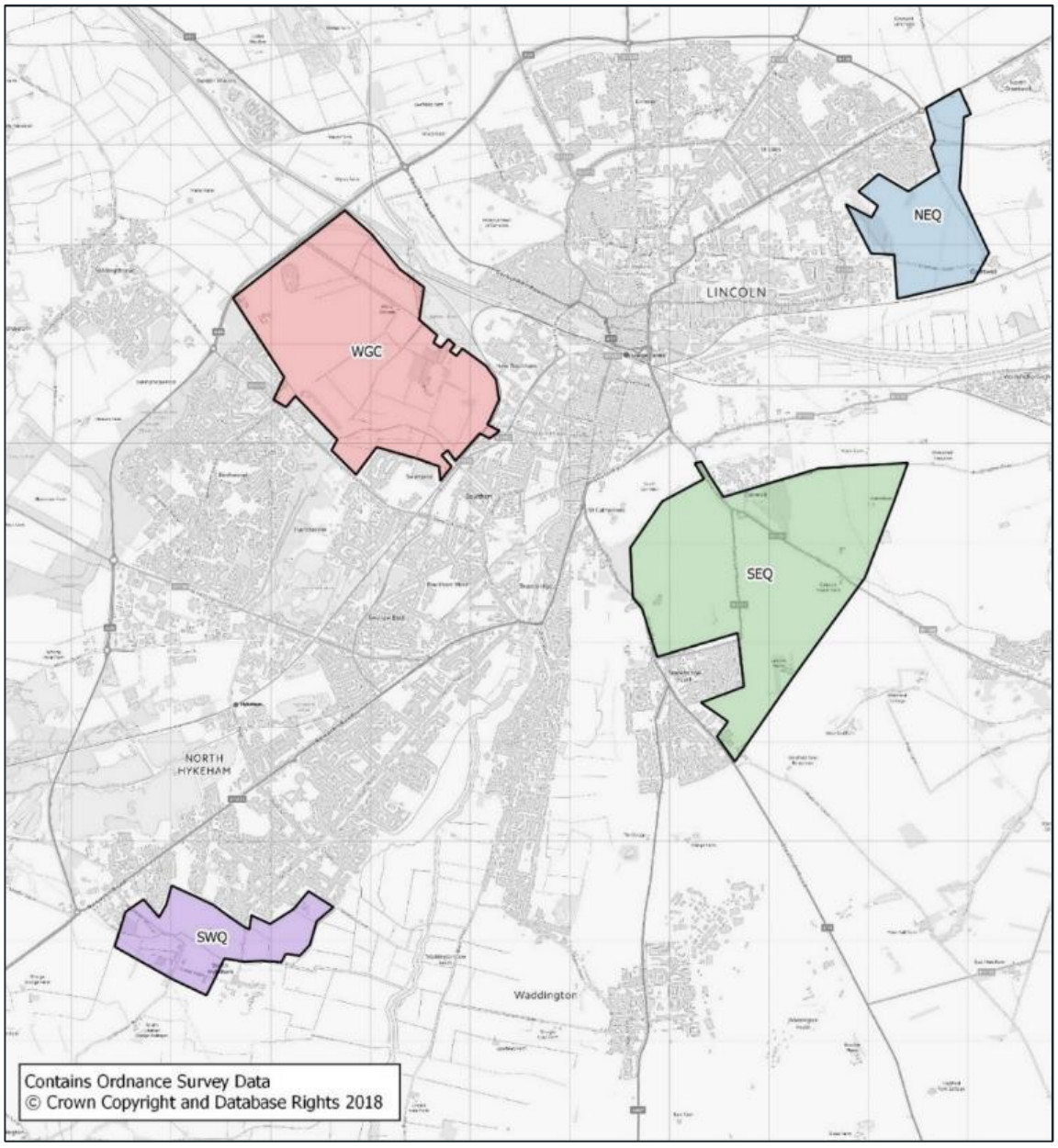
The uncertainty classifications for each of the SUEs are described in Table 4-3.

Table 4-3 Uncertainty Assumptions for SUEs

Site	Current Status	Uncertainty Assumption
NEQ	Outline planning permission granted for Phase 1 (500 homes). Phase 2 (900 homes) is dependent on the opening of the LEB but not forecasting work has been undertaken.	Phase 1 classified as MTL. Phase 2 classified as RF.
SEQ	Forecasting completed by WSP in September 2018. Scenario for 3,600 dwellings up to 2036 at the end of the Local Plan period. Outputs were provided to developer consultant to feed into TA.	3,600 dwellings up to 2036 classified as MTL. 2,400 dwellings post-2036 classified as RF.

Site	Current Status	Uncertainty Assumption
SWQ	Linked to the delivery of the NHRR in the Local Plan. The dependent development test is the only recent forecasting work to be undertaken.	Full development classified as RF. (Dependent development test to be undertaken as part of the economic appraisal).
WGC	Forecasting completed by WSP in December 2017. Scenario for full development delivered by 2036. Outputs were provided to developer consultant to feed into TA.	Full development classified as MTL.

Figure 4-1 SUE Locations



4.5.2 OTHER DEVELOPMENT SITES

There were 91 other development sites identified in the Uncertainty Log – 72 residential and 19 employment areas.

A tabulation of all sites, including the uncertainty, is given in Appendix A.

4.6 INFRASTRUCTURE AND SERVICES

In addition to development sites, the Uncertainty Log also details supply assumptions. These can be categorised into:

- Changes to highway infrastructure; and
- Changes to public transport service provision.

4.6.1 HIGHWAY INFRASTRUCTURE

The highway network schemes identified in the Uncertainty Log include:

- Major highway schemes in the FMA: most notably LEB which is under construction;
- Junction improvement schemes in the FMA;
- Major highway schemes in the rest of Lincolnshire;
- A46 Newark Northern Bypass as the only Road Investment Strategy (RIS) scheme in the model buffer area (none in the FMA); and
- Supporting network for the committed SUE development sites to access the existing network.

The complete list is provided in Table 4-4.

Network changes to support the SUEs were based on the latest masterplans available. This information was provided by LCC and included details on site access and egress. Appendix B includes masterplan drawings for NEQ, WGC and SEQ which the following text describes.

NEQ (Phase 1) and SEQ connect to the existing network at priority junctions or roundabouts, and the new links only provide access to and from the development zones.

For WGC, there is a spine road traversing the site connecting Skellingthorpe Road, Tritton Road and Beevor Street which provides a route for 'through' traffic as well as access to the development. The A46 Link Road directly connecting WGC to the A46 at a new roundabout was also included, as agreed with LCC and is consistent with the development assumptions for WGC stated in Table 4-3.

The highway schemes were classified based on the WebTAG definitions (see Table 4-2) and reviewed by WSP and LCC consistent with the process stated for the development sites. Those classified as NC or MTL were included in the Do Minimum networks. These are mapped in Figure 4-2.

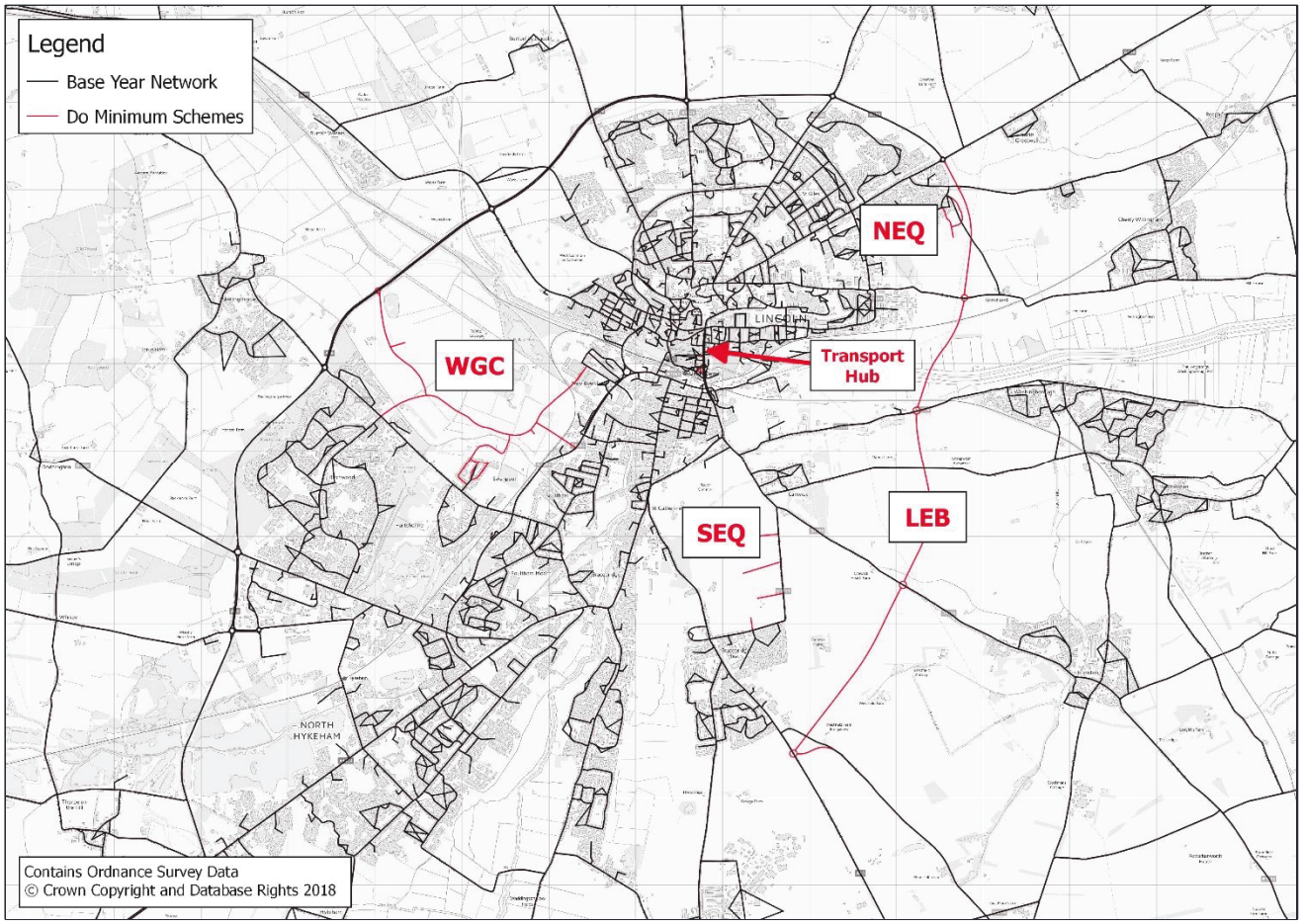
Table 4-4 Uncertainty Classifications for Highway Network Schemes

Name	Description	Uncertainty	Comment
Lincoln Eastern Bypass	7.5km single carriageway bypass between A158 Wragby Road and A15 Sleaford Road.	NC	Under construction (due for completion in 2020).

Name	Description	Uncertainty	Comment
Lincoln Transport Hub	Construction of a new Lincoln Transport Hub which includes changes to the highway alignment and accesses.	NC	Completed. Opened January 2018.
Wragby Road Improvements	Lengthening and widening of both Wragby Road and Wolsey Road.	NC	Completed in September 2018.
A46 Dunholme / Welton Roundabout	New three-armed roundabout replacing the current T-junction.	MTL	Planning permission granted. Expected completion 2020.
A46 Riseholme and Nettleham Roundabouts	Enlarging both roundabouts to incorporate additional lanes and constructing a dual carriageway between the junctions.	H	
A46 / A57 Roundabout	Option testing for changes to junction layout and design.	RF	
NEQ Supporting Network	Network changes to support Phase 1 development access.	MTL	
	Network changes to support Phase 2 development access.	RF	
SEQ Supporting Network	Network changes to support development.	MTL	
SWQ Supporting Network	Network changes to support development.	RF	
WGC Supporting Network	Network changes to support development including A46 Link Road	MTL	
Lincolnshire Coastal Highway	Corridor study based around current coastal highway as a strategic route between A1, Lincoln and the coast	H	
Fixed Speed Area			
Grantham Southern Relief Road	3.5km relief road to link to A52 at Somerby Hill to the A1.	NC	Phase 1 complete; Phase 2 construction to begin early 2018

Name	Description	Uncertainty	Comment
Spalding Western Relief Road	Relief road to provide a new route around west of Spalding connecting Spalding Common to Spalding Road/Pinchbeck Road.	Section 1: MTL Section 2-5: H	
A46 Newark Northern Bypass (RIS)	Improve A46/1A1 junction to remove pinch point and upgrade to dual carriageway (RIS 1 feasibility only).	RF	
Boston Distributor Road	Relief road to provide a new route around west of Boston connecting A16 to the north, A1121 and A52, and A16 to the south.	H	

Figure 4-2 Do Minimum Highway Network Schemes



4.6.2 PUBLIC TRANSPORT SERVICES

Changes to public transport service provision identified in the Uncertainty Log include:

- Revisions to existing local bus routes and services; and

- Northern Rail service route extension to Leeds.

The completed list is provided in Table 4-5.

These were included in the Uncertainty Log so that the forecast public transport assignment costs reflected changes to services.

It was assumed the current level of service for public transport will be maintained in each of the forecast years except where changes were explicitly identified in the Uncertainty Log.

The public transport service changes were classified based on the WebTAG definitions (see Table 4-2) and agreed by LCC, consistent with the process stated for the development sites and highway schemes.

Table 4-5 Uncertainty Classifications for Public Transport Services

Name	Description	Uncertainty	Comment
Northern Rail timetable change – May 2018	Direct Lincoln <> Leeds service introduced (via Sheffield and Wakefield).	NC	Introduced in 2018
Local bus route changes – Transport Hub	Re-routeing of services through new Transport Hub.	NC	Introduced in 2018
Park and Ride	New Park and Ride bus service from Waitrose (Searby Road) to City Centre.	NC	Introduced in 2017.

5 DEMAND FORECASTING

5.1 INTRODUCTION

This chapter details the demand forecasting, including:

- Background growth;
- Development trip generation;
- Development trip distribution;
- Core Scenario matrix totals; and
- Alternative growth scenario demand.

This has been prepared with reference to the guidance set out in WebTAG Unit M4 Forecasting and Uncertainty (May 2018).

