Document Reference: LCC6

Proof of Evidence
Transport Modelling and Traffic

Paul Smith MSc, CMILT
On behalf of Lincolnshire County Council

Public Inquiry in respect of the Lincoln Eastern Bypass and the following orders:

1. The Lincolnshire County Council (A15 Lincoln Eastern Bypass) (Classified Road) (Side Roads) Order 2014

2. The Lincoln County Council (A15 Lincoln Eastern Bypass) Compulsory Purchase Order 2014

3. Application In Relation To Proposed Compulsory Purchase Of Land Held By The Canal & River Trust

Department for Transport Reference: NATTRAN/EM/LAO/0084

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1 Introduction

1.1 Experience and Qualifications

1.1.1 I am Paul Smith, a Technical Director employed by Mouchel, which is Lincolnshire County Council's Technical Services Partner. I have a Bachelor of Arts Degree in Geography and a Master of Science Degree in Transport Planning. I am a Chartered Member of the Institute of Logistics and Transport.

1.1.2 I have 23 years' experience in transport modelling, with a focus on transport infrastructure appraisal and business case development in the United Kingdom, Middle East and East Asia. I have technical expertise in multi-modal modelling and am responsible for leading and directing modelling projects for a range of clients. I also have expertise in transport economics and financial analysis, due diligence, operations and policy-related matters.

1.1.3 My involvement in the LEB scheme commenced in January 2015 including the model review, specification of detailed surveys and subsequent refinement of the traffic model. Subsequent to this I have taken time to understand the background to the scheme and the current position in terms of design, operational assessment, value for money and the statutory process. Much of my knowledge of history of the scheme has been imparted by the previous Inquiry traffic witness, my colleague Dr Billington.

1.1.4 For the current Inquiry, my evidence concentrates on the traffic data analysis and modelling whilst my colleague Dr Billington will present evidence relating specifically to transport planning issues. In this way, we will be able to provide a clearer understanding, at a more detailed level, of a number of issues, in order to better inform this Inquiry.

1.1.5 There are no substantive differences in the information provided by Dr Billington to the previous Inquiry and the information provided to this Inquiry in the evidence of Dr Billington and myself. However, through, for example, recent consultation with stakeholders, updating of accident data and collection of additional traffic data, we are able to provide a greater level of detail, which serves to confirm the conclusions drawn in Dr Billington's evidence to the previous Inquiry.

1.2 Basis for my Evidence

1.2.1 My evidence relates to the current Lincoln Eastern Bypass (LEB) single carriageway scheme and is based on industry standard techniques utilising observed traffic data and modelling software as described below. Details of the traffic data collection and modelling have been provided as supporting documents to the planning application and are included as the 2012 LMVR (Document Reference: CD90).

1.2.2 Traffic data has previously been collected on a number of occasions in and around Lincoln including in 2006, 2008 and 2011. This has included:

- Postcard Interview data collected at 18 locations forming a cordon around Lincoln and on a number of key roads into the city. This has allowed a detailed picture of the pattern of traffic movements to be established;

- Automatic Traffic Count (ATC) data collected at 98 sites each of which operated over several weeks. This has allowed current traffic flows to be established at key locations;

- Manual Classified Link Count (MCLC) data collected at 34 locations in and around Lincoln. This has allowed additional information on the breakdown of traffic by vehicle type to be established;

- Manual Classified Junction Count (MCJC) data at 92 locations in and around Lincoln. This has allowed the pattern of turning traffic at key junctions to be established; and

- Journey Time Survey data collected directly over 10 routes and supplemented by data obtained from the TrafficMaster system. This has allowed journey times and speeds of traffic to be established.

1.2.3 The data was used in the construction of the Greater Lincoln Traffic Model designed to forecast movement in and around Lincoln in order to appraise infrastructure proposals.

1.2.4 This data has been presented to the previous 2014 Public Inquiry together with additional traffic turning movements, queue lengths and pedestrian and cyclist movements, conducted on Hawthorn Road and Kennel Lane in

November 2013. The addition of the extra detail in 2013 was sufficient to provide for the needs of the previous Public Inquiry but given additional time and more detailed critical assessment the opportunity has been taken to deal with the matter more comprehensively for the current exercise. My involvement in the project stems from the requirements to refine the traffic model and reassess the traffic forecasts in the light of additional data collection.

1.2.5 Specifically, in order to better address some issues raised in objections to the Side Road Orders, the following data has been collected. Details are presented in Appendix A.

- Manual Classified Traffic Count data
- Automatic Number Plate Recognition across a cordon in the vicinity of Hawthorn Road in March 2015
- Journey Times for 3 localised routes around East Lincoln in March 2015

1.2.6 These surveys have provided data which allows the more local impacts of the traffic arrangements at Hawthorn Road to be evaluated.

1.2.7 I am satisfied that this weight of survey data is sufficient to give confidence that the modelling and assessment of the scheme is based on sound and reliable information. The more recent information, although showing some differences with the original information, which I will deal with below, acts to confirm the position which supports that confidence.

1.2.8 The modelling of the effects of the scheme has been undertaken using PTV VISUM software. This software is industry standard and utilises the survey data described above, together with anticipated changes in land use, to forecast the traffic flows under various future conditions. However, before the model was used to forecast the future, its ability to replicate current conditions was tested rigorously. This process is called model validation and is conducted to standards set by the Department for Transport (DfT). I provide further details of the modelling process later in my evidence.

1.2.9 The economic assessment of the scheme has been undertaken using the TUBA and COBA programs provided by the DfT and which are industry standard in the UK. These programs compare the benefits of the scheme in terms of travel time and accident savings with the cost of building the scheme. Similar assessments for the LEB have been accepted by the DfT for their business case processes. I provide further details of the economic evaluation of the LEB later in my evidence. Operational assessments of junctions have been undertaken using ARCADY and PICADY which are industry standard software in the UK. These programs assess the likely delays and queues for traffic passing through roundabouts and priority junctions respectively and allow me to draw conclusions regarding how certain junctions will perform in the future.

1.2.10 The data and modelling processes described above allow me to be very confident in providing forecasts of traffic conditions in the future under various scenarios, assessing how well various junction arrangements will operate and determining what the benefits of the LEB scheme will be.

1.2.11 Throughout the duration of the data collection and model refinement LCC and Mouchel have been in contact with the objectors' traffic representatives to provide timely information on surveyed traffic flows and model outputs, both in the form of raw data, reports and abstractions of information from the traffic model.

1.2.12 At the instigation of LCC, a meeting with the objectors' traffic modelling representatives was held at Cherry Willingham Millennium Hall on Wednesday 10th June. At the meeting the objectors raised a number of traffic issues to LCC and its consultants, primarily relating to flow volumes and patterns. These have been subsequently addressed in verbal communications, supply of additional data and reported outputs.

1.3 Structure of my evidence

1.3.1 The LEB, and its local impacts, should not be seen in isolation. Rather it is an integral part of a wider strategy for improving transport in and around Lincoln. In order to present this information in a convenient structure I continue my evidence in Section 2 by describing the following:

- The Greater Lincoln Traffic Model including how it has been used to forecast the impact of the scheme;

- The traffic impacts of the LEB, including the expected traffic flows on the scheme itself, the junction strategy and operation, the local impacts; the wider impacts across the existing traffic network and the forecast safety and economic benefits;

1.3.2 I summarise and give my conclusions in Section 3.

1.3.3 My evidence has three appendices, which are as follows:

- **Appendix A** provides a summary of the updated traffic surveys used to review and refine the Lincoln Traffic Model;

- **Appendix B** provides a summary of the ARCADY testing results for the LEB roundabout junctions in 2033; and

- **Appendix C** provides a summary of the PICADY and LinSig assessments for traffic significant junctions which may be impacted by the closure of Hawthorn Road to through movements.

2 Impacts and Benefits of the LEB

2.1 The Greater Lincoln Transport Model

2.1.1 In order to facilitate the design and assessment of the scheme the Greater Lincoln Transport Model (GLTM) was developed using industry standard PTV VISUM software. The model base year is 2006 and the model covers the urban area of Lincoln and surrounding countryside and broadly aligns with the Lincoln Policy Area (LPA) as shown in the 2012 Local Model Validation Report (Document Reference: CD90).

2.1.2 The model was first developed in 2006 and has been updated, refined and validated on a number of occasions since then. The most recent work undertaken in respect of the model was earlier this year following the 2015 surveys and that tended to confirm the findings and therefore the reliability of the model to be used for the task required.

2.1.3 The GLTM has been used to inform the traffic, economic, noise and air quality assessments for both the LEB Business Case, submitted to the DfT in September 2011, the 2013 Planning Application and the Section 73 application.

2.1.4 The GLTM study area includes all 'A' and 'B' class roads and most minor roads within the LPA. Outside the LPA, the buffer area comprises a coarse network of links including all major 'A' roads; from the A1 in the west to the A153 in the east, and from the M180 in the north to the A52 south. This ensures that all long distance traffic through, into, out of and around the Lincoln area is properly routed.

2.1.5 The GLTM uses three time periods to represent the different travel patterns that exist during a typical weekday, they are as follows:

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

2.1.6 Three vehicle classes have been modelled; Cars, Light Goods Vehicles (LGVs) and Other Goods Vehicles (OGVs). This ensures that the composition of the traffic forecast data can be robustly assessed.

2.1.7 The model calibration and validation process which is described in The Local Model Validation Report Addendum (Document Reference: CD75) and Model Sensitivity Note (Document Reference: CD85) ensures that the traffic model realistically reproduces observed traffic conditions and can be relied on to produce reliable forecasts under changed conditions. The model calibration and validation processes employed for the GLTM are consistent with the guidelines set out by the Design Manual for Roads and Bridges (DMRB).

