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February 2023

London Luton Airport Expansion

Planning Inspectorate Scheme Ref: TR020001

Volume 7 Other Documents

7.02 Transport Assessment Appendices - Part 1 of 3 (Appendices A-E)

Application Document Ref: TR020001/APP/7.02
APFP Regulation: 5(2)(q) and 5(2)(o)

The Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

London Luton Airport Expansion Development Consent Order 202x

7.02 TRANSPORT ASSESSMENT APPENDICES – PART 1 OF 3 (APPENDICES A-E)

Regulation number:	Regulation 5(2)(q) and 5(2)(o)
Planning Inspectorate Scheme Reference:	TR020001
Document Reference:	TR020001/APP/7.02
Author:	Luton Rising

Version	**Date**	**Status of Version**
Issue 1	February 2023	Application issue

Contents

Appendix A: Off Site Highway Works

London Luton Airport Expansion Development Consent Order

Transport Assessment

Appendix A - Off-site Highway Works

27 February 2023

TR020001/APP/7.02 | P01

Contents

1 HIGHWAY MITIGATION PLANS

1.1 Purpose of this document

1.1.1 Luton Rising (a trading name of London Luton Airport Limited), owners of London Luton Airport (the Applicant) has submitted an application under section 37 of the Planning Act 2008 for an order to grant development consent for the expansion of London Luton Airport (the Proposed Development).

1.1.2 This document is part of a suite of documents which forms part of the application for development consent. A full description of all the Application Documents is provided in the Introduction to the Application) (TR020001/APP/1.03] which also forms part of the suite of application documents.

1.1.3 This document is included in the application to comply with Regulation 5(2)(o) of the Infrastructure Planning (Applications: Prescribed Forms and Procedures) Regulations 2009 ("the 2009 Regulations"), which requires:

a) 5(2)(o) 'any other plans, drawings and sections necessary to describe the proposals for which development consent is sought, showing details of design, external appearance, and the preferred layout of buildings or structures, drainage, surface water management, means of vehicular and pedestrian access, any car parking to be provided, and means of landscaping.'

1.1.4 Regulation 5(4) requires that 'Where a plan comprises three or more separate sheets a key plan must be provided showing the relationship between the different sheets'.

1.1.5 Accordingly, a key plan is submitted as part of the application to identify the location of the proposed highway mitigation schemes in relation to the geographical context of the Proposed Development.

1.1.6 As this document is part of the application documentation, it should be read alongside, and is informed by, the other application documents. In particular, the plans should be read alongside the Transport Assessment (TR020001/APP/7.02).