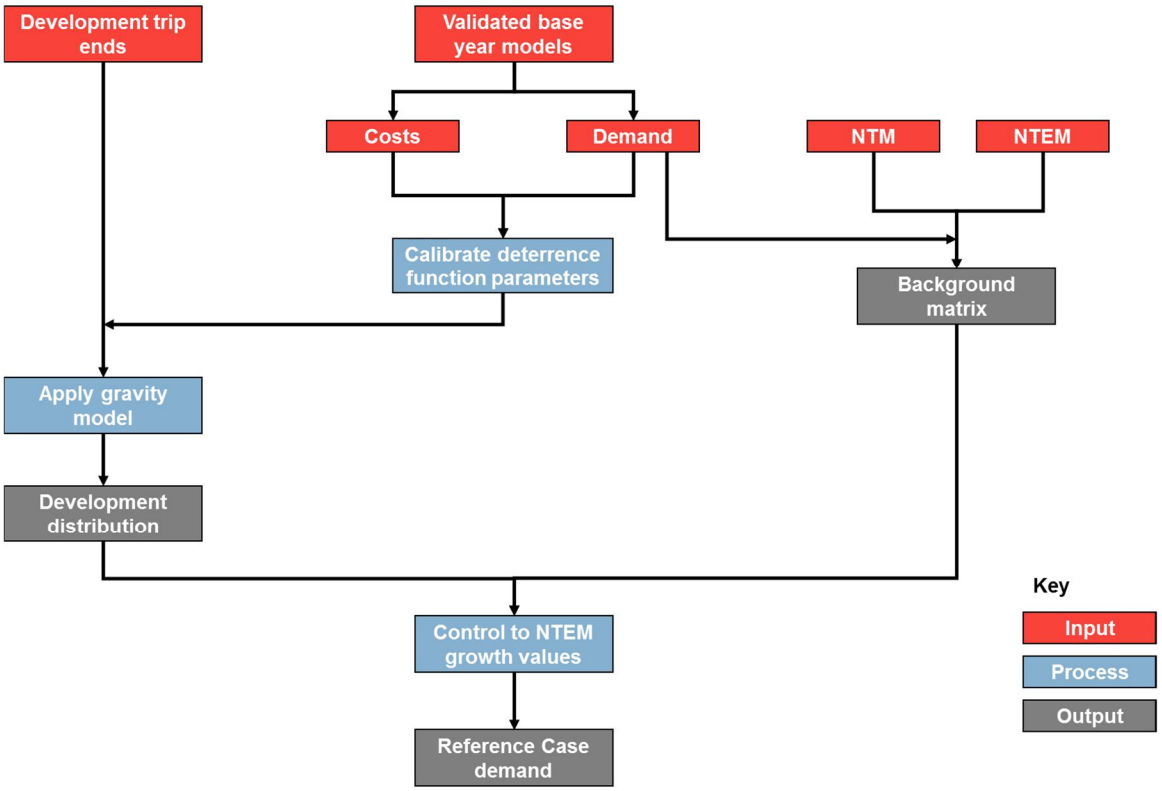
WebTAG M4 describes a reference forecast as an intermediate step for producing forecasts prior to the application of variable demand modelling. It takes into account growth in trip ends over the forecasting period but does not take into account changes in cost.

The process is summarised as follows and illustrated in Figure 5-1.

- Growth factors from NTEM and NTM were applied to the base year demand to develop the background matrix.
- Base year costs and demand were used to calibrate a deterrence function based on the base year trip length distribution.
- The outturn function was used to distribute development trips using a gravity model. This created the development trip matrix.
- The development trip matrix and the background matrix were merged, with the background growth reduced to account for the addition of development trips. Overall growth was controlled to NTEM values at district level in line with WebTAG M4 guidance.

Each of the stages are detailed in the following sections.

Figure 5-1 Reference Case Demand Methodology



5.2 BACKGROUND GROWTH

WebTAG M4 defines a background assumption to be “an assumed change between the base year and the forecast year that is assumed to happen independent of the scheme.”

Background demand changes occur due to various factors including demographic changes, GDP and fuel prices.

5.2.1 NATIONAL TRIP END MODEL

In line with WebTAG guidance the impact of changes to demographic data are accounted for by applying data from the DfT’s National Trip End Model (NTEM) dataset.

Forecast trip ends were extracted from the NTEM version 7.2 to derive background car trip end growth factors for each demand segment. They consisted of origin and destination factors by mode (car driver, bus, rail), by time period (am peak, inter peak, pm peak) and by trip purpose (business, commuting, other).

The growth factors were applied at MSOA level, as the lowest spatial geography defined in NTEM, for zones within the FMA and aggregated to higher geographies corresponding to the zone definitions in the external areas.

A summary of factors for the three districts which encompass the FMA are given in Table 5-1. These provide a high-level indication of the level of growth applied to the demand for each mode in the forecast matrix development including the trends for mode split in the forecast years.

It can be seen that:

- Car driver trip growth ranges from 6-9% in the AM and PM peak period in 2026 rising to 15-21% by 2041. Inter peak period growth is higher linked to the ageing population in NTEM.
- Bus passenger demand largely flat lines in the inter peak and declines in the AM and PM peak periods through the forecast years.
- Rail passenger trip growth is broadly flat in 2026 and with up to 6% growth by 2041. The highest growth is again in the inter peak period.

A consequence of this is that car mode share will increase throughout the forecast years in the Reference Case demand, prior to the impact of variable demand.

Table 5-1 Overall Car Trip End Growth – Study Area Districts

Mode	Year	District	AM Peak		Inter Peak		PM Peak	
			O	D	O	D	O	D
Car Driver	2026	Lincoln	1.09	1.08	1.10	1.10	1.08	1.08
		North Kesteven	1.07	1.07	1.09	1.09	1.07	1.07
		West Lindsey	1.06	1.07	1.09	1.09	1.07	1.06
	2041	Lincoln	1.21	1.19	1.23	1.23	1.18	1.19
		North Kesteven	1.17	1.17	1.22	1.22	1.17	1.17
		West Lindsey	1.15	1.17	1.21	1.21	1.17	1.15
Bus	2026	Lincoln	0.94	0.95	0.97	0.98	0.95	0.94
		North Kesteven	0.98	0.97	0.99	1.00	0.96	0.97
		West Lindsey	0.98	0.97	0.99	0.99	0.96	0.97
	2041	Lincoln	0.91	0.94	0.97	0.97	0.92	0.90
		North Kesteven	0.98	0.96	1.00	1.01	0.94	0.96
		West Lindsey	0.98	0.96	0.98	0.99	0.94	0.95
Rail	2026	Lincoln	1.00	1.01	1.00	1.01	1.01	1.00
		North Kesteven	1.01	1.01	1.01	1.01	1.01	1.01
		West Lindsey	1.00	1.00	1.01	1.01	1.00	1.00
	2041	Lincoln	1.02	1.03	1.03	1.05	1.03	1.02
		North Kesteven	1.04	1.03	1.06	1.06	1.03	1.04
		West Lindsey	1.01	1.03	1.05	1.04	1.03	1.02

5.2.2 NATIONAL TRANSPORT MODEL

Background LGV and HGV forecast growth was derived from the Road Traffic Forecasts (2018 – Reference scenario) which are produced by the DfT from the National Transport Model (NTM).

The factors were applied at Government Region level. Table 5-2 summarises the values for the East Midlands and a complete table is provided in Appendix C.

Table 5-2 Goods Vehicle Growth – East Midlands

Mode	Region	2016	2026	2041
LGV	EM	1.00	1.15	1.38
HGV	EM	1.00	0.99	1.02

5.3 DEVELOPMENT TRIP GENERATION

Development trip generation was obtained from a Transport Assessment where available. This included two of the SUEs (WGC and SEQ) and so incorporates the most recent planning assumptions for their mixed land use.

Local trip rates by land use had been derived from the TRICS database and agreed with LCC for application on recent local studies. These were applied where no Transport Assessment was available.

The car trip rates derived for local development testing are listed in Table 5-3. The units are per dwelling for residential land use and per 100 square metres of Gross Floor Area for employment land use.

Tables 5-4 and 5-5 summarise the development trip generation by year for the SUEs and other development sites combined. Appendix A tabulates the trip generation for each development site individually.

Table 5-3 Local Development Trip Rates

Period	Land Use	Car		LGV		HGV	
		O	D	O	D	O	D
AM Peak Hour	Residential - Houses	0.334	0.106	0.022	0.021	0.000	0.000
	Residential - Mixed	0.266	0.116	0.013	0.017	0.000	0.004
	Residential - Flats	0.166	0.062	0.010	0.006	0.003	0.003
	Employment - Business	0.137	1.435	0.047	0.074	0.003	0.006
	Employment - Industrial	0.053	0.252	0.087	0.072	0.013	0.003
	Employment - Mixed	0.094	0.826	0.068	0.073	0.008	0.004
Inter Peak Period	Residential - Houses	0.133	0.134	0.020	0.018	0.001	0.001
	Residential - Mixed	0.133	0.147	0.019	0.020	0.002	0.003
	Residential - Flats	0.080	0.079	0.016	0.017	0.002	0.002
	Employment - Business	0.273	0.224	0.052	0.055	0.005	0.004
	Employment - Industrial	0.090	0.076	0.052	0.052	0.010	0.009
	Employment - Mixed	0.179	0.148	0.052	0.053	0.007	0.006
PM Peak Hour	Residential - Houses	0.137	0.270	0.009	0.028	0.000	0.000
	Residential - Mixed	0.189	0.270	0.021	0.030	0.000	0.000
	Residential - Flats	0.130	0.221	0.006	0.010	0.000	0.000
	Employment - Business	1.070	0.103	0.029	0.011	0.003	0.002
	Employment - Industrial	0.291	0.037	0.034	0.014	0.003	0.000
	Employment - Mixed	0.669	0.069	0.032	0.013	0.003	0.001

Table 5-4 Development Trip Generation 2026

Development	AM Peak		Inter Peak		PM Peak	
	O	D	O	D	O	D
North East Quadrant	134	48	58	57	55	112
South East Quadrant	443	177	191	204	238	397
Western Growth Corridor	625	289	298	313	367	493
Other Development Sites	1,393	734	660	657	787	1,191
Total	**2,595**	**1,248**	**1,207**	**1,231**	**1,447**	**2,193**

Table 5-5 Development Trip Generation 2041

Development	AM Peak		Inter Peak		PM Peak	
	O	D	O	D	O	D
North East Quadrant	178	63	77	76	73	149
South East Quadrant	1,383	645	608	635	815	1,222
Western Growth Corridor	1,668	771	794	834	980	1,314
Other Development Sites	2,542	1,420	1,211	1,196	1,475	2,146
Total	**5,771**	**2,899**	**2,690**	**2,741**	**3,343**	**4,831**

5.4 DEVELOPMENT TRIP DISTRIBUTION

Development trip distribution was undertaken using a gravity model approach.

The gravity model was calibrated on the validated GLTM base year models to a Tanner function, by time period and user class.

The Tanner function is defined as

$$F(C_{ij}) = C_{ij}^{\cdot 1} e^{X_2 C_{ij}}$$

where:

- C_{ij} is the generalised cost from zone i to zone j; and
- X_1 and X_2 are parameters to be calibrated.

The calibrated parameters for X_1 and X_2 are summarised in Appendix D alongside the base year and calibrated average trip length. It also includes plots of the observed and estimated trip length distributions by demand segment for each time period.

5.5 CORE SCENARIO REFERENCE MATRIX TOTALS

As described in Section 5.1, the outturn development trip matrix and the background matrix were merged, with the background growth reduced to account for the addition of development trips. Overall growth was controlled to NTEM values at district level in line with WebTAG M4 guidance.

The outturn Reference Case demand totals are summarised in Tables 5-7 and 5-8 by forecast year. The base year demand summary in the same format is provided in Table 5-6.

Table 5-6 Base Year Demand Summary (persons)

Mode	Format	Purpose	AM Period	Inter-Peak	PM Period	Off-Peak	24-hour
Highways	PA	HBW (fromHome)	133,733	49,197	32,971	46,438	262,339
		HBW (returnHome)	25,518	61,929	128,547	35,367	251,360
		HBW (total)	*159,251*	*111,126*	*161,518*	*81,805*	*513,699*
		HBEB (fromHome)	42,337	17,207	9,020	16,449	85,013
		HBEB (returnHome)	7,880	23,640	20,482	12,086	64,088
		HBEB (total)	*50,218*	*40,847*	*29,502*	*28,535*	*149,102*
		HBO (fromHome)	143,309	227,221	90,532	93,873	554,936
		HBO (returnHome)	47,605	266,283	151,285	92,538	557,711
		HBO (total)	*190,915*	*493,504*	*241,817*	*186,411*	*1,112,647*
	OD	NHBEB	22,332	73,300	14,094	9,823	119,550
		NHBO	48,210	220,859	86,729	38,599	394,397
	Total		*470,926*	*939,636*	*533,659*	*345,174*	*2,289,394*
Public Transport (Bus + Rail)	PA	HBW (fromHome)	2,467	666	615	493	4,240
		HBW (returnHome)	441	1,148	1,824	367	3,779
		HBW (total)	*2,908*	*1,814*	*2,438*	*859*	*8,020*
		HBEB (fromHome)	321	320	121	112	874
		HBEB (returnHome)	83	392	228	62	764
		HBEB (total)	*404*	*712*	*349*	*174*	*1,639*
		HBO (fromHome)	1,512	2,608	453	486	5,059
		HBO (returnHome)	136	3,193	946	572	4,847
		HBO (total)	*1,648*	*5,801*	*1,399*	*1,059*	*9,906*
	OD	NHBEB	185	707	174	132	1,198
		NHBO	346	1,863	851	373	3,433
	Total		*5,492*	*10,896*	*5,211*	*2,597*	*24,196*

Table 5-7 Reference Case Demand Summary 2026 (persons)