2.1.8 The validation process demonstrated that in all cases, the GLTM compares very well with the observed situation and it has been demonstrated that the 2006 base year traffic model, for each of the three modelled time periods, provides an accurate representation of the current traffic demands across Lincoln, and within the locality of the main focus of the Public Inquiry.

2.1.9 The forecasting process is designed to compare a Do-Minimum (DM) situation with a Do-Something (DS). The DM network includes the validated 2006 base road network for the model area plus changes which have been or are planned to be implemented before the LEB, most significantly the Lincoln East-West Link (Phase 1), including the Canwick Road Improvement element of that scheme.

2.1.10 The DS network is the same as the DM network but with the addition of the LEB single carriageway scheme (including its associated junctions).

2.1.11 The forecasting work has been undertaken for two years; the opening year (2018) and the design year (2033), for both of the DM and DS options described above. Both of these have been assessed against a package of development assumptions referred to as the Core Scenario. The Core Scenario relates to the most likely pattern of changes in housing, employment and other land use and has been developed by reference to information provided by the planning authorities. Different development assumptions are implicit in the 2033 DM and DS scenarios, relating to development dependency covered later in the report.

2.1.12 To inform on detail during this process a number of traffic surveys have been conducted. The traffic surveys permit an understanding of flow movements and help in the calibration and interpretation of modelled outputs.

2.2 2015 Traffic Surveys

2.2.1 The 2015 survey data is invaluable in comparing observed reality against both the 2006 base year, with an allowance for development which has taken place since, and the DM network conditions in 2018 immediately prior to the proposed opening of LEB. Several survey types have been conducted including Automatic Number Plate Recognition, Junction Counts and Journey Times.

2.2.2 Automatic Number Plate Recognition (ANPR) is a technique used to establish movements between specific points. The survey locations are referenced in Appendix A. ANPR surveys in the vicinity of Hawthorn Road indicate the heaviest movements surveyed occur between Hawthorn Road (Bunkers Hill) and Carlton Boulevard, via St Augustine Road. It should be noted that the severance caused by the LEB alignment will not affect this turn. Indeed the ability to make the turn will be improved due to a removal of oncoming traffic resultant from LEB severance. Beyond this the traffic turn volume itself would be reduced due to a diversion of traffic onto LEB. The surveyed traffic movements between Carlton Boulevard and Hawthorn Road and points to the east would be affected by severance, but as explained by my colleague Dr Billington there are several safe and convenient alternative routes available for this.

2.2.3 From the junction surveys, in the AM peak hour Hawthorn Road is moderately trafficked (around 250 Passenger Car Units (PCUs) per direction) in the vicinity of the proposed LEB. There is somewhat less traffic travelling the other way, towards the school at Cherry Willingham. The other adjacent road corridors are both busier with up to 915 PCUs on the A15 Wragby Road, north of the Hawthorn Road junction and 640 PCUs on Greetwell Road. Towards Outer Circle Road traffic increases and the use of the circular route is heaviest in the southbound direction, with up to 1,130 PCUs south of the Carton Centre. Carlton Boulevard flows are relatively heavy at the western end of the alignment with over 600 PCUs turning out onto Outer Circle Road. Of those entering St Augustine Road from the north (390 PCUs) the majority (66%) come from Hawthorn Road West.

2.2.4 The surveyed average inter-peak hour flows on Hawthorn Road are around 50% less than the AM peak and are more balanced by direction. Flows on Wragby Road and Greetwell Road are also significantly reduced. Outer Circle Road remains relatively busy with up to 790 PCUs per hour per direction.

2.2.5 The PM peak surveys demonstrate a directionality of flow, with 320 PCUs using Hawthorn Road towards the eastern villages as opposed to 175 PCUs in the reverse direction. The alignment is relatively lightly trafficked compared to Greetwell Road (550 PCUs) and A15 Wragby Road (930 PCUs prior to the A158 junction). In the PM peak the Outer Circle Road has much heavier traffic than in the inter-peak, with the northbound traffic being the predominant flow (970 PCUs).

2.2.6 From earlier model development work the traffic estimates on Hawthorn Road were originally identified as over 500 PCUs in the AM peak westbound direction. This is much higher than more recent survey data for 2013 and 2015 which suggests values around half of that flow in the AM peak hour westbound direction. As Hawthorn Road is a key focus of the analysis it was decided to review the issue in greater detail. This is covered later in the evidence in respect of a Model Sensitivity Test.

2.2.7 Whilst the discussion above has related to link flows, in respect of turning counts, one of the heaviest movements along Hawthorn Road (West) is the right turn into St Augustine Road with 258 PCUs and 127 PCUs observed in the AM and PM peak hours respectively. This confirms the findings from the ANPR analysis.

2.2.8 Turning flows at the Hawthorn Road / Croft Lane junction were relatively light, with the heaviest movement in the AM peak being the left turn from Hawthorn Road in to Croft Lane with 179 PCUs observed. The heaviest movement in the PM peak was the right turn from Hawthorn Road to Croft Lane with 185 PCUs observed.

2.2.9 Turning flows at the Hawthorn Road / Kennel Lane junction were also light. The heaviest movement in the AM peak hour was the right turn from Kennel Lane to Hawthorn Road with 152 PCUs observed. During the PM peak hour the heaviest turn was the left turn from Hawthorn Road to Kennel Lane with 129 PCUs observed.

2.2.10 Turn flows out of Kennel Lane at its northern end are reasonably comparable in the AM and PM peaks with the heaviest movement being the left turn onto the A158 towards Lincoln at 135 and 111 PCUs respectively. The inter-peak figure is approximately half that value. Turns into Kennel Lane are highest from the Horncastle direction in the AM peak but biased towards traffic from Lincoln in the PM peak.

2.2.11 To gauge present day travel conditions, journey time surveys have been conducted to and from the centre of the area of interest to the closest junction on Outer Circle Road. Outer Circle Road represents a location which affords access to many destinations within the city, either via radial or circumferential routes. The routes have been surveyed as follows:

- Route 1 – Junction of Hawthorn Rd / Kennel Lane to Outer Circle Road via Hawthorn Road, St Augustine Road and Carlton Boulevard;
- Route 2 – Junction of Hawthorn Rd / Kennel Lane to Outer Circle Road via Kennel Lane, Wragby Road and Bunkers Hill; and,
- Route 3 – Junction of Hawthorn Rd / Kennel Lane to Outer Circle Road via Kennel Lane and Wragby Road via Hawthorn Road, Croft Lane, Church Lane, Fiskerton Road and Greetwell Road.

2.2.12 The tabulation of surveyed travel times is indicated below.

Table 2-1 – Surveyed Local Journey Times

Travel Times	Route 1 (mins)		Route 2 (mins)		Route 3 (mins)	
	WB	EB	WB	EB	WB	EB
AM	5.9	5.9	7.2	6.3	8.4	7.1
IP	5.9	5.6	6.4	5.8	7.0	6.9
PM	6.6	5.9	6.1	6.0	6.9	6.9
Distance (kilometres)	4.5	4.5	5.0	5.0	5.6	5.6
Difference compared to Route 1	**WB**	**EB**	**WB**	**EB**	**WB**	**EB**
AM			1.3	0.4	2.5	1.2
IP			0.4	0.2	1.1	1.3
PM			-0.5	0.0	0.4	0.9
Distance (kilometres)			0.5	0.5	0.6	0.6

2.2.13 This shows that the assumed peak directional routes (towards Lincoln in the AM and from Lincoln in the PM) are not always the longest travel times. The AM eastbound time via all routes is significant. Inter-peak travel times are commonly although not consistently lower, whilst PM travel times demonstrate slower routes westbound, due to the wider mix of trip purposes and traffic distribution. Trip lengths are up to 0.5 kilometres more for Wragby Road and 0.4 kilometres more for Greetwell Road routes, although the Greetwell Road route could be shortened by use of High Street and Waterford Lane.

2.2.14 Excess travel times are a maximum of 2.5 minutes into Lincoln in the morning via Route 3. Choice of Route 2 would reduce this to 1.3 minutes. In most other cases excess travel time is minimal.

2.3 New Developments

2.3.1 Since the earlier inquiry the original Core Strategy approach to local development has been superseded by the Central Lincolnshire Local Plan which has a similar statutory remit. The model forecast procedure has been revised to ensure that updated background traffic growth rates have been included. The opportunity has been taken to include specific details of residential and employment developments generating in excess of 50 trips within any peak hour. Developments that have either been constructed since 2006, or that have been identified as being likely to be constructed by either the opening or design year, have been included. This specific detail complements the general background growth implicit within the DfT TEMPRO forecasts. The schedule of developments therefore represents focussed growth in specific localities including:

- Bunker's Hill Development – residential development served from St Augustine Road and Carlton Boulevard comprising approximately 400 dwellings (under construction since 2006);
- Land South East of Carlton Boulevard – residential development comprising 124 dwellings (constructed 2007 – 2010);
- Jubilee Close, Cherry Willingham – residential development comprising 110 dwellings;

- North East Quadrant – sustainable urban extension comprising 2,000 residential dwellings and five hectares of employment development. Access arrangements in the forecasting have been amended in accordance with the latest masterplan. The recent planning application for the first 500 dwellings, including provision for 150 before the implementation of the LEB, has also been taken account of. Details of the process undertaken are provided in Forecast and Economics Update Note Deposit Item (CD84).