1.2 Scope and format of the Highway Mitigation Plans

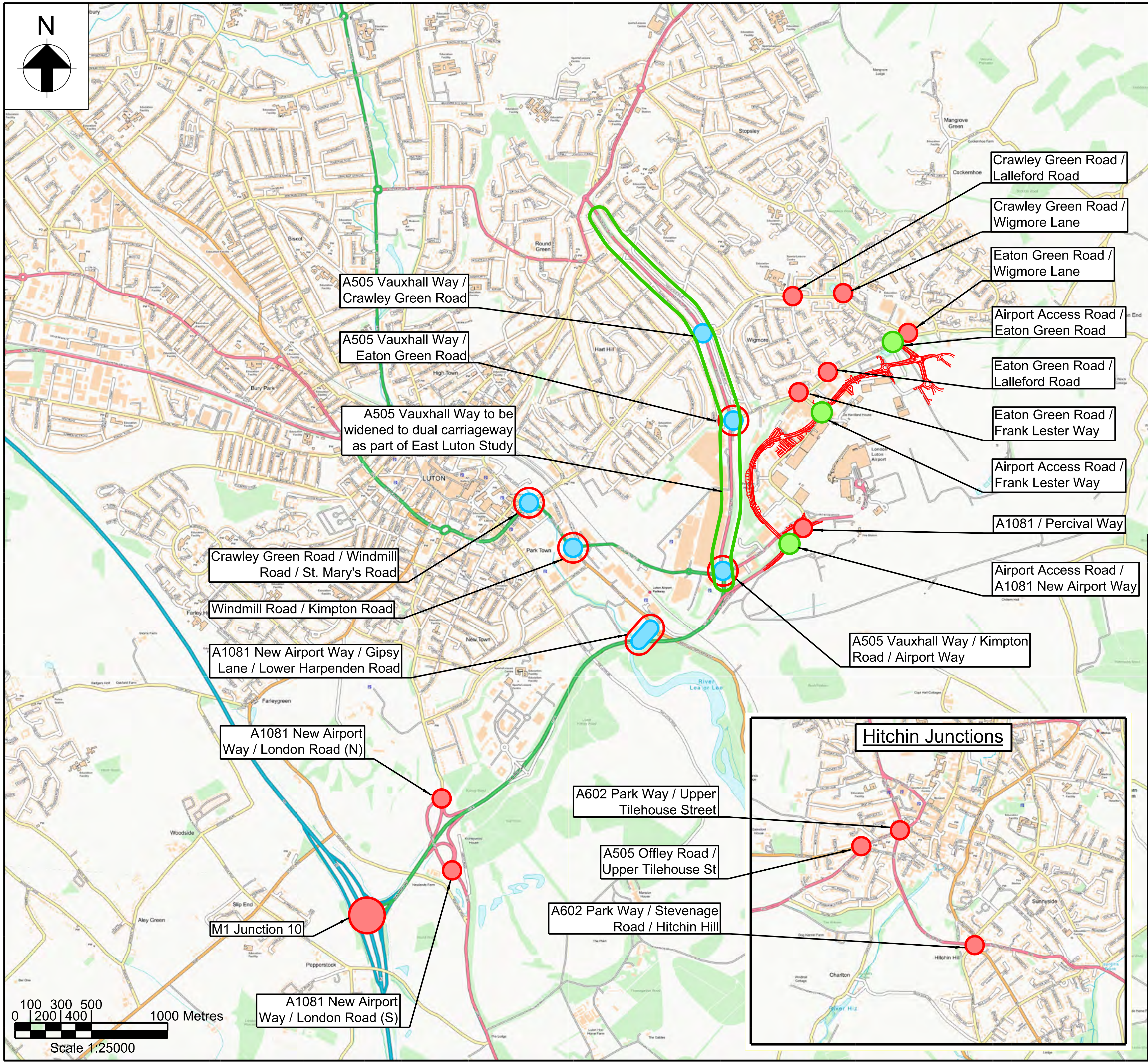
1.2.1 The purpose of the Highway Mitigation Plans is to show indicative proposals for various highway improvements which are required to provide additional capacity for traffic associated with the Proposed Development.

1.3 Highway Mitigation Plans Drawing List

Highway Mitigation Plans Drawing Name	Drawing Number	Work No.
Highway Mitigation Location Plan	LLADCO-3C-ARP-SFA-SWI-DR-CE-0001	Overview
Potential Rural Traffic Management Locations	LLADCO-3C-ARP-SFA-SWI-DR-CE-0002	N/A
Potential Area of Residential Parking Restrictions	LLADCO-3C-ARP-SFA-SWI-DR-CE-0003	N/A
Highway Mitigation- Vauxhall Way / Eaton Green Road Future Baseline	LLADCO-3C-ARP-SFA-HWM-DR-CE-0001	N/A
Highway Mitigation- Windmill Road / Manor Road Future Baseline	LLADCO-3C-ARP-SFA-HWM-DR-CE-0002	N/A
Highway Mitigation- A1081 New Airport Way / B653 / Gipsy Lane Future Baseline	LLADCO-3C-ARP-SFA-HWM-DR-CE-0003	N/A
Highway Mitigation- Windmill Road / Kimpton Road Future Baseline	LLADCO-3C-ARP-SFA-HWM-DR-CE-0004	N/A
Highway Mitigation- Vauxhall Way / Crawley Green Road Future Baseline	LLADCO-3C-ARP-SFA-HWM-DR-CE-0034	N/A
Highway Mitigation- Vauxhall Way / Kimpton Road Future Baseline	LLADCO-3C-ARP-SFA-HWM-DR-CE-0035	N/A
Highway Mitigation- A1081 New Airport Way / B653 / Gipsy Lane Assessment Phase 1	LLADCO-3C-ARP-SFA-HWM-DR-CE-0005	6e(b)