Mode	Format	Purpose	AM Period	Inter-Peak	PM Period	Off-Peak	24-hour
Highways	PA	HBW (fromHome)	142,997	51,922	34,974	49,419	279,312
		HBW (returnHome)	27,258	65,317	136,579	37,531	266,686
		HBW (total)	*170,255*	*117,240*	*171,553*	*86,951*	*545,998*
		HBEB (fromHome)	45,629	18,464	9,689	17,717	91,499
		HBEB (returnHome)	8,455	25,393	22,027	12,962	68,837
		HBEB (total)	*54,084*	*43,856*	*31,716*	*30,679*	*160,335*
		HBO (fromHome)	158,444	251,982	99,047	103,886	613,360
		HBO (returnHome)	52,454	295,670	165,899	102,218	616,240
		HBO (total)	*210,898*	*547,652*	*264,947*	*206,104*	*1,229,600*
	OD	NHBEB	24,048	78,499	15,111	10,516	128,174
		NHBO	53,267	245,390	95,142	42,515	436,314
	Total		*512,551*	*1,032,636*	*578,468*	*376,764*	*2,500,420*
Public Transport (Bus + Rail)	PA	HBW (fromHome)	2,457	670	628	494	4,249
		HBW (returnHome)	452	1,071	1,764	351	3,637
		HBW (total)	*2,909*	*1,741*	*2,391*	*845*	*7,886*
		HBEB (fromHome)	323	326	121	114	884
		HBEB (returnHome)	77	391	228	61	757
		HBEB (total)	*400*	*717*	*350*	*175*	*1,641*
		HBO (fromHome)	1,508	2,630	458	488	5,084
		HBO (returnHome)	134	3,219	974	581	4,908
		HBO (total)	*1,643*	*5,849*	*1,432*	*1,069*	*9,992*
	OD	NHBEB	185	721	176	133	1,215
		NHBO	348	1,884	877	377	3,486
	Total		*5,485*	*10,912*	*5,225*	*2,598*	*24,220*

Table 5-8 Reference Case Demand Summary 2041 (persons)

Mode	Format	Purpose	AM Peak	Inter-Peak	PM Peak	Off-Peak	24-hour
Highways	PA	HBW (fromHome)	154,350	55,591	37,657	53,184	300,781
		HBW (returnHome)	29,551	69,808	146,575	40,301	286,236
		HBW (total)	*183,902*	*125,399*	*184,232*	*93,485*	*587,017*
		HBEB (fromHome)	49,675	20,007	10,519	19,265	99,466
		HBEB (returnHome)	9,185	27,525	23,931	14,065	74,704
		HBEB (total)	*58,860*	*47,532*	*34,450*	*33,329*	*174,171*
		HBO (fromHome)	177,227	282,170	109,979	116,206	685,582
		HBO (returnHome)	58,601	331,427	184,441	114,224	688,694
		HBO (total)	*235,828*	*613,597*	*294,420*	*230,430*	*1,374,275*
	OD	NHBEB	26,129	85,052	16,363	11,367	138,910
		NHBO	59,374	274,714	105,421	47,212	486,721
	Total		*564,092*	*1,146,294*	*634,886*	*415,823*	*2,761,094*
Public Transport (Bus + Rail)	PA	HBW (fromHome)	2,486	689	641	503	4,319
		HBW (returnHome)	455	1,021	1,749	341	3,566
		HBW (total)	*2,941*	*1,710*	*2,390*	*845*	*7,885*
		HBEB (fromHome)	332	337	124	117	909
		HBEB (returnHome)	74	398	234	61	767
		HBEB (total)	*406*	*734*	*358*	*179*	*1,676*
		HBO (fromHome)	1,567	2,716	479	506	5,267
		HBO (returnHome)	141	3,321	1,033	604	5,098
		HBO (total)	*1,707*	*6,036*	*1,512*	*1,110*	*10,365*
	OD	NHBEB	189	745	181	136	1,251
		NHBO	369	1,957	932	393	3,651
	Total		*5,612*	*11,182*	*5,372*	*2,662*	*24,828*

5.6 ALTERNATIVE GROWTH SCENARIO DEMAND

Modelling alternative growth scenarios includes consideration of both national and local uncertainty.

5.6.1 NATIONAL GROWTH

The process for adjusting to national high and low growth assumptions is defined in Section 4.2 of WebTAG M4.

- The high/low growth scenarios consist of forecasts that are based on a proportion of the base year demand added/subtracted from the Core scenario.
- The proportion of base year demand to be added is based on a parameter p which varies by mode. The recommended values are:
  - Highway: p = 2.5%
  - Bus: p = 1.5%
  - Rail: p = 2.0%
- For a forecast year between 1 and 36 years after the base year, the proportion of base year demand to add/subtract should be $\sqrt{x}p$ where x is the number of years after the base year.

The derived adjustment proportions of the base demand are listed in Table 5-9.

Table 5-9 Adjustment Proportions for High and Low Growth

Year	Highway	Bus	Rail
2026	7.91%	4.74%	6.32%
2041	12.50%	7.50%	10.00%

5.6.2 LOCAL UNCERTAINTY

It is stated in WebTAG M4 that the variation of local uncertainty can be considered in the High and Low growth scenarios. This is based on changes to the inclusion/exclusion of specific development sites in the High/Low growth scenarios from the Core.

The Core scenario development assumptions were detailed in Section 4.5. Specific focus was given to the uncertainty for the SUEs (see Section 4.5.1) due to the scale of those developments. Table 5-10 summarises the assumptions agreed and applied; both cases are expanded build out from the Core Scenario assumption to include the 'reasonably foreseeable' growth.

Table 5-10 Development Site Inclusion in Low and High Scenarios

Scenario	Development Site Changes
Low Growth	No changes from the Core.
High Growth	As per Core, plus: • NEQ Phase 2 – 900 homes by 2036 • SEQ extended (post-2036) build out – additional 650 homes by 2041.

The figure of 650 homes for SEQ is based on pro-rata of the remaining 2,400 homes between the period 2036 to 2054 (where 2054 is the stated completion data from local documentation).

In line with WebTAG M4 there were no changes to the supply assumptions other than the addition of access points to the network to accommodate the additional development areas.

6 SUPPLY FORECASTING

6.1 INTRODUCTION

The changes to the network supply in the forecast years is summarised by coding of future schemes, making changes to the external area fixed speed and updating parameters for generalised costs.

This chapter describes each of those areas including:

- Do Minimum scheme coding;
- Do Something scheme coding;
- Next Best and Low Cost scheme coding;
- Fixed speed forecasting;
- Forecast year assignment generalised costs; and
- Forecast year network checks.

6.2 DO MINIMUM SCHEME CODING

The Do Minimum network coding was based on the validated base year networks with the addition of committed and more than likely highway schemes.

The identification and locations of such schemes was described in Section 4.6.

Do Minimum scheme coding in SATURN was based on the coding manual used to develop the base year networks. This provided consistency in coding values and parameters across the network such as saturation flows and speed flow curves. For LEB, the coding was checked for consistency with the existing roundabouts on the A46 including the use of a consistent GAP value.

6.3 DO SOMETHING SCHEME CODING

The key scheme design features are summarised as follows, which follow from the option design descriptions which were set out in the OAR and agreed to form the basis for the design assumptions at this stage.

- The road is a dual carriageway with design speed 70mph.
- LEB / A15 Roundabout
    - The scheme ties into the existing roundabout with two lane entry.
- Grantham Road / Brant Road / South Hykeham Road Roundabouts
    - New roundabout junctions. The scheme has two lane entries and the other arms (existing single carriageways) have one lane approach plus flare.
- A46 / A1434 (Pennell's) Roundabout
    - Upgraded from existing roundabout. The roundabout is enlarged to three lane circulatory. The scheme, A46 and A1434 arms have three lane entries. Middle Lane has two lane entry.
- There is no junction with Station Road (new over bridge).
- Somerton Gate Lane is stopped up.

It is conventional, and recommended by the SATURN manual, to code large roundabouts as a series of priority junctions in SATURN and that approach was used. That was consistent with the existing roundabouts on the A46 and the LEB scheme coding in Do Minimum.

Saturation flows and an appropriate speed flow curve were obtained from the coding manual used to develop the base year and Do Minimum networks. This provided consistency in coding values and parameters across the network.

A GAP value of 2.5 was applied to each of the roundabouts in the scheme coding. This is consistent with the existing coding on the A46 and LEB roundabouts.

However, the GAP times at Pennell's roundabout were subsequently reduced to 2.0. This was informed by junction modelling undertaken in ARCADY. The initial assignments in SATURN showed that the modelled capacities at Pennell's roundabout were a lot less than those modelled in ARCADY. This discrepancy is likely due to how SATURN reflects lane allocations using the exploded junction approach and this is more prevalent with such a large roundabout. Therefore, the GAP values were reduced to better reflect the capacities modelled by ARCADY in the SATURN assignments.

6.4 NEXT BEST AND LOW COST SCHEME CODING

The Next Best scheme is a single carriageway road with 'future proofed' junctions and structures which would enable the main carriageway to be upgraded to dual carriageway in the future. This was reflected in the model by coding the roundabout junctions with dual carriageway capacity.

The key coding interpretations are summarised as follows.

- The road is a single carriageway with a design speed of 60mph.
- LEB / A15 Roundabout
    - The scheme ties into the existing roundabout with one lane approach plus a flare of length 3.5 pcus.
- Grantham Road / Brant Road / South Hykeham Road Roundabouts
    - New roundabout junctions. The scheme (and the other arms) has one lane approach plus flare of length 3.5 pcus. The geometry of the roundabouts are consistent with Do Something.
- A46 / A1434 (Pennell's) Roundabout
    - Upgraded from existing roundabout. The roundabout is enlarged to three lane circulatory consistent with Do Something. The scheme, A46 and A1434 arms have three lane entries. Middle Lane has two lane entry.

The Low Cost scheme is a single carriageway road with single carriageway standard junctions (i.e. no 'future proofing').

The key coding interpretations are summarised as follows.

- The road is a single carriageway with a design speed of 60mph.
- LEB / A15 Roundabout
    - The scheme ties into the existing roundabout with one lane approach plus flare.
- Grantham Road / Brant Road / South Hykeham Road Roundabouts

- New roundabout junctions. The scheme (and the other arms) has one lane approach plus flare. The diameters of the roundabouts are smaller than for Next Best. In SATURN this is reflected by a lower circulatory capacity.

- A46 / A1434 (Pennell's) Roundabout
  - Upgraded roundabout than exists in Do Minimum but still with two lane circulatory. All arms have two lane entries.

6.5 FIXED SPEED FORECASTING

Outside of the highway model simulation area, a reduction in network speeds has been applied to reflect the impacts of increased congestion in the future.

Data for potential changes in speed by region and road category were obtained from the DfT Road Traffic Forecasts 2018[1] ('reference' scenario) and used to factor the base year fixed speeds.

The factors are listed in Table 6-1 for the East Midlands. The complete list for all regions is provided in Appendix E.

Link speeds in the PT assignment are derived from the respective highway assignment so changes to travel times in the highway model are also reflected in the bus service travel times in the PT model. Link speeds coded in the rail network are assumed to be constant in future years unless identified for a specific upgrade (or other) scheme within the Uncertainty Log.

Table 6-1 Fixed Speed Forecast Year Factors – East Midlands

Time Period	Road Type	Region	2016	2026	2041
AM	Motorway	EM	1.000	1.032	0.959
	A Road – Principal	EM	1.000	1.007	0.972
	A Road – Non Principal	EM	1.000	0.986	0.965
	B and C Roads	EM	1.000	0.996	0.990
IP	Motorway	EM	1.000	1.015	0.949
	A Road – Principal	EM	1.000	0.999	0.966
	A Road – Non Principal	EM	1.000	0.988	0.969
	B and C Roads	EM	1.000	0.997	0.991
PM	Motorway	EM	1.000	1.109	0.936
	A Road – Principal	EM	1.000	1.006	0.967
	A Road – Non Principal	EM	1.000	0.984	0.961
	B and C Roads	EM	1.000	0.996	0.989

[1] https://www.gov.uk/government/publications/road-traffic-forecasts-2018

6.6 FORECAST YEAR ASSIGNMENT GENERALISED COST PARAMETERS

Forecast year generalised cost parameters were derived from data in the DfT's WebTAG Databook (May 2018[2]). The generalised cost parameters for each forecast year and time period are listed in Table 6-2.

Toll charges in the base year highway buffer networks have been adjusted to forecast years using the GDP deflator values from the WebTAG Databook. The values are listed in Table 6-3.

The public transport assignment values of time were also derived from the WebTAG Databook. These are listed in Table 6-4. The value of time for bus and rail differs for business since this is defined as 'working time' with the higher value for rail attributed to the higher average trip length (and travel time) compared to bus which is typically focussed on more local trips.

The public transport fares were similarly uplifted by the GDP deflator. The values are listed in Table 6-5.

Table 6-2 Highway Generalised Cost Parameters

Year	User Class	PPM			PPK		
		AM	IP	PM	AM	IP	PM
2016	Business	30.10	30.84	30.53	12.30	12.30	12.30
	Commuting	20.18	20.51	20.25	5.80	5.80	5.80
	Other	13.92	14.83	14.58	5.80	5.80	5.80
	LGV	21.27	21.27	21.27	13.32	13.32	13.32
	HGV	49.67	49.67	49.67	37.76	37.76	37.76
2026	Business	33.60	34.43	34.08	11.90	11.90	11.90
	Commuting	22.53	22.90	22.61	5.55	5.55	5.55
	Other	15.55	16.56	16.28	5.55	5.55	5.55
	LGV	23.75	23.75	23.75	13.65	13.65	13.65
	HGV	55.45	55.45	55.45	51.62	51.62	51.62
2041	Business	44.50	45.60	45.14	11.14	11.14	11.14
	Commuting	29.84	30.33	29.95	5.23	5.23	5.23
	Other	20.59	21.93	21.56	5.23	5.23	5.23
	LGV	31.45	31.45	31.45	13.19	13.19	13.19
	HGV	73.44	73.44	73.44	55.98	55.98	55.98

[2] Full version reference "June 2018 v1.10.1" which was a 'correction to original May 2018 release'

Table 6-3 Highway Modelled Toll Charges

Year	Route	Business	Commute	Other	LGV	HGV
2016	Humber Bridge	116	138	138	118	707
	Dunham Bridge	31	37	37	47	77
	M6 Toll	425	505	505	869	849
2026	Humber Bridge	138	165	165	142	844
	Dunham Bridge	37	44	44	57	92
	M6 Toll	507	604	604	1038	1015
2041	Humber Bridge	192	228	228	196	1170
	Dunham Bridge	51	61	61	78	128
	M6 Toll	703	837	837	1438	1406

**toll costs in pence, 2010 prices, perceived costs*

Table 6-4 Public Transport Generalised Cost Parameters

Year	User Class	Bus – PPM	Rail – PPM
2016	Business	17.95	52.25
	Commuting	17.82	17.82
	Other	8.14	8.14
2026	Business	20.04	58.33
	Commuting	19.90	19.90
	Other	9.08	9.08
2041	Business	26.54	77.25
	Commuting	26.35	26.35
	Other	12.03	12.03

Table 6-5 Public Transport Fare Increases

PT Fares	2016	2026	2041
Growth Factor	1.00	1.21	1.67

**relative to 2016 base with 2010 price base*

7 VARIABLE DEMAND FORECASTING

7.1 INTRODUCTION

This chapter details the application and impacts of variable demand modelling in the forecast years including:

- Requirement for variable demand modelling;
- Variable demand methodology;
- Variable demand model convergence; and
- Impacts of variable demand modelling.