2.4 Traffic Model Review and Sensitivity Analysis

2.4.1 Given the increased concentration on detailed issues it was decided that additional research would be wise to investigate the reality of the situation. Invariably the best method of checking detail involves reference to survey information. Options available to deal with the most recent survey data included recommencing the modelling exercise from first principles, which was neither necessary nor desirable, or alternatively carrying out appropriate and targeted work to bring forward an update. The latter approach was considered to be the correct one to follow, particularly given that outcomes could be tested through sensitivity testing, if required.

2.4.2 The Hawthorn Road count discrepancy referenced in Paragraph 2.2.6 has been investigated and it is apparent that the original 2006 traffic survey in this location was problematic, leading to revised techniques for inclusion of travel demands within the original model. To this effect the latest count evidence collected in 2015 has been employed in a sensitivity test designed to quantify the impacts of lower Hawthorn Road flow rates on the projected traffic flow patterns.

2.4.3 In this test a confirmatory exploration of the 2006 model has been undertaken, with additional validation to match specific surveyed flows. The model produces a very close level of fit, both strategically and locally within the vicinity of Hawthorn Road. This is reported in the Model Sensitivity Note, (Document Reference CD85).

2.4.4 In the sensitivity test a knowledge of the 2015 survey flows on Hawthorn Road has been incorporated in an alternative 2006 Local Model calibration, reflecting the traffic pattern evident in recent surveys. The alternative calibration was subsequently used to develop a forecast scenario (with the

same forecast assumptions as the core model but applied to a modified base). The impacts of the sensitivity test are quoted, where relevant, later in this evidence.

3 LEB Traffic Impacts

3.1 Forecast Traffic Flows on LEB

3.1.1 The expected daily traffic flows on the LEB for 2018 and 2033, taken from the Core Scenario modelling, are shown on Figures 3-1 and 3-2 below.

Figure 3-1 – Two-way 24hr AADT Summary: 2018 Do-Something (Core Scenario)

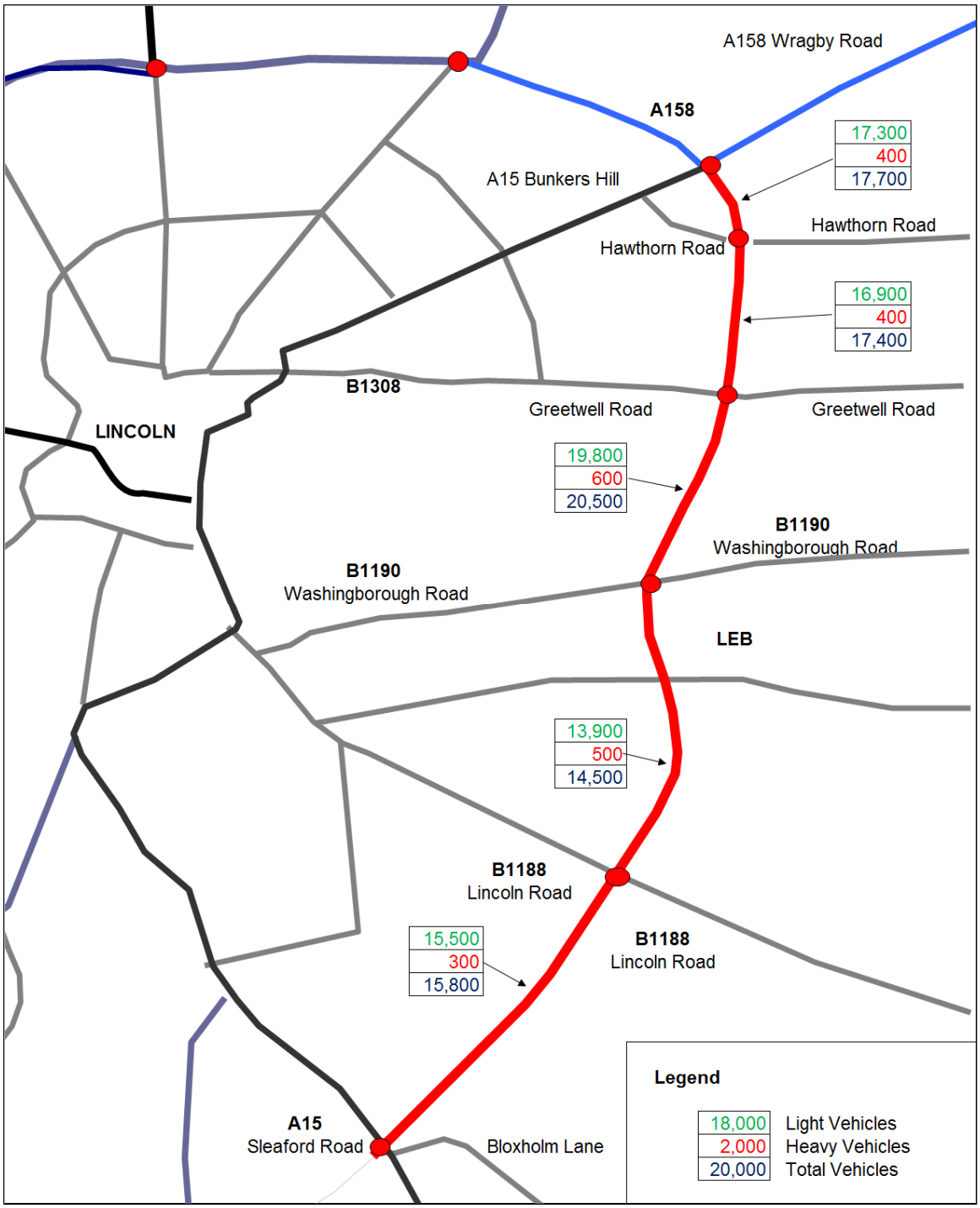
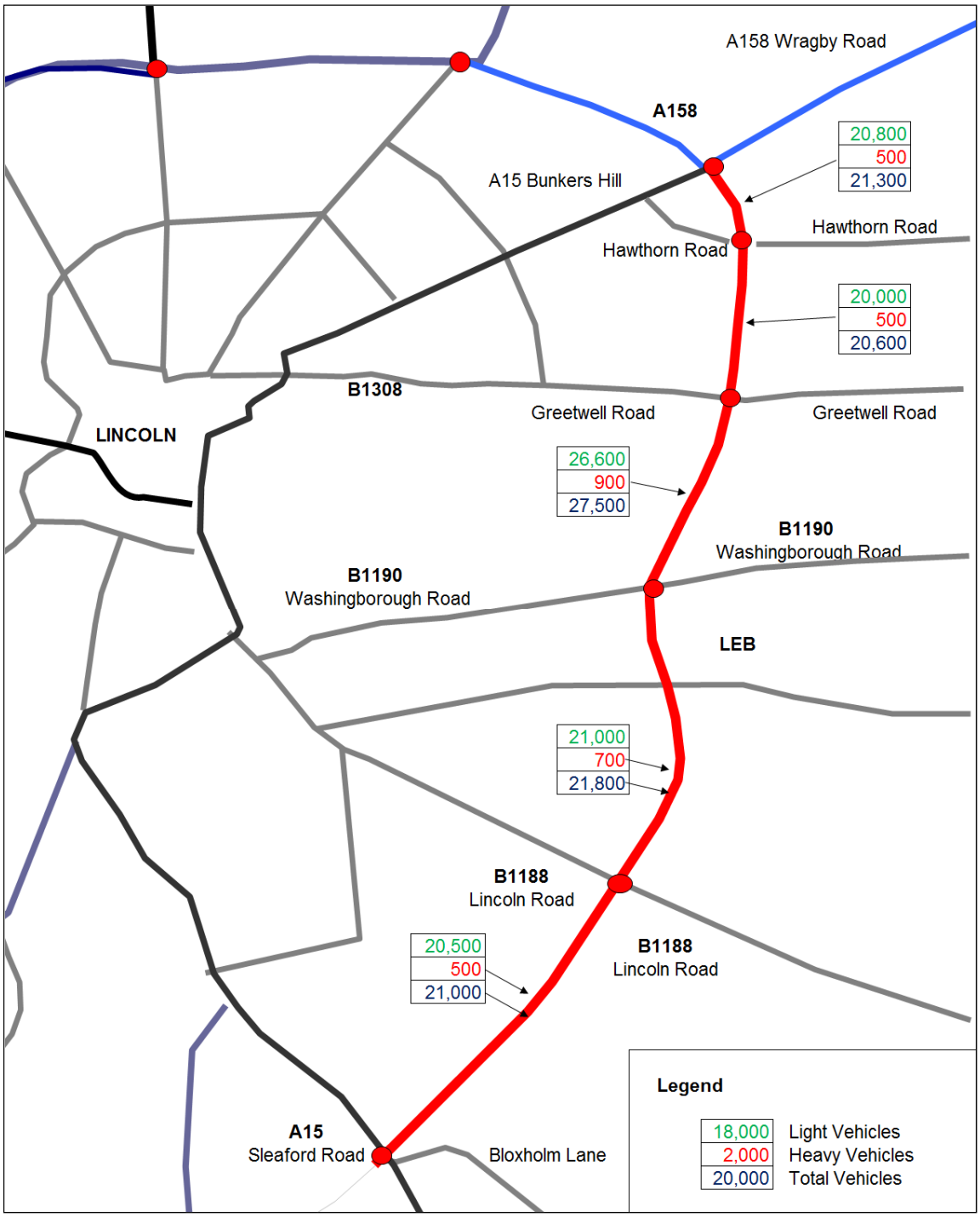


Figure 3-2 – Two-way 24hr AADT Summary: 2033 Do-Something (Core Scenario)



3.1.2 These figures show that the scheme is expected to experience high flows from its opening year. From the perspective of the single carriageway alignment, DMRB extract TA 46/97 (CD100) provides advice on Traffic Flow Ranges for Use in the Assessment of New Rural Roads. It does not prescribe maximum capacities for standards of road and the flow ranges given should be "used as a starting point for the assessment of rural trunk road links; see paragraph 3.3".