This has been prepared with reference to the guidance set out in WebTAG Unit M2 Variable Demand Modelling (March 2017).

7.2 VARIABLE DEMAND METHODOLOGY

The variable demand forecasts were developed using the Greater Lincoln Variable Demand Model (GLVDM). The specification of GLVDM was considered appropriate for this purpose having been developed in line with the latest WebTAG guidance. The model is described throughout the remainder of this sub-section.

7.2.1 VARIABLE DEMAND PROCESS

The variable demand process employed a pivot-point model which used incremental cost changes to derive changes in demand from a reference trip matrix. It had been calibrated to predict the traveller responses of:

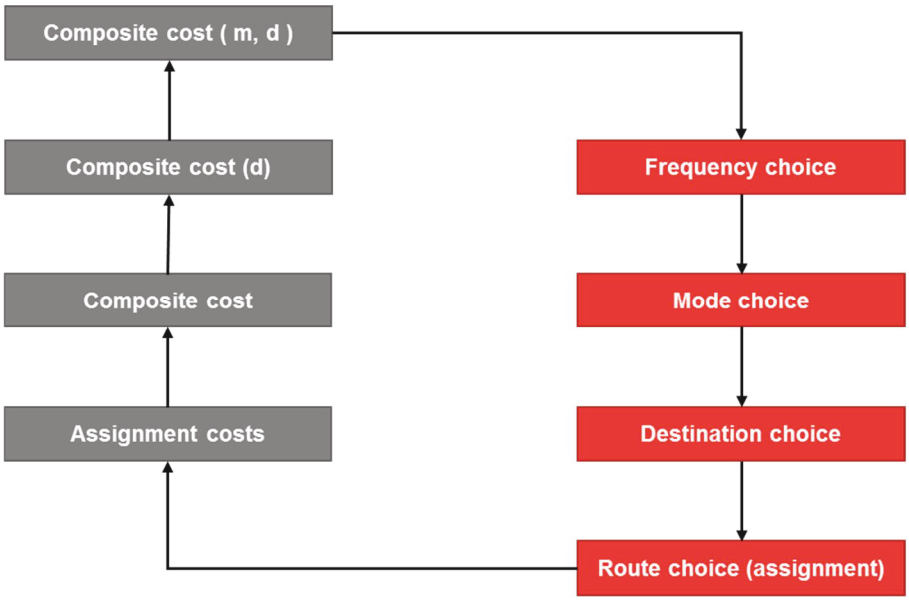
- Mode choice (between highway and public transport); and
- Destination choice (a change of origin and/or destination).

It did not predict change in travel demand for LGVs or HGVs which were assumed fixed (in accordance with WebTAG M2) but susceptible to re-routeing at the assignment stage.

The modelled choice responses and hierarchy are illustrated in Figure 7-1.

- An acceptable level of calibration in the realism testing was achieved without **frequency choice** being utilised therefore this was not invoked.
- It is advised in WebTAG M2 that it is almost always desirable to include a **mode choice** response and this was included.
- There was no clear local evidence of changing time choices so **time of day choice** response was excluded.
- Mode specific **destination choice** responses for highway and public transport were included.
- The **route choice** was undertaken in the respective highway and public transport assignment models.

Figure 7-1 Demand Model Choice Responses and Hierarchy



7.2.2 AREA OF INFLUENCE

The variable demand was applied to trips which interact (wholly within, to or from) an Area of Influence which is illustrated in Figure 7-2. This includes:

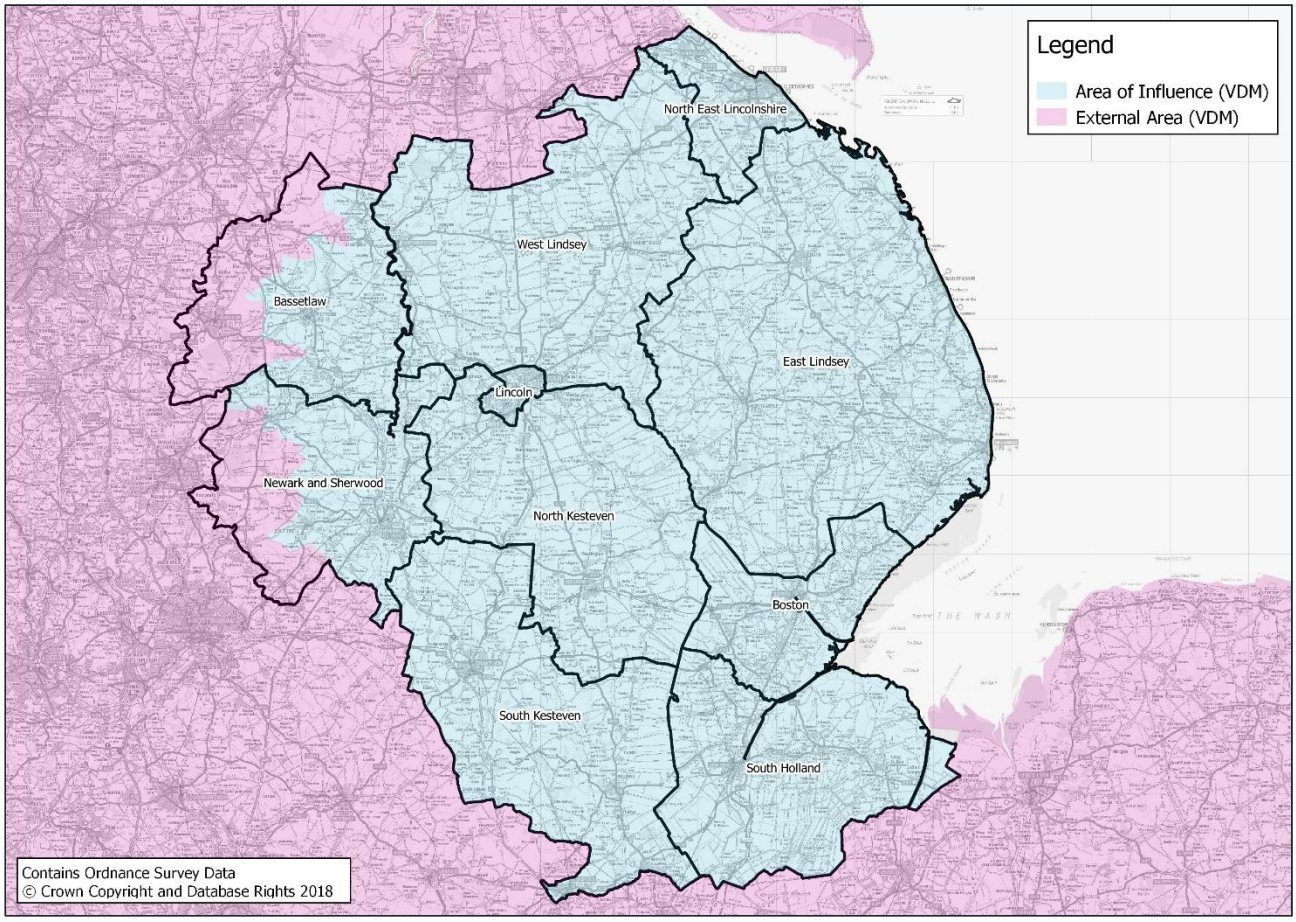
- Lincolnshire County comprising seven districts – Lincoln, North Kesteven, West Lindsey, South Kesteven, East Lindsey, Boston and South Holland;
- North East Lincolnshire – to model the full extent of the A46 to the east coast (near Cleethorpes); and
- The eastern areas of Bassetlaw and Newark and Sherwood districts in Nottinghamshire.

This area was determined by the inclusion of the scheme in the Do Something scenarios and considering the areas over which traffic flows changed by 10% on the existing highway network when the scheme is introduced.

In particular, this includes all of the areas of the model for which most attention has been placed on network coding, PT service provision, zone density and base year validation in the highway and PT models. Beyond this area, network coverage and zone representation are at a more disaggregate level with decreasing detail further from the model study area and fixed speed coding in the external areas.

Cost damping has been applied; the requirement for which was established during the base year realism testing. The Area of Influence covers a large geographical area which necessarily includes a component of long distance trips. This is in line with WebTAG M2 which states that cost damping may be required due to the 'sensitivity of demand responses to changes in generalised cost [reducing] with increasing trip length'.

Figure 7-2 Demand Model Area of Influence



7.3 VARIABLE DEMAND MODEL CONVERGENCE

Convergence of the variable demand model is defined by the %GAP, in this context referring to the demand/supply gap. This is in line with WebTAG M2 guidance and formulation. It measures how far the current flow is from the equilibrium point and would therefore be zero in a perfect model.

The GLVDM criteria is set that the %GAP for highway demand and for total demand must be below 0.05% which is tighter than the suggested value of 0.1% in WebTAG M2.

All VDM forecasts achieve the pre-specified convergence criteria of 0.05%.

Table 7-1 summarises the variable demand model convergence statistics for the Core Scenario runs. It is observed that the 2041 forecasts took more loops than 2026 which is to be expected given the greater travel demand in the later forecast year.

Table 7-1 Variable Demand Model Convergence

Year	Scenario	Number of Loops	Highway GAP%	Total GAP%
2026	Do Minimum	9	0.024	0.029
	Do Something	9	0.022	0.028
2041	Do Minimum	10	0.031	0.034
	Do Something	10	0.035	0.037

7.4 VARIABLE DEMAND FORECAST MATRIX TOTALS

Table 7-2 presents the daily summary for the variable demand forecast. This presentation of the data also shows the high-level impact of mode choice.

The following key trends are observed.

- There is year on year growth in demand for highway and PT (combined bus and rail) trips.
- There is some abstraction of PT demand to highway in Do Minimum relative to the Reference Case, where forecast year supply drives mode shift, increasing as a proportion in the later forecast year.
- There is a smaller abstraction of PT demand to highway in Do Something relative to Do Minimum, where the introduction of the scheme results in some mode shift in the VDM forecast. The lower magnitude of change is not unexpected since the NHRR is an east to west bypass which has low competition from PT services compared to LEB which has a more direct impact on Lincoln City Centre which is the key focal point for bus services in the area.

Tables 7-3 and 7-4 present the highway demand changes by trip purpose and time period for Do Minimum versus the Reference Case and Do Something versus Do Minimum respectively.

It is observed:

- There is a net increase in highway demand for all trip purposes.
- There is a net increase in highway demand for most time periods (across both comparisons) but with a small amount of inter-period shift attributed to the destination choice and differing PA/OD conversion proportions. (Sector changes are presented in the next section).

Those impacts are mirrored in 2041 to a greater magnitude.

Tables 7-5 to 7-8 present the complete post-VDM demand summaries for Do Minimum and Do Something by forecast year with the detailed breakdown by trip purpose and time period. These are consistent with similar tables for the base and Reference Case demand in Section 5.5.

Table 7-2 Variable Demand Forecast Daily Summary by Mode (persons)

Mode	Year	Ref C	DM	DS	DM - Ref C	DS - DM
Highway	2016	2,289,394				
	2026	2,500,420	2,501,569	2,501,687	1,149	117
	2041	2,761,094	2,763,444	2,763,566	2,350	122
PT	2016	24,196				
	2026	24,220	23,071	22,954	-1,149	-117
	2041	24,828	22,477	22,356	-2,350	-122

Table 7-3 VDM Impact (DM – Ref C) by Purpose and Period 2026 (persons)

Highway	AM	IP	PM	OP	Total
Business	-64	128	22	0	87
Commute	155	-97	192	54	304
Other	-166	415	327	182	758
Total	**-75**	**446**	**541**	**236**	**1,149**

Table 7-4 VDM Impact (DS – DM) by Purpose and Period 2026 (persons)

Highway	AM	IP	PM	OP	Total
Business	9	0	-4	1	7
Commute	41	12	-1	12	64
Other	22	-124	129	20	47
Total	**72**	**-112**	**124**	**33**	**117**

Table 7-5 Do Minimum Demand Summary 2026 (persons)

Mode	Format	Purpose	AM Peak	Inter-Peak	PM Peak	Off-Peak	24-hour
Highways	PA	HBW (fromHome)	143,217	51,863	34,892	49,457	279,428
		HBW (returnHome)	27,193	65,279	136,853	37,548	266,873
		HBW (total)	*170,410*	*117,142*	*171,745*	*87,005*	*546,301*
		HBEB (fromHome)	45,615	18,487	9,677	17,746	91,525
		HBEB (returnHome)	8,397	25,463	22,054	12,927	68,841
		HBEB (total)	*54,012*	*43,950*	*31,731*	*30,673*	*160,365*
		HBO (fromHome)	158,664	251,637	98,689	104,119	613,109
		HBO (returnHome)	52,042	296,265	166,500	102,130	616,938
		HBO (total)	*210,707*	*547,902*	*265,189*	*206,250*	*1,230,048*
	OD	NHBEB	24,056	78,534	15,117	10,523	128,230
		NHBO	53,292	245,555	95,227	42,551	436,624
	Total		*512,476*	*1,033,083*	*579,009*	*377,001*	*2,501,569*
Public Transport (Bus + Rail)	PA	HBW (fromHome)	2,338	642	587	468	4,034
		HBW (returnHome)	422	1,054	1,727	345	3,548
		HBW (total)	*2,760*	*1,696*	*2,314*	*813*	*7,582*
		HBEB (fromHome)	316	319	118	111	864
		HBEB (returnHome)	74	385	227	60	747
		HBEB (total)	*390*	*704*	*345*	*171*	*1,611*
		HBO (fromHome)	1,483	2,491	423	456	4,853
		HBO (returnHome)	127	3,077	922	565	4,691
		HBO (total)	*1,610*	*5,569*	*1,345*	*1,021*	*9,544*
	OD	NHBEB	177	686	169	126	1,158
		NHBO	323	1,719	793	341	3,175
	Total		*5,259*	*10,374*	*4,966*	*2,472*	*23,071*

Table 7-6 Do Something Demand Summary 2026 (persons)

Mode	Format	Purpose	AM Peak	Inter-Peak	PM Peak	Off-Peak	24-hour
Highways	PA	HBW (fromHome)	143,266	51,860	34,871	49,460	279,456
		HBW (returnHome)	27,185	65,295	136,873	37,556	266,909
		HBW (total)	*170,451*	*117,154*	*171,744*	*87,016*	*546,365*
		HBEB (fromHome)	45,626	18,484	9,677	17,747	91,534
		HBEB (returnHome)	8,394	25,463	22,050	12,927	68,834
		HBEB (total)	*54,020*	*43,948*	*31,727*	*30,674*	*160,368*
		HBO (fromHome)	158,696	251,526	98,677	104,120	613,020
		HBO (returnHome)	52,031	296,245	166,638	102,148	617,062
		HBO (total)	*210,727*	*547,772*	*265,315*	*206,269*	*1,230,082*
	OD	NHBEB	24,057	78,536	15,118	10,523	128,234
		NHBO	53,294	245,562	95,230	42,552	436,637
	Total		*512,549*	*1,032,971*	*579,133*	*377,034*	*2,501,687*
Public Transport (Bus + Rail)	PA	HBW (fromHome)	2,323	638	585	465	4,010
		HBW (returnHome)	420	1,039	1,708	341	3,508
		HBW (total)	*2,743*	*1,677*	*2,292*	*806*	*7,518*
		HBEB (fromHome)	316	318	118	111	863
		HBEB (returnHome)	74	385	227	60	746
		HBEB (total)	*390*	*703*	*345*	*171*	*1,609*
		HBO (fromHome)	1,474	2,482	422	454	4,832
		HBO (returnHome)	126	3,069	920	564	4,678
		HBO (total)	*1,600*	*5,551*	*1,341*	*1,018*	*9,510*
	OD	NHBEB	176	684	168	125	1,154
		NHBO	321	1,712	789	340	3,163
	Total		*5,230*	*10,328*	*4,936*	*2,460*	*22,954*

Table 7-7 Do Minimum Demand Summary 2041 (persons)

Mode	Format	Purpose	AM Peak	Inter-Peak	PM Peak	Off-Peak	24-hour
Highways	PA	HBW (fromHome)	155,003	55,414	37,415	53,289	301,121
		HBW (returnHome)	29,365	69,705	147,163	40,331	286,563
		HBW (total)	*184,368*	*125,119*	*184,578*	*93,620*	*587,685*
		HBEB (fromHome)	49,669	20,062	10,482	19,342	99,555
		HBEB (returnHome)	9,023	27,710	24,004	13,964	74,702
		HBEB (total)	*58,693*	*47,771*	*34,487*	*33,306*	*174,257*
		HBO (fromHome)	177,838	281,091	108,997	116,864	684,790
		HBO (returnHome)	57,421	333,223	185,823	113,917	690,384
		HBO (total)	*235,259*	*614,314*	*294,820*	*230,781*	*1,375,174*
	OD	NHBEB	26,151	85,140	16,380	11,384	139,054
		NHBO	59,422	275,008	105,569	47,275	487,274
	Total		*563,893*	*1,147,352*	*635,834*	*416,366*	*2,763,444*
Public Transport (Bus + Rail)	PA	HBW (fromHome)	2,252	636	570	454	3,912
		HBW (returnHome)	404	962	1,619	321	3,306
		HBW (total)	*2,656*	*1,599*	*2,189*	*775*	*7,217*
		HBEB (fromHome)	314	319	117	111	860
		HBEB (returnHome)	69	379	224	59	730
		HBEB (total)	*383*	*697*	*340*	*170*	*1,590*
		HBO (fromHome)	1,475	2,455	419	448	4,797
		HBO (returnHome)	128	3,051	921	568	4,669
		HBO (total)	*1,603*	*5,505*	*1,340*	*1,017*	*9,466*
	OD	NHBEB	167	657	164	119	1,107
		NHBO	321	1,663	784	330	3,097
	Total		*5,129*	*10,121*	*4,818*	*2,410*	*22,477*

Table 7-8 Do Something Demand Summary 2041 (persons)

Mode	Format	Purpose	AM Peak	Inter-Peak	PM Peak	Off-Peak	24-hour
Highways	PA	HBW (fromHome)	155,064	55,412	37,393	53,296	301,164
		HBW (returnHome)	29,361	69,718	147,165	40,340	286,583
		HBW (total)	*184,425*	*125,130*	*184,557*	*93,636*	*587,748*
		HBEB (fromHome)	49,678	20,061	10,483	19,343	99,565
		HBEB (returnHome)	9,020	27,712	23,998	13,964	74,694
		HBEB (total)	*58,698*	*47,773*	*34,481*	*33,308*	*174,259*
		HBO (fromHome)	177,863	281,004	108,992	116,874	684,733
		HBO (returnHome)	57,405	333,216	185,927	113,931	690,479
		HBO (total)	*235,269*	*614,220*	*294,919*	*230,805*	*1,375,212*
	OD	NHBEB	26,151	85,142	16,380	11,384	139,059
		NHBO	59,424	275,016	105,572	47,277	487,288
	Total		*563,967*	*1,147,280*	*635,910*	*416,409*	*2,763,566*
Public Transport (Bus + Rail)	PA	HBW (fromHome)	2,237	632	567	451	3,887
		HBW (returnHome)	402	949	1,599	317	3,267
		HBW (total)	*2,639*	*1,581*	*2,166*	*768*	*7,154*
		HBEB (fromHome)	314	318	117	111	859
		HBEB (returnHome)	69	378	223	59	729
		HBEB (total)	*383*	*696*	*340*	*169*	*1,588*
		HBO (fromHome)	1,466	2,445	417	447	4,776
		HBO (returnHome)	127	3,040	919	566	4,652
		HBO (total)	*1,594*	*5,484*	*1,336*	*1,013*	*9,427*
	OD	NHBEB	166	654	164	119	1,103
		NHBO	319	1,655	781	328	3,084
	Total		*5,101*	*10,071*	*4,787*	*2,397*	*22,356*

7.5 VARIABLE DEMAND FORECAST SECTOR ANALYSIS

The impact of destination choice in the variable demand forecasts is considered using sector analysis. The sectors are illustrated in Figure 7-3.

Tables 7-9 and 7-10 present the data for the AM and PM peak respectively in 2026.

The data is presented for the demand in vehicles for all user classes combined. (The observed impacts show similar patterns between user classes).

Comparing Do Something and Do Minimum, it is observed:

- The largest increases at trip end level in the AM peak are observed for destinations in Sector 4 [Bracebridge Heath and Canwick] and Sector 5 [North Hykeham]. The transpose is observed for origins in the PM peak. Sectors 4 and 5 are at the western and eastern extents of the scheme and this increase is attributed to the scheme improving accessibility to those areas.
- There is an increase for inter-sector trips between Sector 4 and Sector 5 in both directions and a decrease in intra-sector trips for those two sectors. This is attributed to the scheme improving east-west connectivity between those sectors where route choice is limited in the Do Minimum.
- The largest increase for an OD pair in the AM peak is Sector 9 [East North Kesteven] to 5. The transpose has a similar increase in the PM peak. This is an east-west movement that will directly benefit from the scheme.
- There are some decreases between Sector 18 [Midlands exc. Lincs and Notts] and Sectors 14 [South Kesteven] / 15 [Nottinghamshire] which is partly due to increases between Sector 18 and Sector 12 [East Lindsey] plus smaller increases between Sector 18 and the Lincoln urban area sectors. The scheme induces demand to/from the [Rest of] Midlands into the Lincoln urban area and the east of Lincolnshire. These are longer distance east-west trips which directly benefit from the scheme.

The observed impacts show similar patterns in the inter peak period, and are similar in 2041 but to a greater magnitude. A complete set of tables are provided in Appendix F.

Figure 7-3 Impacts of VDM Sector System

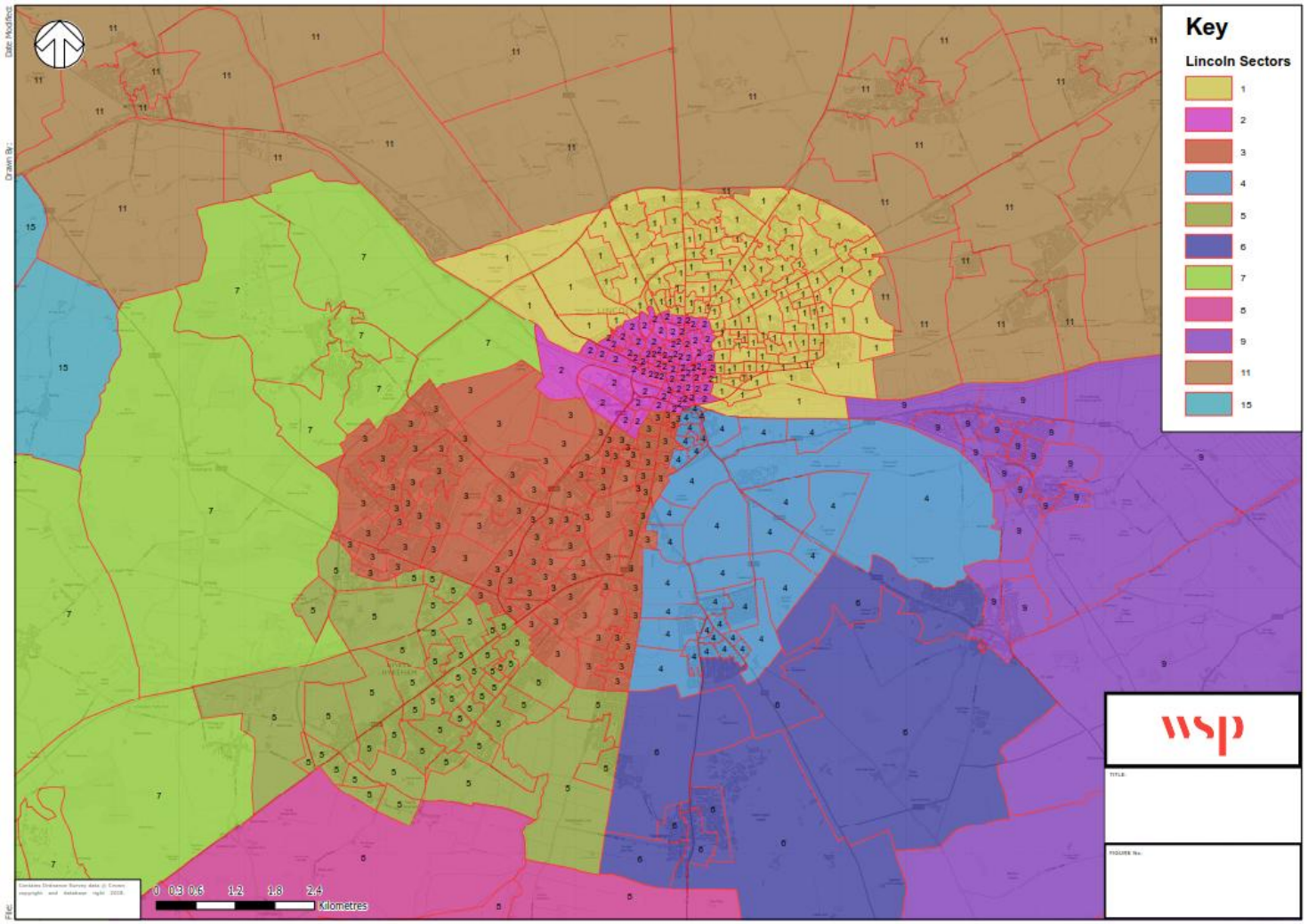


Table 7-9 VDM Highway Impacts by Sector (DS – DM) 2026 AM

OD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1	-20	-4	6	-6	10	4	0	6	-4	-1	-2	0	0	2	2	0	0	3	0	0	-3
2	-2	0	1	-2	2	0	0	1	-1	0	0	1	0	0	0	0	0	0	0	0	1
3	15	2	-7	-5	-15	1	-1	1	3	0	4	3	1	0	-1	0	0	1	0	0	2
4	-7	-7	-5	-9	20	-5	3	6	-6	-1	-5	-2	0	1	16	2	0	9	0	-4	5
5	10	0	-12	26	-29	9	0	0	11	0	7	8	8	0	1	0	0	-2	0	0	36
6	-1	-5	1	-8	10	0	1	0	0	0	1	0	0	0	4	0	0	1	0	-1	2
7	2	0	-6	10	-3	2	-1	0	1	0	-1	1	1	0	-3	0	0	-1	0	0	3
8	6	-1	-3	19	-4	2	-1	-5	1	-1	0	1	0	-2	-14	0	0	-2	0	-1	-6
9	-18	-5	3	-9	32	0	2	2	-7	0	-6	-3	-1	0	8	0	0	11	0	-1	9
10	1	0	0	0	1	0	0	0	0	-1	-1	-1	0	0	0	0	0	0	0	0	0
11	3	1	4	-3	12	3	0	1	-3	-3	-10	-1	0	0	1	-1	0	2	0	0	6
12	-1	0	1	-1	4	1	0	0	-1	-1	-1	-15	-2	0	2	0	-1	10	1	0	-3
13	0	0	0	0	5	0	0	0	0	0	0	0	-2	0	0	0	0	-1	0	0	1
14	1	1	1	3	2	0	0	0	0	0	0	0	0	5	-1	0	0	-14	-1	0	-4
15	8	4	4	22	0	4	-1	-5	2	0	0	1	0	0	-21	-1	0	-15	-1	0	0
16	1	0	0	2	1	0	0	0	0	-1	0	0	0	0	-3	0	0	0	0	0	-1
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	5	2	2	6	0	1	0	-1	0	0	4	12	-2	-19	-19	0	0	0	0	0	-8
19	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	0	0	-1
Total	2	-12	-9	43	50	21	2	7	-5	-8	-9	4	0	-14	-26	-2	-1	3	0	-7	40

Table 7-10 VDM Highway Impacts by Sector (DS – DM) 2026 PM

OD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1	-14	-1	15	-9	15	-1	2	3	-19	0	-13	-3	-2	1	10	0	0	6	0	0	-9
2	-3	-1	3	-5	6	-2	0	1	-8	0	1	0	-1	1	5	1	0	3	0	1	0
3	6	-1	-9	-2	-12	-5	-2	1	3	0	9	1	0	1	6	0	0	3	0	0	2
4	-5	-7	-1	-20	28	-7	11	20	-9	0	-5	-2	0	5	31	2	0	14	0	0	57
5	14	0	-13	19	-38	10	-5	-2	24	0	14	3	2	0	-2	0	0	0	0	1	27
6	1	-3	-2	-5	6	1	1	1	0	0	0	1	-1	0	3	0	0	4	0	0	6
7	1	0	-3	4	1	2	-1	0	4	0	0	0	1	0	-2	0	0	0	0	0	7
8	7	0	-5	16	-2	3	0	-4	2	0	1	0	0	-1	-7	0	0	-1	0	0	8
9	-6	-2	2	-6	7	1	0	1	-5	0	-7	-2	0	0	2	0	0	0	0	0	-13
10	0	0	0	0	0	0	0	0	0	-1	-2	-1	0	0	0	-1	0	0	0	0	-3
11	-2	1	3	-5	6	0	-1	1	-3	-1	-9	-1	0	0	2	0	0	4	0	0	-5
12	-1	1	2	-3	5	1	1	0	-3	-1	-1	-15	-1	0	1	0	0	8	1	0	-5
13	-1	-1	0	0	4	0	0	0	-1	0	-1	-2	-2	0	0	0	0	-1	0	-1	-3
14	0	0	0	1	0	0	0	-2	0	0	0	0	0	5	0	0	0	-15	0	0	-12
15	4	0	-5	31	2	10	-4	-13	10	0	1	2	1	-1	-23	-2	0	-16	0	0	-2
16	1	0	0	0	0	0	0	-1	0	-1	0	0	0	0	-1	0	0	0	0	0	-1
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
18	4	0	-1	7	-2	1	-1	-2	13	0	4	9	-1	-16	-15	0	0	0	0	0	1
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-3
Total	3	-14	-14	23	23	15	2	3	7	-2	-7	-6	-2	-5	10	-1	0	10	0	1	47

8 CORE SCENARIO ASSIGNMENT RESULTS

8.1 INTRODUCTION

This chapter details the outputs from the variable demand forecast assignments.