3.2 Junction Strategy for LEB

3.2.1 The LEB junction strategy was determined during the design phase for the original dual carriageway scheme. The strategy was developed in accordance with DMRB Volume 6 and specifically follows the advice set out in the documents listed below (Document Reference: CD100):

- TD 9/93 Amendment No.1 Highway Link Design;
- TD 40/94 Layout of Compact Grade Separated Junctions;
- TD 42/95 and Geometric Design of Major/Minor Priority Junctions; and
- TA 23/81 Junctions and Accesses: Determination of Size of Roundabouts

3.2.2 The major road junctions along the LEB were identified as being A158 Wragby Road, Greetwell Road, B1190 Washingborough Road, B1188 Lincoln Road and A15 Sleaford Road. In accordance with the guidance and the forecast traffic flows, the most appropriate solution was to design these junctions as at-grade roundabouts.

3.2.3 As discussed in other evidence, the current design for LEB is for a single carriageway scheme and the forecast traffic flows shown in Figures 3-1 and 3-2 continue to justify an at-grade roundabout at each of these locations. In addition Lincolnshire County Council has aspirations to upgrade the scheme to a dual carriageway at some point in the future. With this aim, and as explained within the Statement of Reasons / Statement of Case, the County Council has future proofed the design of the single carriageway scheme to ensure that decisions made now will not prevent some future upgrade to dual carriageway standard. This means that the rationale for the selection of the junction standards for the major junctions remains appropriate.

3.2.4 In relation to the minor roads crossed by the line of the LEB, Hawthorn Road, Heighington Road and Bloxholm Lane, the guidance indicates that three options are appropriate namely; stopping up, provision of a left in, left out junction or grade separation without connection.

3.2.5 In the dual carriageway design Hawthorn Road and Heighington Road were both designed as grade separated without connection. However, as part of

the change to the design it was considered necessary to modify Hawthorn Road to a left in left out junction. This contributed to the necessary scheme cost savings whilst still allowing local traffic to continue to access Lincoln via the A158, A15, Greetwell Road and the LEB, via Hawthorn Road. This design change, which includes the provision of a Non-Motorised User (NMU) bridge, contributes a saving in scheme cost in the order of £500,000.

3.2.6 In addition, the change in design for the Hawthorn Road junction will have the benefit of a reduction in traffic flows through the residential areas around Hawthorn Road and Carlton Boulevard to the west of the LEB. It will also make Hawthorn Road more attractive for non-motorised users as a through route will be retained via the NMU bridge.

3.2.7 In relation to Heighington Road, the concept of grade separation without connection is considered to be the correct solution in terms of safety and providing value for money. This view has been consistent throughout the development of the scheme. Mr Chetwynd will provide further details of this issue in his evidence.

3.2.8 It was recognised that although a junction was required with Bloxham Lane in order to provide access to properties, particularly on the eastern side of the LEB, a left in / left out junction was not appropriate. The preferred solution was to realign Bloxholm Lane to meet with the Sleaford Road Roundabout. Following the change to a single carriageway design this was maintained as it remained the most appropriate solution.

3.2.9 Although the forecast flows for the LEB are high for a single carriageway road, I do not expect there to be significant queuing, as is observed on the A46 western bypass of the city. This is because, as described above, the junctions on the scheme have been designed with a possible future upgrade to dual carriageway standard in mind and so are able to allow more traffic to enter and circulate the roundabout thereby reducing entry delays. The operation of the junctions has been assessed using ARCADY, which compares peak hour flows with the capacity provided by each arm of a roundabout and predicts the resulting queue lengths. ARCADY is widely used in highway design in the UK and provides very reliable predictions of roundabout operation and queues. Appendix B shows a summary of the ARCADY results, in addition to the full output, for each of the roundabouts.

The ARCADY assessments have been undertaken at the 2033 design year using a peaked traffic flows profile which reflects short term 'peak within peak' conditions and which provides a more stringent test than using a flat profile. The assessments can therefore be considered to be a 'worst case' scenario.

3.2.10 It can be seen that in the design year (2033) the majority of junctions on the scheme are forecast to operate below capacity (RFC of 0.85). The majority of arms operate with very little queuing traffic in either morning (AM) or evening (PM) peaks. The junction with the highest forecast RFC values is the Greetwell Road junction in the AM peak. RFC values of 0.920 and 0.917, resulting in queues of 10 and 7 PCUs, are forecast on the LEB north and Greetwell Road east arms respectively. It is of note that these values are maximum values which are only forecast to occur during the middle of the peak period due to the peaked profile of the assessment flows.

3.3 Wider Traffic Impacts

3.3.1 To demonstrate the wider impact of the LEB on the existing Lincoln traffic network, the change in traffic flows for north-south movements across Lincoln have been forecast. When assessing wider scheme impacts, it is normal practice to identify alternative routes which cross a screenline (a theoretical line across an area which can be used to measure the number of vehicle trips crossing each point) and to compare the predicted flows on these roads in situations with and without the scheme. Lincoln is crossed in an east-west direction by the River Witham and the Fossdyke Navigation which form a convenient screenline that can be used to measure north south movements through Lincoln. Including the LEB, six points were used to measure these movements across the city. As the LEB is expected to be attractive to longer distance traffic movements, in addition to the screenline in Lincoln, two wider screenlines were used to capture and summarise the movements to the east and west of the city.

3.3.2 The traffic flow differences resulting from the introduction of the LEB are shown in the tables below. They demonstrate that a number of city centre routes would be expected to experience a significant reduction in average daily traffic in both the opening year and the design year for the LEB, most notably the A15 Broadgate which is a key existing route through the centre of Lincoln which is forecast to see a reduction in average daily traffic flows of up to 26%.

Figure 3-3 – Lincoln North-South Screenline Definition

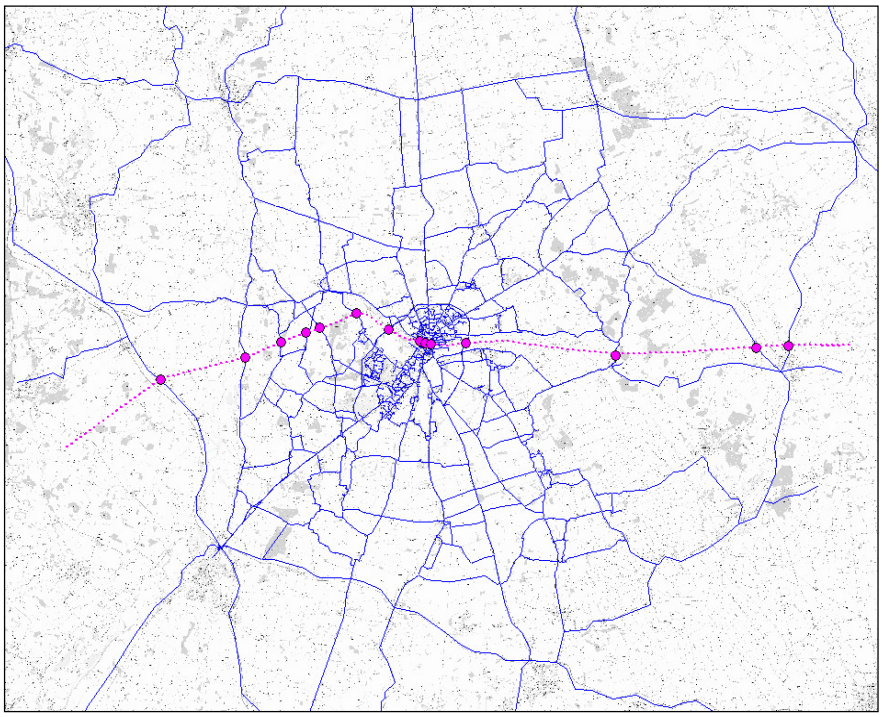


Table 3-1 – Traffic Relief Afforded by LEB – Opening Year 2018

Part of Cordon	Forecast Traffic Flow Changes (AADT)	Forecast Traffic Flow Changes (% Difference)
West of Lincoln	-1,000	-2%
A46	-2,000	-7%
City Centre - Brayford Way	-3,000	-11%
City Centre - Wigford Way	0	-1%
City Centre - Broadgate	-10,000	-26%
LEB (Greetwell Road - Washingborough Road)	20,000	-
East of Lincoln	-100	-1%

Table 3-2 – Traffic Relief Afforded by LEB – Design Year 2033

Part of Cordon	Forecast Traffic Flow Changes (AADT)	Forecast Traffic Flow Changes (% Difference)
West of Lincoln	-3,000	-4%
A46	-2,000	-6%
City Centre - Brayford Way	-3,000	-10%
City Centre - Wigford Way	0	-2%
City Centre - Broadgate	-10,000	-23%
LEB (Greetwell Road - Washingborough Road)	27,000	-
East of Lincoln	-1,000	-8%

3.3.3 These traffic flow changes in the city will allow the County Council and its partners to bring forward a range of other measures which will facilitate and promote sustainable travel and contribute to achieving the objectives of LITS.