The outputs are divided in the following sub-sections.

- Highway model assignment convergence;
- Network statistics – including vehicle kilometres, vehicle hours and average speed;
- Network reassignment effects – including flow difference comparisons; and
- Network performance – including link delay comparisons.

8.2 HIGHWAY MODEL ASSIGNMENT CONVERGENCE

An assignment model is deemed to have converged if no significant changes in travel cost occur across all routes between successive iterations. WebTAG Unit M3-1 Highway Assignment Modelling (January 2014) recommends a number of criteria to be applied for all model assignments in order to achieve a final solution (i.e. route choice, with flow and delays produced from the model deemed stable).

WebTAG M3-1 recommends that model iterations should continue until at least four successive values of the percentage of links with flow or cost changes only change by at most 1% for at least 98% of cases. The criteria are replicated in Table 8-1.

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

For the GLTM base models, a tighter criteria of 99% was used. This was carried over into the forecast models and is in line with the preference in WebTAG that tighter levels of convergence may be achieved for scheme appraisal applications.

Each of forecast models converge well and to WebTAG standards. The convergence statistics for Do Minimum and Do Something are presented in Tables 8-2 to 8-5.

Table 8-1 Highway Assignment Convergence Criteria

Criteria	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 flow change (P2) < 1%	Four consecutive iterations > 98%
Percentage change in total user costs (V)	Four consecutive iterations < 0.1%

Source: WebTAG M3-1 Table 4

Table 8-2 Assignment Convergence Statistics – Do Minimum 2026

AM Peak			Inter Peak			PM Peak		
Loop	%Flow	%Gap	Loop	%Flow	%Gap	Loop	%Flow	%Gap
20	99.2	0.00033	19	99.4	0.00024	45	99.1	0.00040
21	99.3	0.00026	20	99.1	0.00014	46	99.4	0.00025
22	99.4	0.00027	21	99.3	0.00041	47	99.4	0.00057
23	99.2	0.00023	22	99.1	0.00009	48	99.3	0.00029

Table 8-3 Assignment Convergence Statistics – Do Something 2026

AM Peak			Inter Peak			PM Peak		
Loop	%Flow	%Gap	Loop	%Flow	%Gap	Loop	%Flow	%Gap
25	99.1	0.00012	16	99.1	0.00007	28	99.4	0.00049
26	99.1	0.00019	17	99.2	0.00007	29	99.3	0.00010
27	99.6	0.00009	18	99.3	0.00007	30	99.1	0.00023
28	99.5	0.00016	19	99.3	0.00004	31	99.0	0.00019

Table 8-4 Assignment Convergence Statistics – Do Minimum 2041

AM Peak			Inter Peak			PM Peak		
Loop	%Flow	%Gap	Loop	%Flow	%Gap	Loop	%Flow	%Gap
54	99.1	0.00087	32	99.5	0.00046	53	99.1	0.00220
55	99.3	0.00190	33	99.4	0.00011	54	99.0	0.00150
56	99.1	0.00150	34	99.6	0.00010	55	99.1	0.00220
57	99.2	0.00150	35	99.7	0.00009	56	99.2	0.00220

Table 8-5 Assignment Convergence Statistics – Do Something 2041

AM Peak			Inter Peak			PM Peak		
Loop	%Flow	%Gap	Loop	%Flow	%Gap	Loop	%Flow	%Gap
31	99.0	0.00089	22	99.2	0.00007	58	99.1	0.00061
32	99.2	0.00088	23	99.5	0.00007	59	99.2	0.00059
33	99.5	0.00067	24	99.6	0.00005	60	99.1	0.00047
34	99.5	0.00072	25	99.4	0.00005	61	99.4	0.00240

8.3 NETWORK STATISTICS

The overall highway network performance statistics for the FMA (see Section 2.2) are presented in Tables 8-6 to 8-8 by time period.

The results present the strategic impact of the different scenarios on the wider network performance, including:

- Total assigned trips (pcus);
- Total travel distance (pcu-kms);
- Total travel time (pcu-hrs);
- Average journey speed (kph);
- Transient queues (pcu-hrs) – i.e. queues which pass through within the modelled period; and
- Over-capacity queues (pcu-hrs) – i.e. queues which are unable to clear within the modelled period.

The results are summarised as follows.

- The increase in average speed from 2016 to DM2026 can be attributed to the additional capacity and higher link speed provided by LEB.
- Average speed in DM2041 is lower than 2016 attributed to the level of growth in the design year exceeding a level that LEB can provide congestion relief, such that the average speed is similar to the base year conditions.
- Average speed is higher in DS than DM. This is partly due to the high speed of the scheme but also attributed to reduced congestion in other parts of the network.
- Total travel distance increases through the years and it increases from DM to DS. This indicates that the scheme offers a longer but faster route choice compared to existing options, including local rat running through North Hykeham.
- Total queues decrease in DS compared to DM as would be expected due to the additional capacity provided by the scheme.
- A similar pattern is generally observed for total travel time and over-capacity queues.

Figure 8-1 illustrates the average speed.

Table 8-6 FMA Network Statistics Core Scenario – AM Peak

Simulation Area Network Statistics	2016	2026		2041	
		DM	DS	DM	DS
Total Assigned Trips (pcus)	237,606	257,382	257,430	283,720	283,774
Transient Queued Time (pcu-hrs)	1,635	1,735	1,636	2,151	2,063
Overcapacity Queued Time (pcu-hrs)	53	100	50	272	191
Total Travel Time (pcu-hrs)	7,418	8,101	7,934	9,552	9,394
Travel Distance (pcu-kms)	343,251	377,173	389,257	420,370	434,760
Average Journey Speed (kph)	46.3	46.6	49.1	44.0	46.3

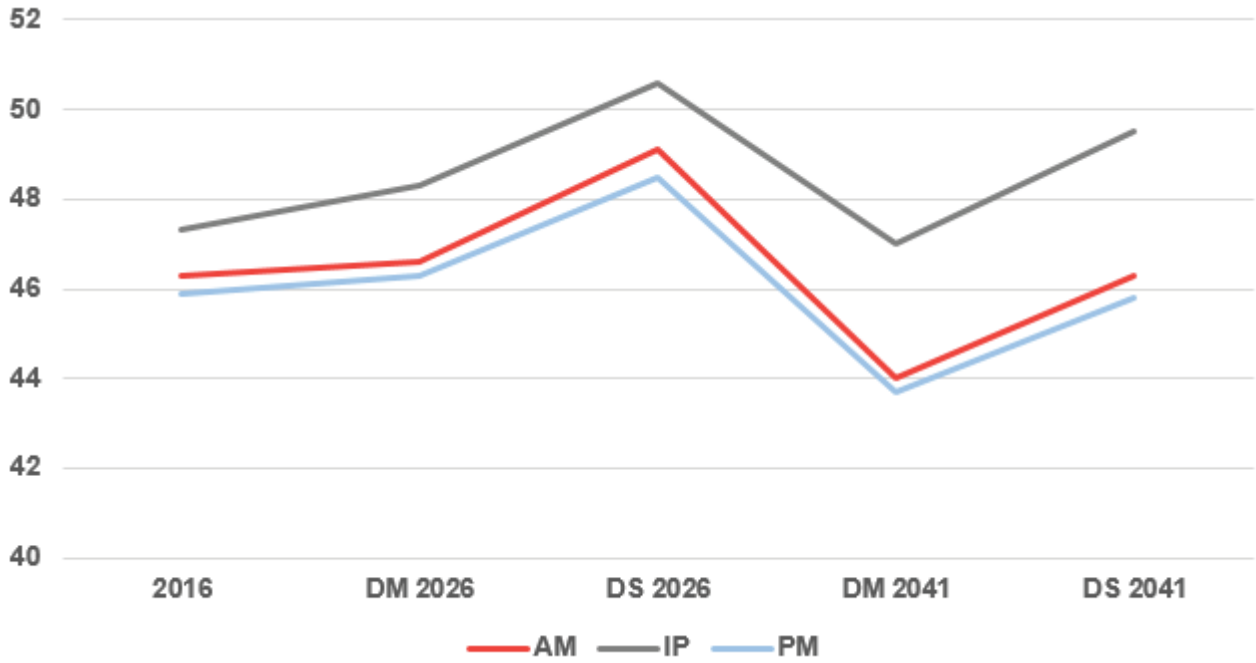
Table 8-7 FMA Network Statistics Core Scenario – Inter Peak

Simulation Area Network Statistics	2016	2026		2041	
		DM	DS	DM	DS
Total Assigned Trips (pcus)	167,244	182,746	182,735	203,291	203,289
Transient Queued Time (pcu-hrs)	1,273	1,343	1,248	1,612	1,506
Overcapacity Queued Time (pcu-hrs)	3	2	0	31	5
Total Travel Time (pcu-hrs)	5,686	6,239	6,125	7,284	7,164
Travel Distance (pcu-kms)	268,776	301,380	309,710	342,083	354,884
Average Journey Speed (kph)	47.3	48.3	50.6	47.0	49.5

Table 8-8 FMA Network Statistics Core Scenario – PM Peak

Simulation Area Network Statistics	2016	2026		2041	
		DM	DS	DM	DS
Total Assigned Trips (pcus)	230,339	249,414	249,471	274,468	274,503
Transient Queued Time (pcu-hrs)	1,726	1,816	1,747	2,222	2,161
Overcapacity Queued Time (pcu-hrs)	53	112	71	287	241
Total Travel Time (pcu-hrs)	7,617	8,338	8,215	9,765	9,662
Travel Distance (pcu-kms)	349,419	385,737	398,112	427,172	442,452
Average Journey Speed (kph)	45.9	46.3	48.5	43.7	45.8

Figure 8-1 FMA Average Speed Core Scenario



8.4 NETWORK REASSIGNMENT EFFECTS

The highway network reassignment effects are illustrated through flow difference plots for two comparisons:

- Do Minimum minus Base; and
- Do Something minus Do Minimum.

The mapping uses a consistent colour scheme where green indicates a flow increase in the first-named forecast and blue indicates a flow decrease in the first-named forecast.

8.4.1 DO MINIMUM AND BASE

The key change in the network between the base and Do Minimum is LEB.

Figures 8-2 to 8-4 show the flow difference by time period in 2026 and the following observations are noted, with the red numbers annotated on the AM image to indicate the locations:

- The new links naturally show a large increase in this presentation. This includes LEB and the development infrastructure for WGC. There are forecast flow increases on existing links adjacent to SEQ and NEQ as a result of development traffic in those locations. **(1)**
- For existing links, there are forecast increases in flow on most sections of the A46 and also the A15 from the south. The latter is attributed to the impact of LEB. **(2)**
- There is a noticeable forecast increase in flow on South Hykeham Road and Mill Lane which are adjacent to the proposed SWQ location. This is attributed to trips using those routes to avoid Pennell's Roundabout between the A46 southern arm and A1434. **(3)**
- There is a forecast decrease in flow on the Bunkers Hill / Wragby Road / A15 corridor through the east of Lincoln City Centre attributed to the impact of LEB. **(4)**

The forecast patterns are similar in 2041, however the impact of LEB for reducing congestion in the city centre is less pronounced with more links showing a flow increase due to the greater level of demand. A complete set of mapping is provided in Appendix H.

Figure 8-2 Flow Difference DM2026 minus Base – AM Peak

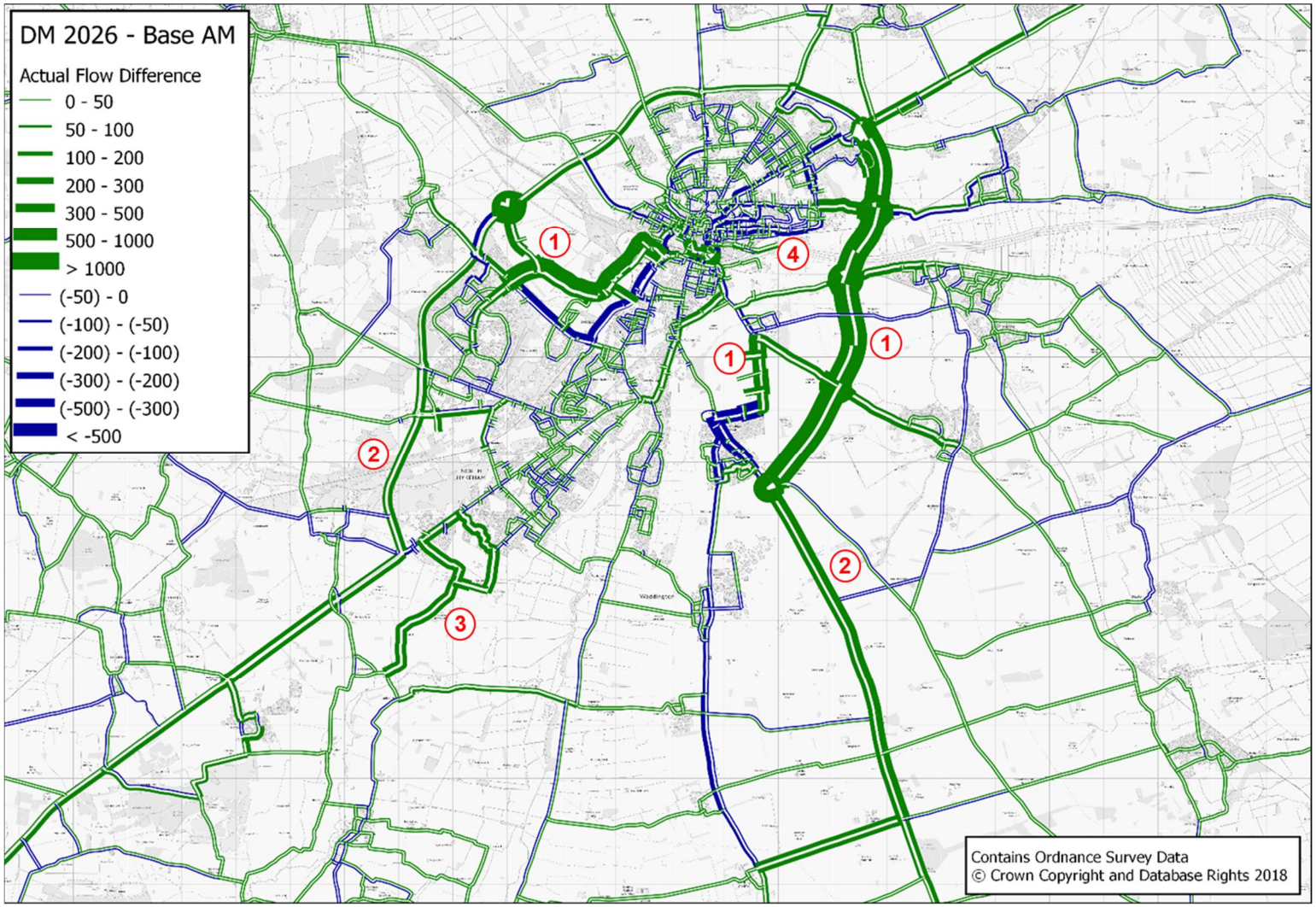


Figure 8-3 Flow Difference DM2026 minus Base – Inter Peak

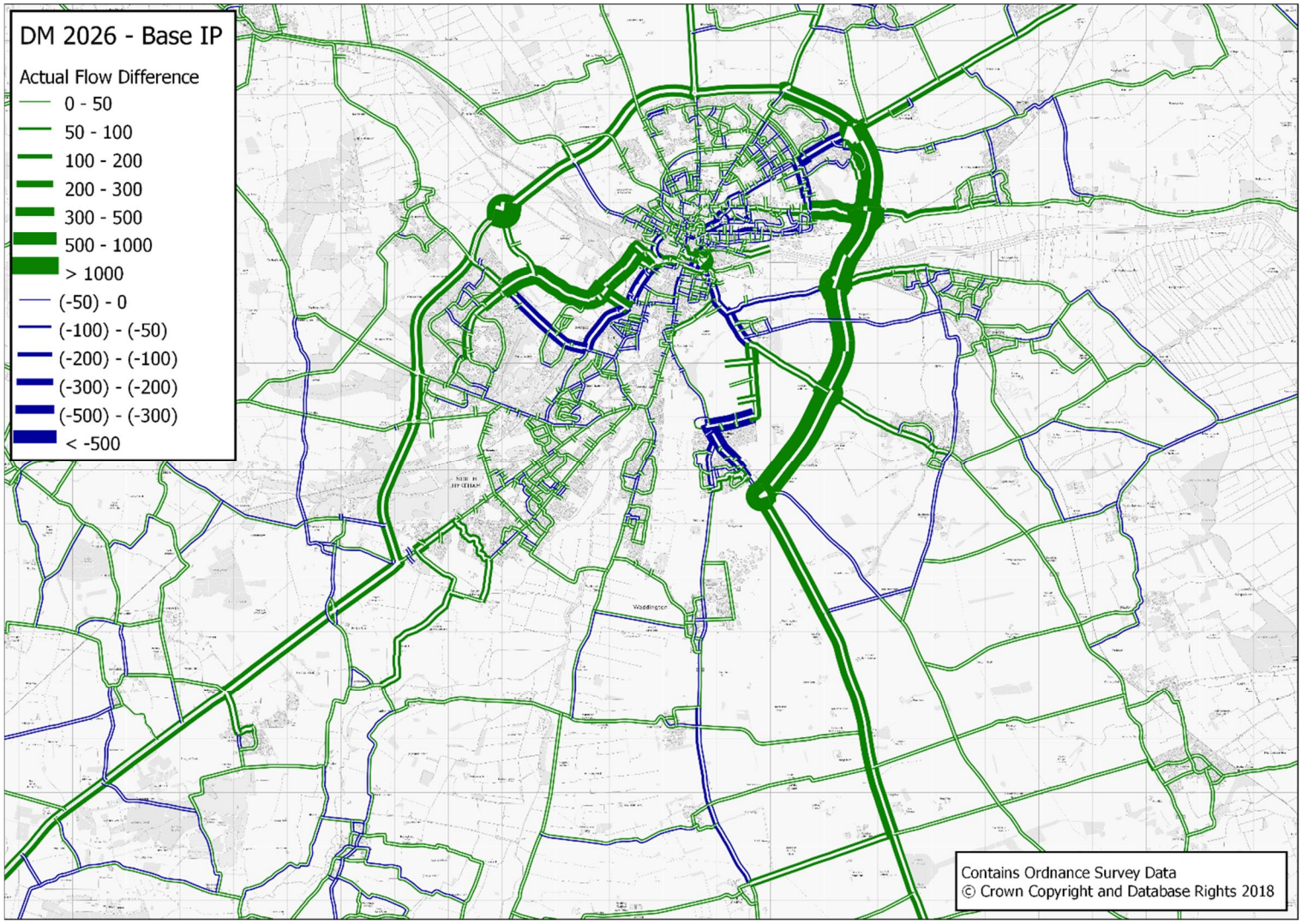
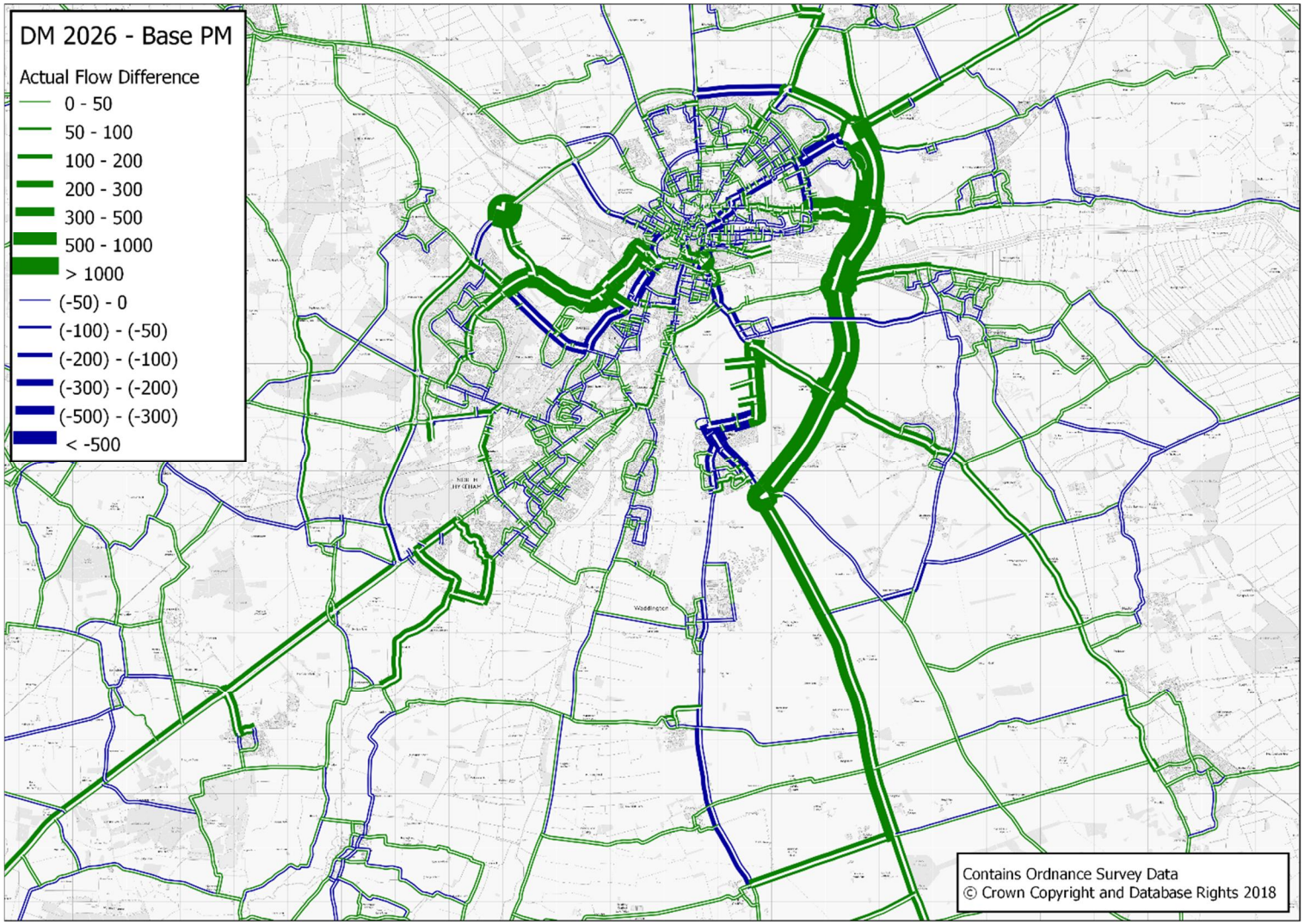


Figure 8-4 Flow Difference DM2026 minus Base – PM Peak



8.4.2 DO SOMETHING AND DO MINIMUM

Figures 8-5 to 8-8 show the flow difference by time period in 2026 and the following observations are noted, with the red numbers annotated on the AM image to indicate the locations:

- In the AM and PM peaks there are generally forecast flow reductions on the A46 around Lincoln in the central and northern sections. **(1)**
    - The impact is generally neutral or a flow increase on the section adjacent to Pennell's roundabout since the scheme induces more traffic through the junction.
- In the inter peak period, the reduction in flow for the A46 is greater with forecast flow reductions on all links.
    - The above two points indicate that in the peak hours, local traffic avoids the A46 in Do Minimum due to the level of congestion. In Do Something the relief for the A46 in the peak hours, through re-routeing of strategic trips to the scheme, is offset, by re-routeing of local traffic to the A46. Whereas in the inter peak, the A46 is less congested in Do Minimum and therefore less re-routeing of local trip occurs.
- There is an increase in flow on LEB attributed to the scheme providing an alternative route around the urban area and the impact of completing the ring road. The impact is largest at the sections closest to the NHRR scheme. **(2)**
- There are forecast flow increases on B1188 Lincoln Road to the south east of Lincoln City Centre. This is attributed to the impact of completing the ring road. **(3)**
    - With the scheme in place, trips from the A46 south west of Lincoln towards the City Centre (southern and eastern sides in particular) can reroute via the scheme and LEB. The B1188 induces this traffic as an optimal radial route for some of those trips into the City Centre.
- There are flow reductions on the majority of links in the south of the Lincoln urban area. Noticeably A1434 Newark Road, the A15 (in the city centre) and the Mill Lane / Meadow Lane / Station Road corridor through the Hykeham and Waddington areas. **(4)**
- There are flow reductions on the route through the villages of Harmston and Aubourn.
- There are flow increases close on South Hykeham Road, Brant Road and Grantham Road close to the scheme junctions due to trips rereouteing to access or exit the scheme. **(5)**
- In the rural area south of the scheme, there is a noticeable forecast flow increase on the A607 immediately north of Boothby Graffoe and a forecast flow decrease on the B1202 Heath Lane at the same junction. This is attributed to rerouteing at the A607 / B1202 junction. In Do Minimum, trips use the B1202 / A15 towards Lincoln whereas in Do Something trips stay on the A607. The scheme improves east-west connectivity and trips in the rural area reroute based on access points to the scheme. **(6)**

The forecast patterns are similar in 2041 but to a greater magnitude. A complete set of mapping is provided in Appendix H.