3.4 Journey Time Benefits

3.4.1 The introduction of the LEB layout will provide additional capacity within the local highway network. This is primarily focussed on north-south movements through Lincoln, and given the pinch point of the River Witham crossing in the centre of the city, manifested through the relief of radial routes including the A15, the B1308 and the B1190. The travel time savings go hand-in-hand with the flow reductions seen above, where junction saturation, queuing and blocking back is reduced, improving progression through the network and improving network conditions.

3.4.2 The improvements serve to unlock the development potential of a number of sites including some major locations such as North-East and South-East Quadrant Sustainable Urban Extensions, and to improve traffic conditions for developments further afield such as the Western Growth Corridor Sustainable Urban Extension.

3.5 Junction Layout and Performance

3.5.1 The LEB bisects a number of radial routes over its length. Each intersection is designed as a roundabout with a flared single carriageway approach providing for dual-lane circulatory entry on all arms. These junctions have been assessed for operational performance using the ARCADY software suite. The results of this shows that all but one junction are forecast to operate within capacity in the 2033 design year and for the one junction which

exceeds capacity, the maximum queue length on the highest over-capacity arm does not exceed 10 vehicles in the peak of the worst peak hour.

3.6 Local Traffic Impacts of Hawthorn Road Junction Strategy

3.6.1 In this section I will describe the expected impacts that the design of the Hawthorn Road junction will have on local traffic in the areas to the east and west of the LEB. In addition I will also show that the design will also deliver a number of wider benefits.

3.6.2 Dr Billington's evidence demonstrates that there are adequate reasonable and convenient alternative routes for all the traffic movements which currently use Hawthorn Road. In order to quantify the impact in terms of expected traffic flows, the GLTM has been used to assess the local traffic impacts of the Hawthorn Road junction and also of the alternative of providing an overbridge. The forecast flows for these options are shown in the figures below. They show the AM Peak, Inter Peak and PM Peak traffic flows on the road links surrounding Hawthorn Road for the following scenarios:

- 2018 Do Minimum – The forecast traffic flows without the LEB in place;
- 2018 Left in Left Out – The forecast traffic flows with the LEB in place and the left in left out junction at Hawthorn Road;
- 2018 Hawthorn Road Overbridge – The forecast traffic flows with the LEB in place and the overbridge at Hawthorn Road – Reepham Alternative 1;
- 2018 Hawthorn Road Overbridge and Left in Left Out – The forecast traffic flows with the LEB in place, the overbridge at Hawthorn Road and a compact grade separated junction between LEB and Hawthorn Road – Reepham Alternative 2;
- 2033 Do Minimum – The forecast traffic flows without the LEB in place;
- 2033 Left in Left Out – The forecast traffic flows with the LEB in place and the left in left out junction at Hawthorn Road; and

- 2033 Hawthorn Road Overbridge – The forecast traffic flows with the LEB in place and the overbridge at Hawthorn Road – Reepham Alternative 1.

- 2033 Hawthorn Road Overbridge and Left in Left Out – The forecast traffic flows with the LEB in place, the overbridge at Hawthorn Road and a compact grade separated junction between LEB and Hawthorn Road – Reepham Alternative 2;

3.6.3 The flows for these scenarios are depicted below in two-way, peak hour, total flow format.

Figure 3-4 – 2018 AM Peak Hour Two-way Vehicular Flows

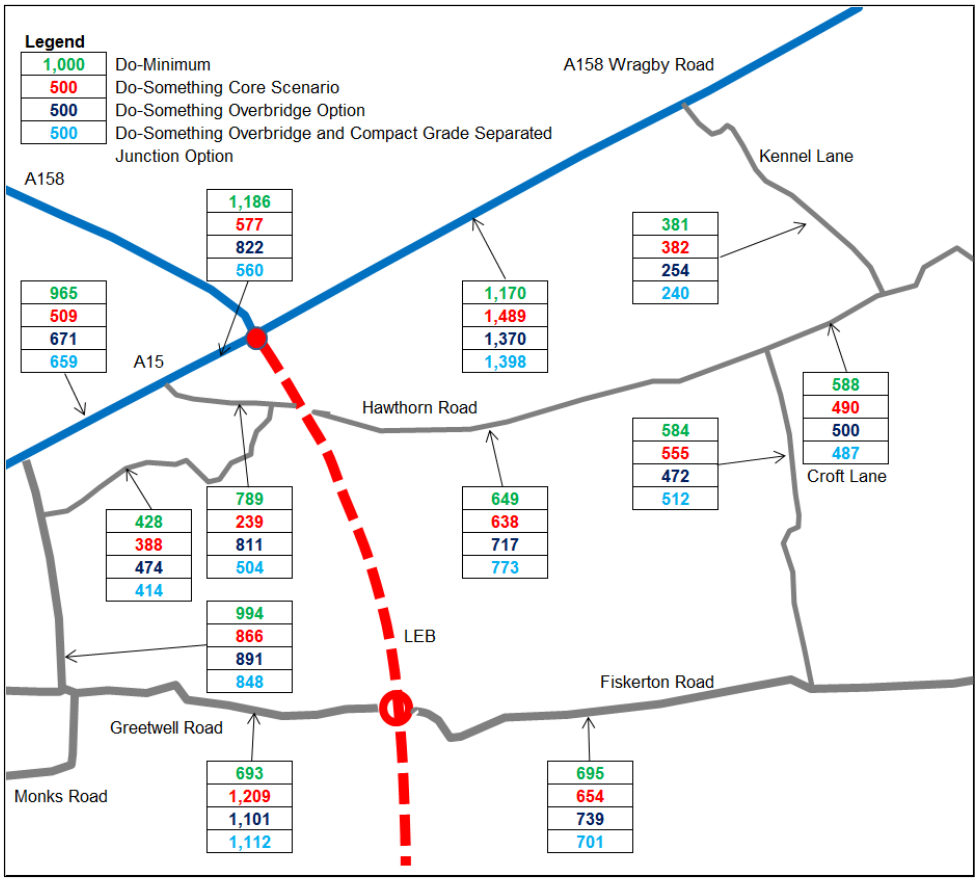


Figure 3-5 – 2018 PM Peak Hour Two-way Vehicular Flows

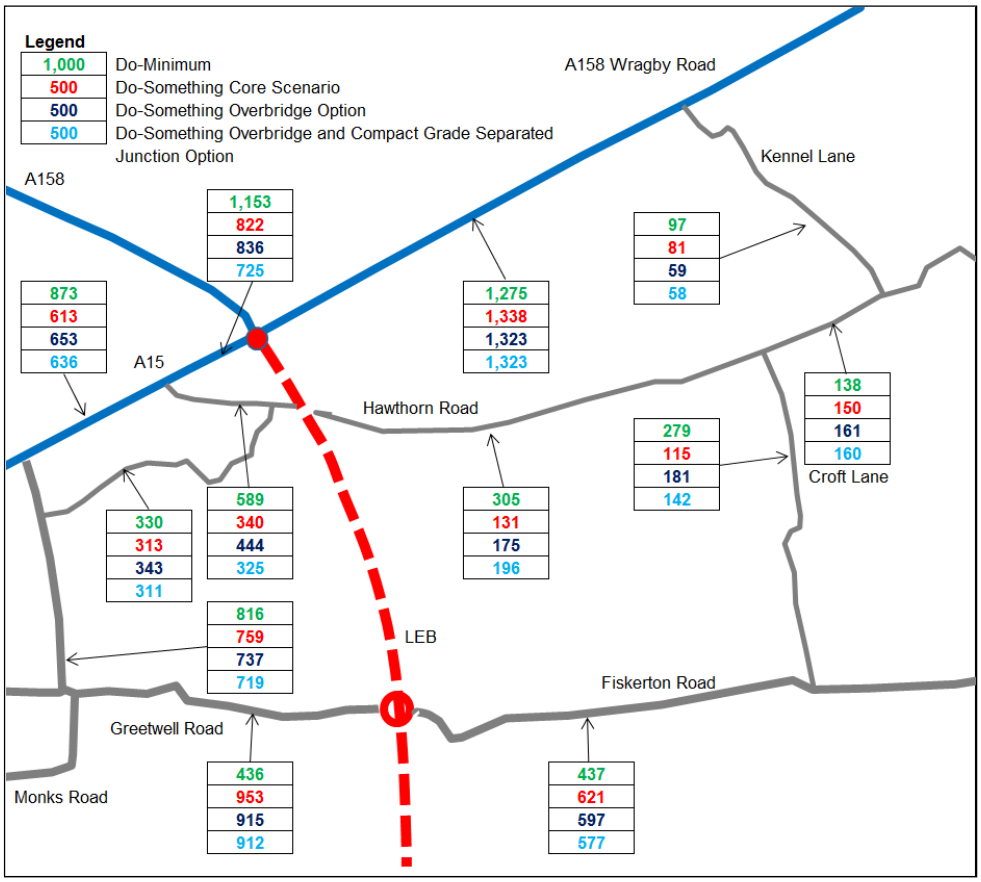


Figure 3-6 – 2018 PM Peak Hour Two-way Vehicular Flows

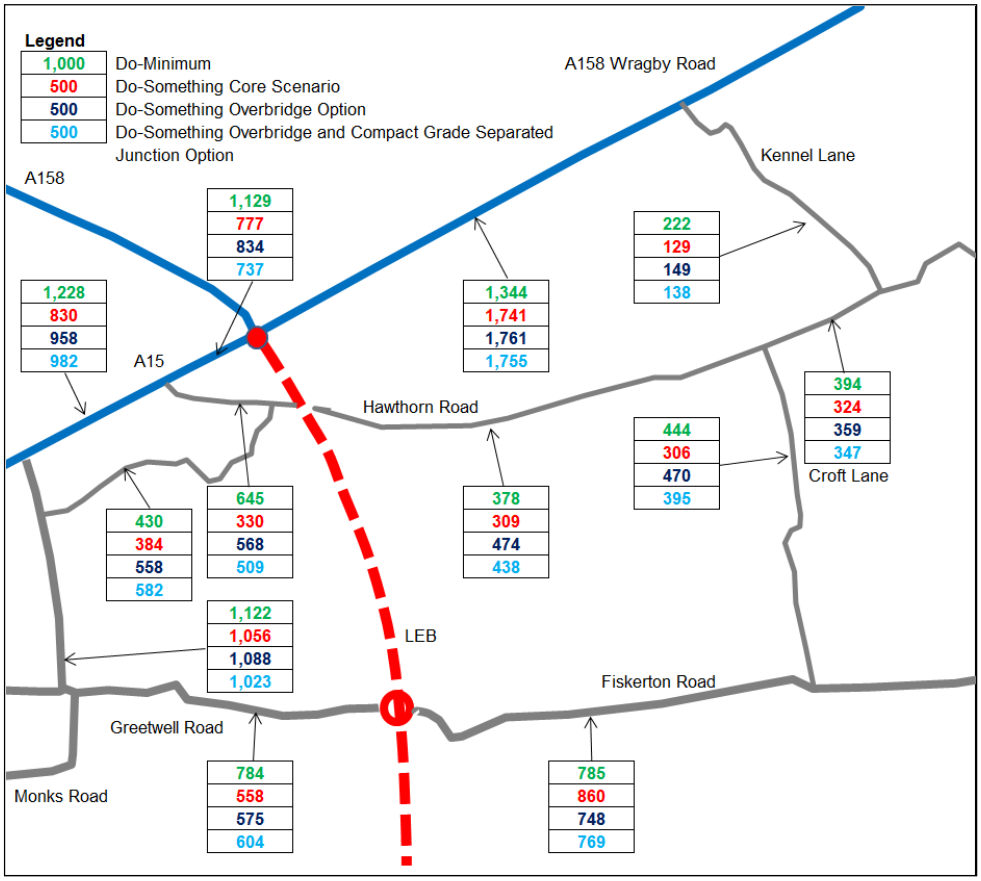


Figure 3-7 – 2033 AM Peak Hour Two-way Vehicular Flows

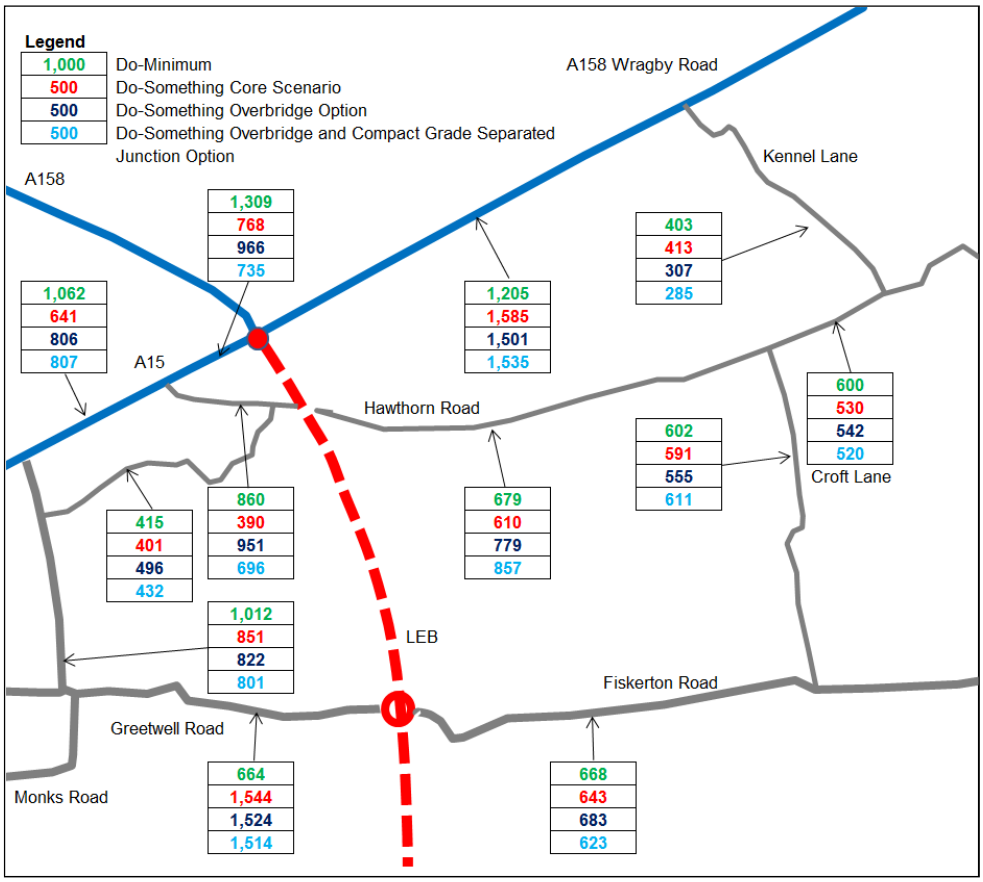


Figure 3-8 – 2033 Inter-peak Hour Two-way Vehicular Flows

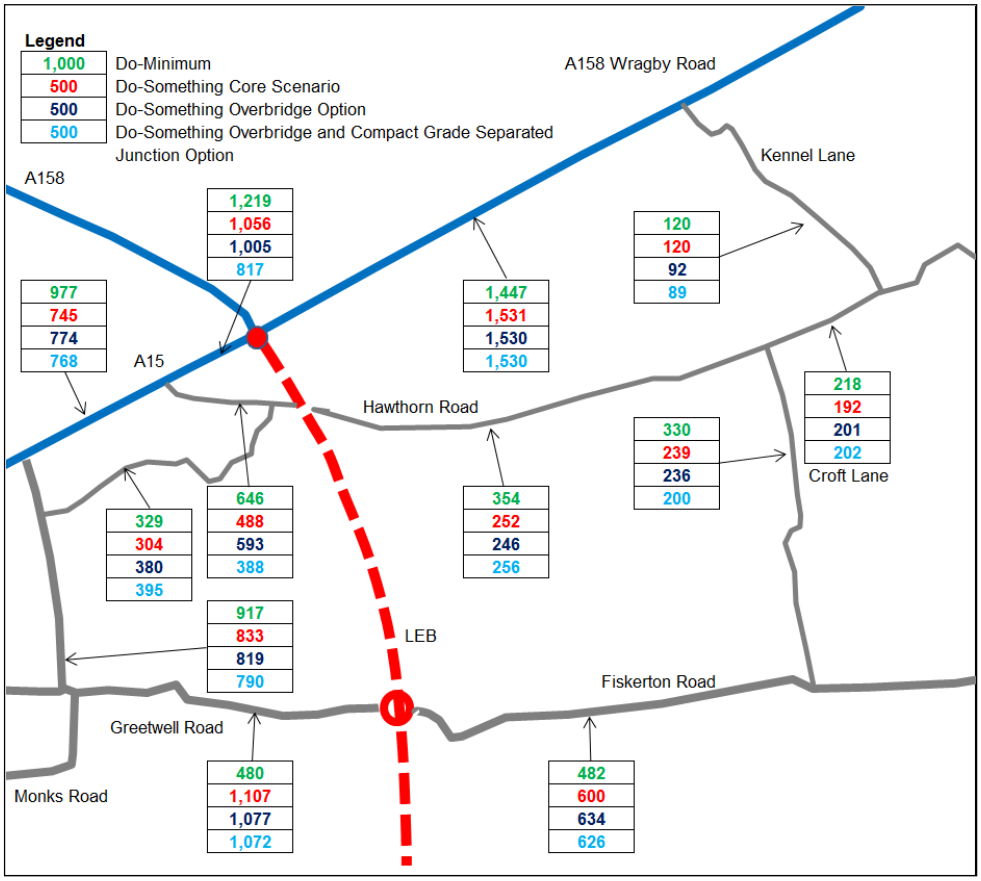
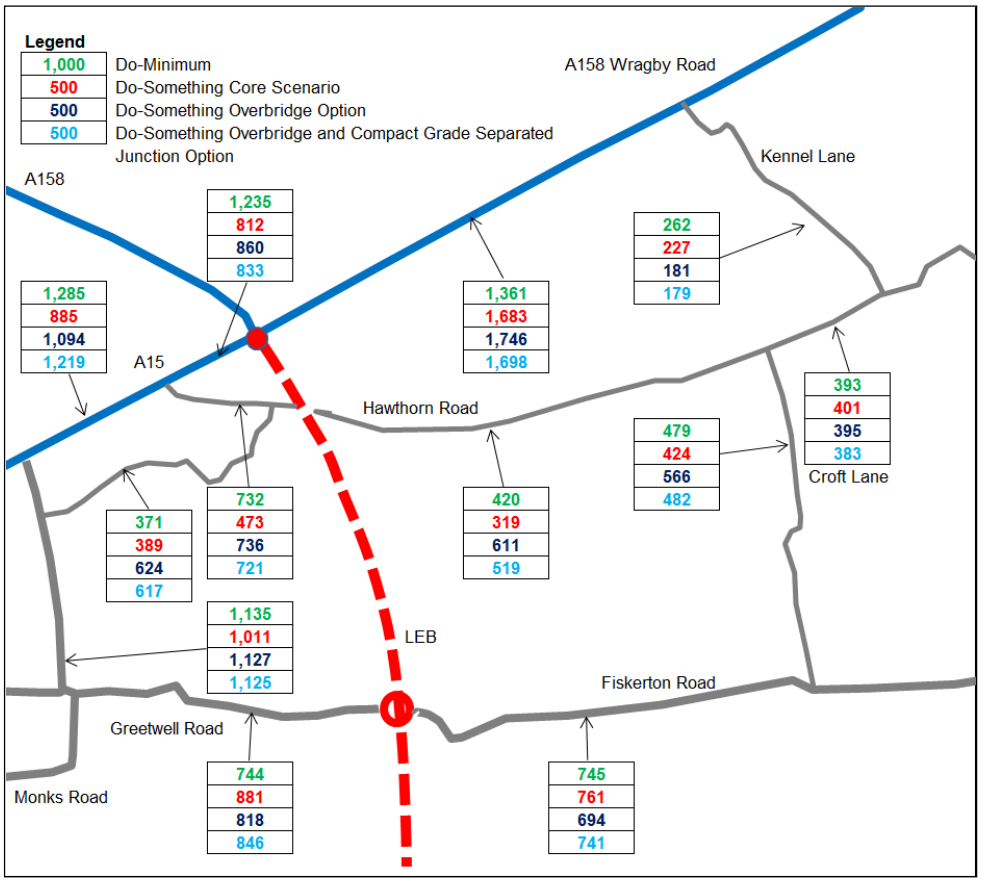