Figure 8-5 Flow Difference DS2026 minus DM2026 – AM Peak

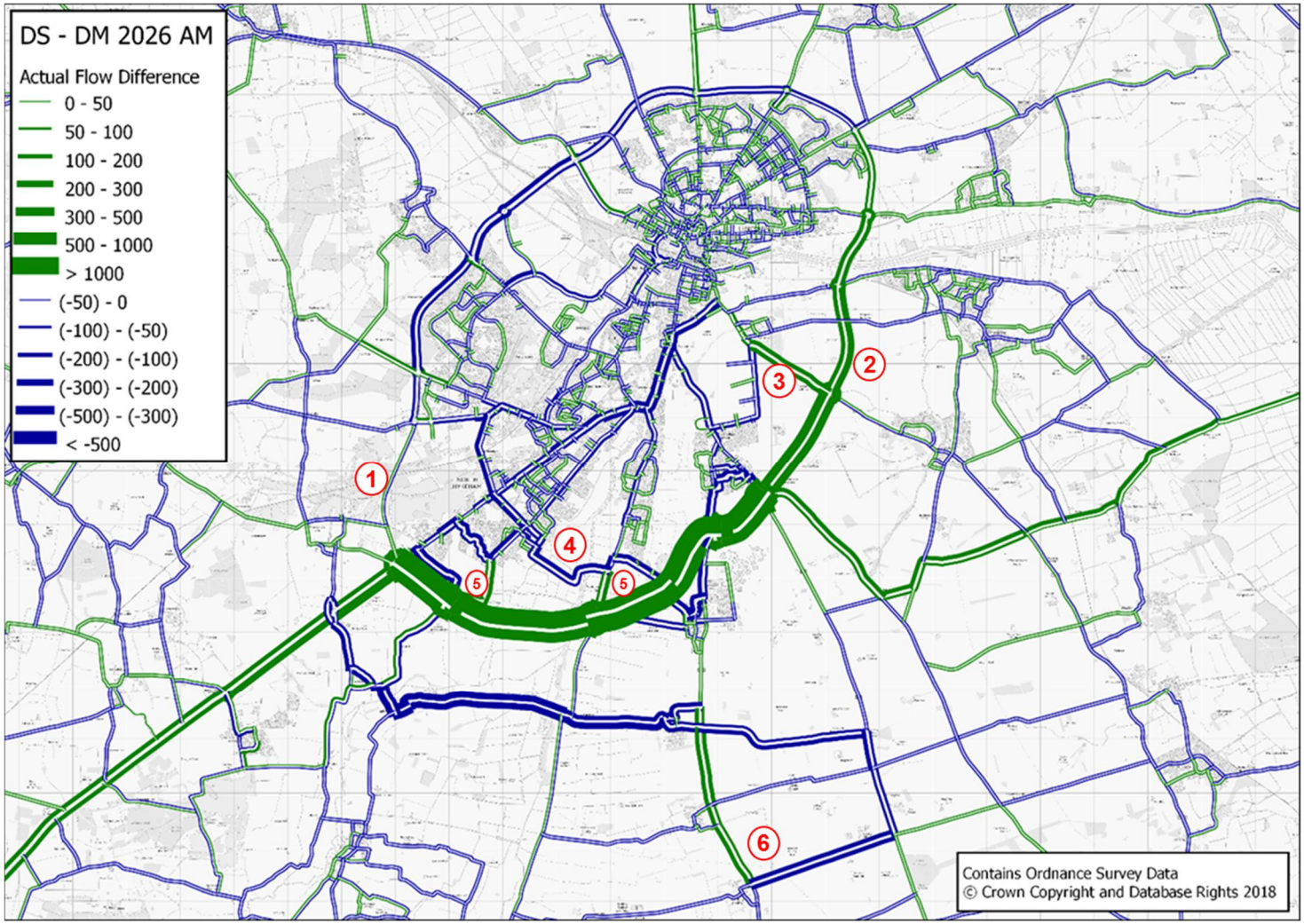


Figure 8-6 Flow Difference DS2026 minus DM2026 – Inter Peak

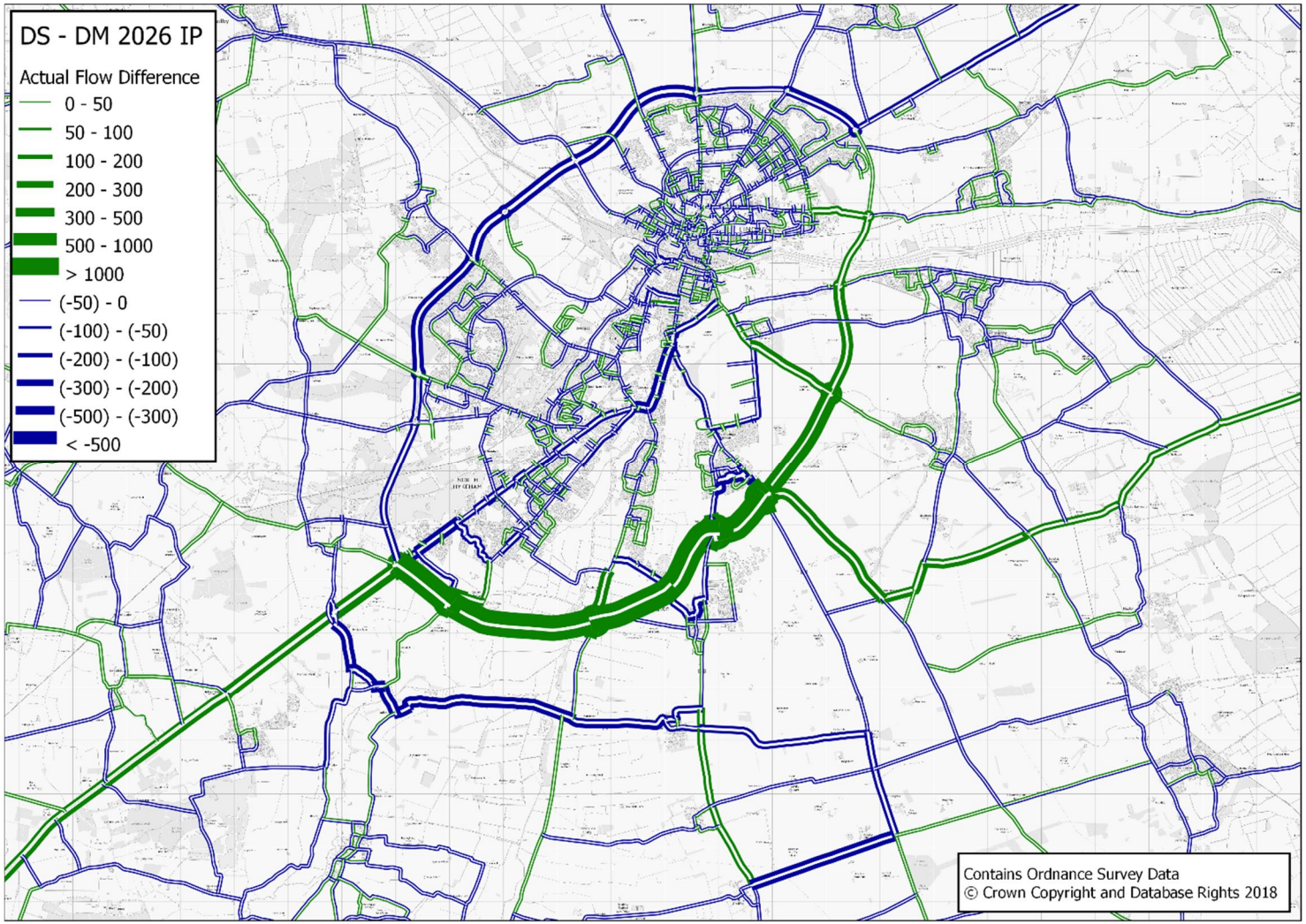
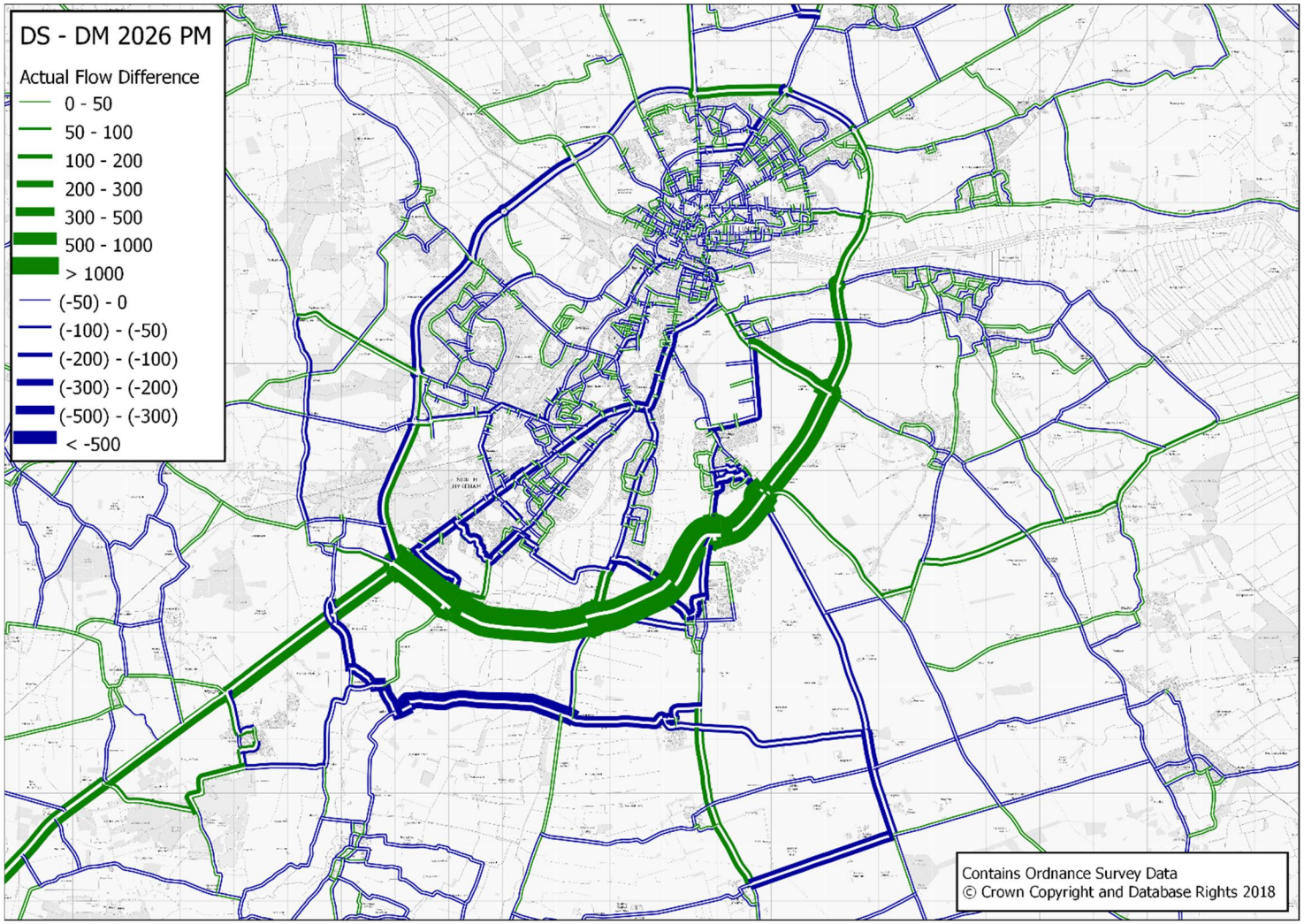


Figure 8-7 Flow Difference DS2026 minus DM2026 – PM Peak



8.5 NETWORK PERFORMANCE

The highway network performance is illustrated through delay difference plots. These are presented for Do Something minus Do Minimum.

Similar to the flow difference mapping a consistent colour scheme has been used where green indicates a flow increase in Do Something and blue indicates a flow decrease in Do Minimum.

Figures 8-8 to 8-10 show the delay difference by time period in 2026.

The observations correlate with the flow difference mapping.

- There are forecast delay decreases in Do Something on the majority of links in North Hykeham area, Lincoln City Centre and through the villages of Harmston and Aubourn. This is attributed to the forecast flow decreases in those various locations.
- There are forecast delay increases in Do Something on all sections of LEB which are attributed to the forecast flow increases on LEB.
- The largest forecast delay increase is on the southernmost section of LEB at the approach to the scheme which is consistent with the section with the largest forecast flow increase on LEB. This is attributed to the impact of completing the ring road. The scheme provides an alternative route choice around Lincoln including LEB onto the scheme which increases demand at that location.

The forecast patterns are similar in 2041 but to a greater magnitude. A complete set of mapping is provided in Appendix I.

Figure 8-8 Delay Difference DS2026 minus DM2026 – AM Peak

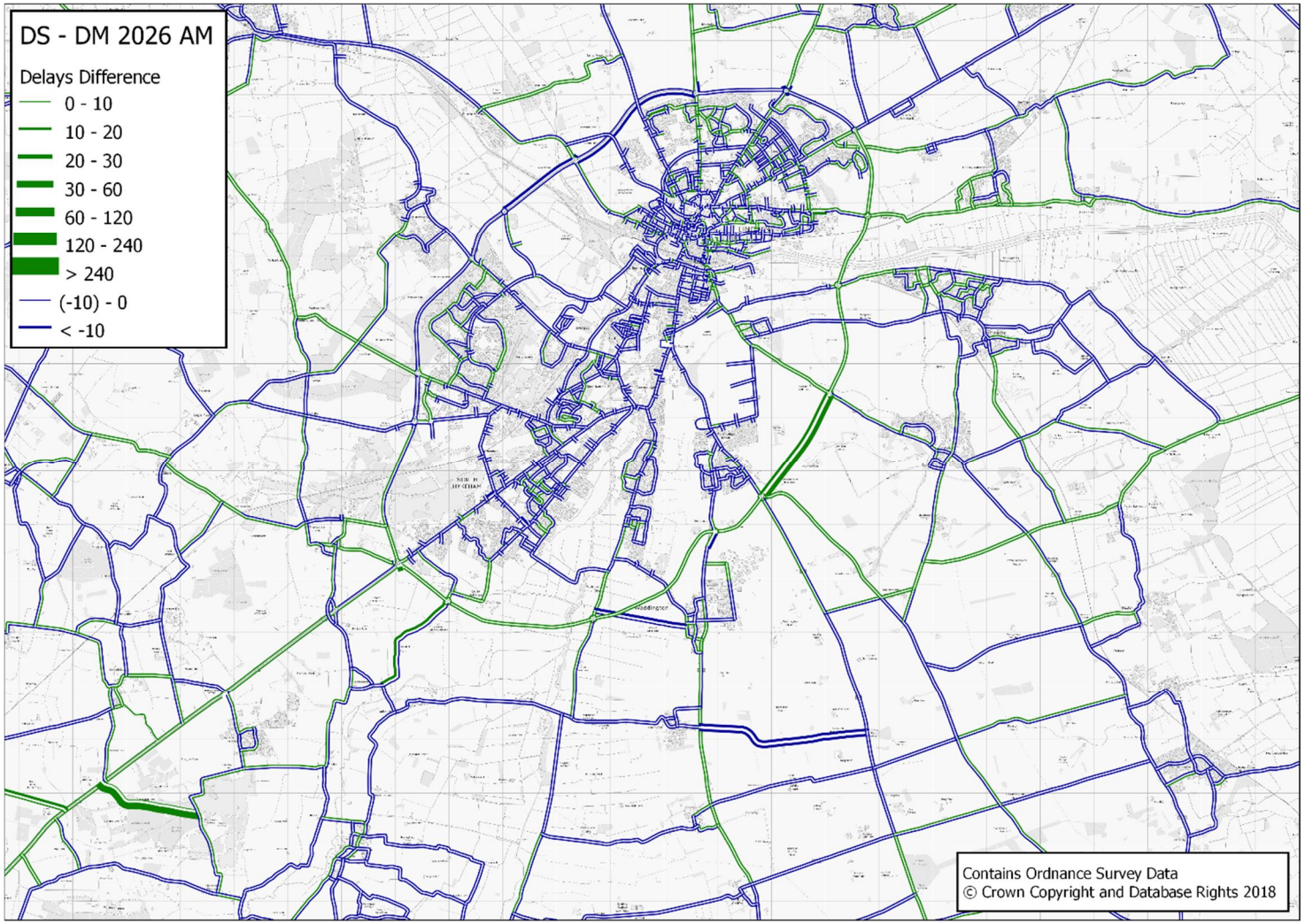


Figure 8-9 Delay Difference DS2026 minus DM2026 – Inter Peak