Figure 3-9 – 2033 PM Peak Hour Two-way Vehicular Flows



3.6.4 It can be seen that when comparing the forecast flows for the situations with the Hawthorn Road junction and with the alternative overbridge, the most significant differences are expected on Hawthorn Road and Carlton Boulevard to the west of the LEB where these roads pass through residential areas. With the scheme, these areas will experience lower traffic flows than the overbridge option. On Hawthorn Road it is expected that this traffic relief will be in the order of 3,100 vehicles per day in both 2018 and 2033 when compared to the overbridge option. For Carlton Boulevard it is expected that it will be in the region of 1,000 vehicle per day in 2018 and 1,500 vehicles per day by 2033 when compared to the overbridge option. These lower flows will bring localised benefits in terms of reduced noise, improved air quality and reduced severance and will also result in localised safer conditions for pedestrians and cyclists.

3.6.5 An additional test, including both an overbridge and a compact link road between LEB and Hawthorn Road, has also been evaluated. This has resulted in higher traffic flows on Hawthorn Road and again no discernible relief for the St Augustine Road / Carlton Boulevard area. The traffic flow

increases on Hawthorn Road are in the order of 1,200 vehicles per day in 2018 and 1,000 vehicles per day in 2033. On Carlton Boulevard the increases are in the order 650 vehicles per day in 2018 and 1,400 vehicles per day in 2033.Conversely Kennel Lane sees moderate relief as the range of movements available at the grade separated junction caters for traffic in the LEB southbound direction. This translates to 550 vehicles per day in 2018 and 700 vehicles per day in 2033.

3.6.6 In both cases, the overbridge options lead to excess vehicles on Hawthorn Road East compared with the standard LEB scheme, some 1,300 daily trips by 2033 in the case of both options.

3.6.7 Analysis shows that in the current (and future DM) situation some traffic from the east of Lincolnshire can currently turn left off Wragby Road onto Kennel Lane and then use Hawthorn Road or Fiskerton Road to access areas in the eastern part of Lincoln city centre. With the proposed LEB scheme, this will be a less attractive route for rat running. However, to counter this, it is likely that some additional traffic from Reepham and Cherry Willingham will choose to use Kennel Lane and then turn left onto Wragby Road to access local facilities and the city centre. On balance the Kennel Lane traffic volume remains similar. In order to assess the implications of this on the operation of the Kennel Lane / Wragby Road (A158) junction, PICADY software has been used to analyse how the junction currently operates and how it is forecast to operate following the introduction of the LEB. PICADY is widely used in highway design in the UK and provides very reliable predictions of priority junction operation and queues.

3.6.8 To assess how the junction currently operates, traffic flows from surveys undertaken in March 2015 have been used. To ascertain how the junction may operate following the introduction of the LEB, forecast traffic flows were taken from the GLTM with and without the scheme (Do Something and Do-Minimum). In addition, as a worst case scenario, it was assumed that all the traffic diverted from Hawthorn Road would approach the junction on Kennel Lane and that the junction would continue to operate with a flare length equivalent to one vehicle. I would stress that the modelling analysis does not indicate that this scenario is likely to materialise, however testing this worst case situation provides a very robust assessment of how this junction could operate in the future.

3.6.9 The PICADY results are provided in Appendix C and show the results for the existing traffic flows, along with the Do Minimum, Do Something and “Worst Case” scenarios for the design year 2033. The northeast arm of Wragby Road is Arm A, Kennel Lane is Arm B and the southwest arm of Wragby Road is Arm C.

3.6.10 The results for the exiting AM and PM traffic flows demonstrate that currently the junction of Wragby Road and Kennel Lane operates well within capacity with no significant queuing on any of the junction arms in either the AM or PM period. The highest Ratio to Flow Capacity value is 0.386, well below the maximum practical capacity (0.85).

3.6.11 The results for the design year (2033) indicate that the junction is forecast to operate well within capacity in both the Do Minimum and Do Something scenarios with a maximum RFC of 0.635 occurring on the left turn out of Kennel Lane in the Do Something AM peak.

3.6.12 The results for the worst case scenario indicate that that Kennel Lane arm would operate around maximum theoretical capacity, with an indicative RFC of 1.052 for the left turn and 1.008 for the right turn, in the AM peak. The corresponding maximum queues equate to 18 left turning vehicles and six right turning vehicles. It is of note that this junction has been modelled with a heavily peaked profile and this situation is only forecast for a brief period during the middle of the modelled hour. I would stress once again that this is a worst case scenario for the design year of 2033 and the modelling analysis indicates that this is an unlikely outcome. The junction is forecast to operate within capacity in the worst case PM scenario.

3.6.13 Junction capacity assessments have also been undertaken at the Wragby Road / Outer Cir Road and Outer Cir Road / Carlton Boulevard traffic signal junctions. The assessments have been undertaken using the LinSig software. LinSig is widely used in highway design in the UK and provides very reliable predictions of priority junction operation and queues. The junctions have been modelled using the 2015 surveyed flows in addition to the 2033 forecast flows, both Do Minimum, Do Something and the alternative Do Something scenarios. Full LinSig outputs are presented in Appendix C.

3.6.14 The modelling for the Wragby Road / Outer Cir Road indicates that the junction is currently operating close to capacity with considerable queueing occurring on all arms. This is consistent with the queue surveys at this location.

3.6.15 The situation is forecast to be exacerbated by 2033, with three arms operating above capacity in the AM peak. In the PM peak the same three arms are forecast to operate close to capacity. Queues are also forecast to increase in comparison to the surveyed year.

3.6.16 With the LEB scheme in place, traffic flows are forecast to decrease considerably at this location in the AM peak, particularly on Wragby Road. As a result the junction is forecast to operate within capacity with considerably reduced queuing in the Do Something AM peak. Results for the Do Something PM peak are similar to the Do Minimum with the junction still operating within capacity.

3.6.17 An assessment has also been made of the objectors' scheme proposals. In the objectors' alternative Option 1 (overbridge) scheme the results indicate that that the junction would be close to capacity in the AM peak with three arms operating above 90%. Longer queues, particularly on Wragby Road East, are also forecast in comparison to the Core Do-Something scenario. In the PM peak the junction would be operating at full capacity, with two arms at 100%, with queues also forecast to be longer than the Core Do-Something Scenario.

3.6.18 The objectors' alternative Option 2 (overbridge and compact junction) test also indicates that that the junction would be close to capacity in the AM peak with three arms operating above 90%. Longer queues, particularly on Wragby Road East, are also forecast in comparison to the Core Do-Something scenario. Similarly in the PM peak three arms of the junction would be operating above 90% of capacity with longer queues in comparison with the Core Do-Something scenario.

3.6.19 The modelling for the Outer Cir Road / Carlton Boulevard intersection indicates that this junction is currently operating within capacity, albeit with queuing occurring on all arms. These results are consistent with the queue length surveys at this junction. The junction is also forecast to operate within

capacity in the 2033 Do Minimum and Do Something scenarios in addition to the objector's alternative scenarios.

3.6.20 The capacity of the Bunkers Hill / Hawthorn Road junction has been assessed using PICADY. Results using the 2015 surveyed traffic flows indicate that the junction currently operates with capacity.

3.6.21 By 2033 the Hawthorn Road arm of the junction is forecast to be over capacity in both peak periods with large queues occurring. This is as a result of the high traffic flow volume forecast on Hawthorn Road. With the LEB scheme the junction is much improved and is now forecast to operate within capacity. This can be attributed to the considerable reduction in traffic on Hawthorn Road.

3.6.22 This junction has also been assessed with the Sensitivity Test traffic flows where flows along Hawthorn Road were redefined in the Base Model. The results indicate a similar pattern to the Core Scenario with the Hawthorn Road arm forecast to operate over capacity without LEB and under capacity with LEB.

3.6.23 Flows at this junction are considerably different in the two alternative options suggested by the scheme objectors. The junction has been tested with the provision of an overbridge on Hawthorn Road and with both the overbridge and a compact grade separated interchange with the LEB. The results indicate that the junction is forecast to continue to operate above capacity during the AM peak with the LEB and the overbridge in place. With the overbridge and a compact grade separated junction option the Hawthorn Road arm would be close to its ultimate capacity and above practical capacity during the AM peak. In both of these scenarios the junction is forecast to operate with a lower level of performance as compared to the standard LEB scheme.

3.6.24 The Hawthorn Road / St Augustine Road priority junction has also been assessed using PICADY. The scenarios tested are, the 2015 surveyed, 2033 Core Scenario and the two alternative 2033 options. The results indicate that the junction is forecast to operate well within capacity in all scenarios.

3.6.25 In summary the traffic flows resultant from the introduction of the LEB have been assessed and all junctions have been found to operate satisfactorily as

a result of the scheme. Capacity problems on the Outer Circle Road are resolved by the LEB. Kennel Lane is able to cope with the reassignment resultant from LEB. It also performs well against a worst case reassignment proving the resilience of the network. The overbridge options perform less well in several areas, primarily related to the Wragby Road corridor, where junction traffic volume exceeds capacity even with the LEB in place.

3.7 Traffic Impact of Sensitivity Test

3.7.1 It was earlier reported that a sensitivity test on an alternate validation was undertaken, gauging the impact of recent Hawthorn Road flow observations on traffic model flow patterns. The traffic forecasts have been re-run using this model variant and impacts have been quantified and presented in the Model Sensitivity Note (Document Reference: CD85).

3.7.2 In comparison with the Core Scenario the sensitivity forecast flows generally change as follows:

- lower flows on Wragby Road West of Hawthorn Road;
- higher flows on Hawthorn Road West of St Augustine Road;
- higher flows on St Augustine Road;
- lower flows on Hawthorn Road East of St Augustine Road;
- similar flows on Croft Lane; and
- lower flows on Kennel Lane northbound in the AM peak.

3.7.3 The general pattern of change in the model for this sensitivity test is a greater flow volume between the A158/A15 and St Augustine Road via Hawthorn Road West in the peak periods. Despite the general flow increases in the models the LEB option still provides relief compared to the Do Minimum.

3.7.4 As with the Core Model there are some specific circumstances where flows rise between the Do Minimum and the LEB option. This is primarily the result of a reduction of capacity constraints on “demand” flows elsewhere in the model, permitting a greater “actual” flow to pass through the area within the defined hour. This demonstrates beneficial congestion relief afforded by LEB.

3.7.5 The conclusions of the junction assessments previously quoted do not significantly change as a result of the Sensitivity Test and the summary provided in 3.6.25 remains valid.

3.8 Safety Benefits

3.8.1 An assessment of the accident benefits resulting from the LEB over a 60-year period have been undertaken using the standard approach involving COBA, the DfT economic evaluation software.

3.8.2 As with other areas of the economic evaluation, an updated approach has been taken in relation to dependent development. WebTAG A2.3 "Transport Appraisal in the Context of Dependent Development" (Document Reference: CD101) sets out the guidance on assessing the economic benefits generated by transport in the context of dependent development. Dependent development refers to new development that is dependent on the provision of a transport scheme, which with the new development but in the absence of the transport scheme, the existing transport network would not provide a reasonable level of service to existing and/or new users.

3.8.3 The North East Quadrant Sustainable Urban Extension falls into this category with only 150 units permitted prior to the opening of the LEB, rising to 2,000 units once the scheme has opened.

3.8.4 Under the previous assumptions of a consistent matrix total (with the distribution of growth dependent upon scheme availability) the accident benefits are strongly positive.

Table 3-3 – Accident Analysis – Consistent Methodology

	Number of Accidents Saved	Number of Casualties Saved			Benefits £'000 (2010 Prices)
		Fatal	Serious	Slight	
Savings over 60 years	614	-6	48	629	18,934

3.8.5 If the revised methodology is employed, and a differential trip matrix is introduced to reflect additional dependent development trips, the table below summarises the number of accidents and casualties expected to be saved as a result of the LEB over the 60 year evaluation period. Over 250 accidents will be saved, however fatalities and serious accidents will rise by 13. The COBA

analysis also identifies that the monetised benefits of the accident savings over the evaluation period is forecast to be slightly negative at -£815,000.

Table 3-4 – Accident Analysis – Current Guidance

	Number of Accidents Saved	Number of Casualties Saved			Benefits £'000 (2010 Prices)
		Fatal	Serious	Slight	
Savings over 60 years	254	-10	-3	201	- 815

3.8.6 The LEB network contains an extra daily 8,800 two-way dependent trips which enhances mobility and assists in local economic performance, but impacts slightly on fatalities. The fatality increase is also in part related to higher volumes on LEB, which combines rural road accident rate characteristics (fewer but more serious accidents) with higher traffic volumes. The saving in minor accidents is attributed to traffic flow reductions on Lincoln's urban road network and reflects the traffic relief afforded by the scheme.

3.8.7 To reiterate, if the infrastructure dependent development methodology remained consistent with the approach taken at the previous public inquiry, the benefits accrued to accident savings would be £18.9 million.

3.9 Economic Benefits

3.9.1 An economic appraisal of the scheme was completed in support of the Best and Final Bid Business Case (BaFB) submitted to DfT. The economic assessment is intended to capture the range of costs and benefits derived from the LEB in order to determine its investment worth or value for money. The geographical area of assessment covers the LEB model area. The process is undertaken to DfT requirements using DfT software and includes the following:

- Costs including design, construction, land, preparation and supervision; and
- Benefits including accident benefits, time savings, fuel vehicle operating costs (VOC), non-fuel VOC, Operator and Government revenues.

3.9.2 In all cases, these individual economic assessments are based on comparisons of DM and DS traffic model forecasts for the LEB opening and design years.

3.9.3 The BaFB showed that the benefits of the scheme will far exceed the costs resulting in a Benefit to Cost Ratio (BCR) of 8.435. The DfT accepted this assessment of the scheme and considered it to represent "Very High" value for money, as defined in the DfT's Value for Money Assessment: Advice Note for Local Transport Decision Makers (Document Reference: CD102).

3.9.4 By means of comparison Table 3-6 below shows that, following the model refinement process described in this document, the LEB assessment provides similar benefits. The table shows that the most significant benefits (£911m) are generated as a result of journey time and operating cost savings for vehicles travelling around the network. The BCR remains "Very High' at 9.4. Detail of the full process is included within Forecast and Economic Note Update (CD84).

Table 3-5 – TUBA Benefit Summary (Costs/Benefits in £'000s)

Net Present Value for Benefits	DM v DS
User Benefits	911,137
Carbon Benefits	3,821
Indirect Taxation	-11,018
Accident Benefits	-815
Present Value of Benefits (PVB)	903,125
Present Value of Costs	
Investment Costs	96,304
Present Value of Costs (PVC)	96,304
Overall Impact	
Net Present Value (NPV)	806,821
Benefit to Cost Ratio (BCR)	9.4

3.9.5 In the event that the sensitivity test model is applied to the Value for Money (VfM) assessment the present value of benefits (PVB), excluding accidents, would reduce from £902m to £900m. Hence the impact of minor flow changes on Hawthorn Road is immaterial to the transport economic outcome.

4 Summary and Conclusions

4.1.1 My evidence is based on the original modelling work and also my work to refine the GLTM to assess the latest assumptions implicit in the LEB scheme, leading to both operational assessments demonstrating fitness for purpose and economic scheme evaluation following standard DfT protocol. The value for money objective is clearly fulfilled by a strong economic performance which is testament to the congestion relief afforded by the scheme.

4.1.2 The original GLTM has been diligently constructed from bespoke data collection. This has been subsequently refined through a series of targeted updates, most recently a model refinement in support of the 2015 public inquiry. To ensure that all possibilities were covered in this analysis the evidence surrounding a number of historic counts from the original model was reinterpreted through the development of a sensitivity test to quantify the impact of flow differences in the vicinity of Hawthorn Road. The conclusions reached in this evidence have been tested against the updated (core) model and also the sensitivity model to ensure robustness.

4.1.3 The traffic flows associated with the LEB show a slight decline compared to earlier forecasts. The decline is driven by a reduced TEMPRO growth rate and is proportionate to the updates introduced by the latest DfT forecast protocols.

4.1.4 With regard to the local impacts of the scheme associated with the Hawthorn Road junction, my evidence has shown that the proposal is superior to the objectors' alternatives of proving an overbridge, both with and without a connection to LEB. The scheme offers traffic relief to residential areas, provides a cost saving in the order of £500,000 and will result in lower traffic flows on roads that are unsuitable for high volumes. The residential area adjacent to Hawthorn Road and Carlton Boulevard lying to the west of the line of the scheme will be relieved of through traffic. On Hawthorn Road it is expected that this will be in the order of 3,100 vehicles per day in 2018 and 2033 when compared to the alternative overbridge option. For Carlton Boulevard it is expected that it will be in the region of 1,000 vehicles per day in 2018 and 1,500 vehicles per day by 2033.

4.1.5 Existing junctions have been demonstrated to operate at lower levels of saturation resultant from the opening of the LEB. Even under extreme reassignment assumptions, unlikely to be realised, the Kennel Lane junction will operate at capacity. Under the core model assumptions the junction is expected to operate comfortably within capacity.

4.1.6 Whilst the safety benefits of the LEB show a slight disbenefits, this is primarily the result of dependent development and revised forecast guidance from the DfT. If the analysis is conducted on a similar basis to the last inquiry and a like for like comparison is performed the LEB provides significant safety benefit.

4.1.7 When the scheme is evaluated using the latest economic assumptions the NPV has been maintained at a high level and the transport benefits exceed the costs by a ratio of 9.4 to 1. This is higher than the evaluation approved by DfT at the BaFB stage.