Highway Mitigation Plans Drawing Name	Drawing Number	Work No.
Highway Mitigation- Windmill Road / Kimpton Road Assessment Phase 1	LLADCO-3C-ARP-SFA-HWM-DR-CE-0006	6e(a)
Highway Mitigation- A505 Vauxhall Way / Eaton Green Road Assessment Phase 1	LLADCO-3C-ARP-SFA-HWM-DR-CE-0007	6e(r)
Highway Mitigation- A1081 New Airport Way / London Road (North) Assessment Phase 1	LLADCO-3C-ARP-SFA-HWM-DR-CE-0008	6e(g)
Highway Mitigation- M1 Junction 10 Assessment Phase 1	LLADCO-3C-ARP-SFA-HWM-DR-CE-0009	6e(n)
Highway Mitigation- A1081 New Airport Way / Percival Way Assessment Phase 1	LLADCO-3C-ARP-SFA-HWM-DR-CE-0010	6a(01)
Highway Mitigation- Eaton Green Road / Lalleford Road Assessment Phase 1	LLADCO-3C-ARP-SFA-HWM-DR-CE-0011	6e(d)
Highway Mitigation- Wigmore Lane / Crawley Green Road Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0012	6e(e)
Highway Mitigation- Wigmore Lane / Eaton Green Road Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0013	6e(f)
Highway Mitigation- Eaton Green Road / Frank Lester Way Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0014	6e(q)
Highway Mitigation- Windmill Road / St. Mary's Road / Crawley Green Road Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0015	6e(i)
Highway Mitigation- A505 Vauxhall Way / Kimpton Road Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0016	6e(c)
Highway Mitigation- A1081 New Airport Way / London Road (South) Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0017	6e(h)
Highway Mitigation- Crawley Green Road / Lalleford Road Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0018	6e(j)
Highway Mitigation- A1081 New Airport Way / Airport Access Road Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0019	6a(02)
Highway Mitigation- Airport Access Road / Provost Way Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0020	6a(02)
Highway Mitigation- Airport Access Road / Frank Lester Way Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0021	6a(02)
Highway Mitigation- Airport Access Road / Eaton Green Road Link Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0022	6a(02)
Highway Mitigation- Airport Access Road Entire Alignment Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0023	6a(02)
Highway Mitigation- M1 Junction 10 (Sheet 1 of 2) Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0024	6e(o)
Highway Mitigation- M1 Junction 10 (Sheet 2 of 2) Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0025	6e(0)
Highway Mitigation- A505 / Upper Tilehouse Street Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0026	6e(l)
Highway Mitigation- A505 Upper Tilehouse Street / A602 Park Way Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0027	6e(k)
Highway Mitigation- A602 Park Way / Stevenage Road / Hitchin Hill Assessment Phase 2a	LLADCO-3C-ARP-SFA-HWM-DR-CE-0028	6e(m)
Highway Mitigation- M1 Junction 10 Future Baseline (Sheet 1 of 2)	LLADCO-3C-ARP-SFA-HWM-DR-CE-0029	6e(p)
Highway Mitigation- M1 Junction 10 Future Baseline (Sheet 2 of 2)	LLADCO-3C-ARP-SFA-HWM-DR-CE-0030	6e(p)

Highway Mitigation Plans Drawing Name	Drawing Number	Work No.
Highway Mitigation- Airport Access Road / Provost Way Assessment Phase 2b	LLADCO-3C-ARP-SFA-HWM-DR-CE-0031	6a(03)
Highway Mitigation- Airport Access Road / Frank Lester Way Assessment Phase 2b	LLADCO-3C-ARP-SFA-HWM-DR-CE-0032	6a(03)
Highway Mitigation- Airport Access Road Entire Alignment Assessment Phase 2b	LLADCO-3C-ARP-SFA-HWM-DR-CE-0033	6a(03)



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Junctions requiring mitigation
- Junctions forming part of LBC East Luton Study
- LBC East Luton Study junctions requiring additional mitigation
- New / improved junctions to be provided as part of Airport Access Road
- Vauxhall Way widening forming part of LBC East Luton Study

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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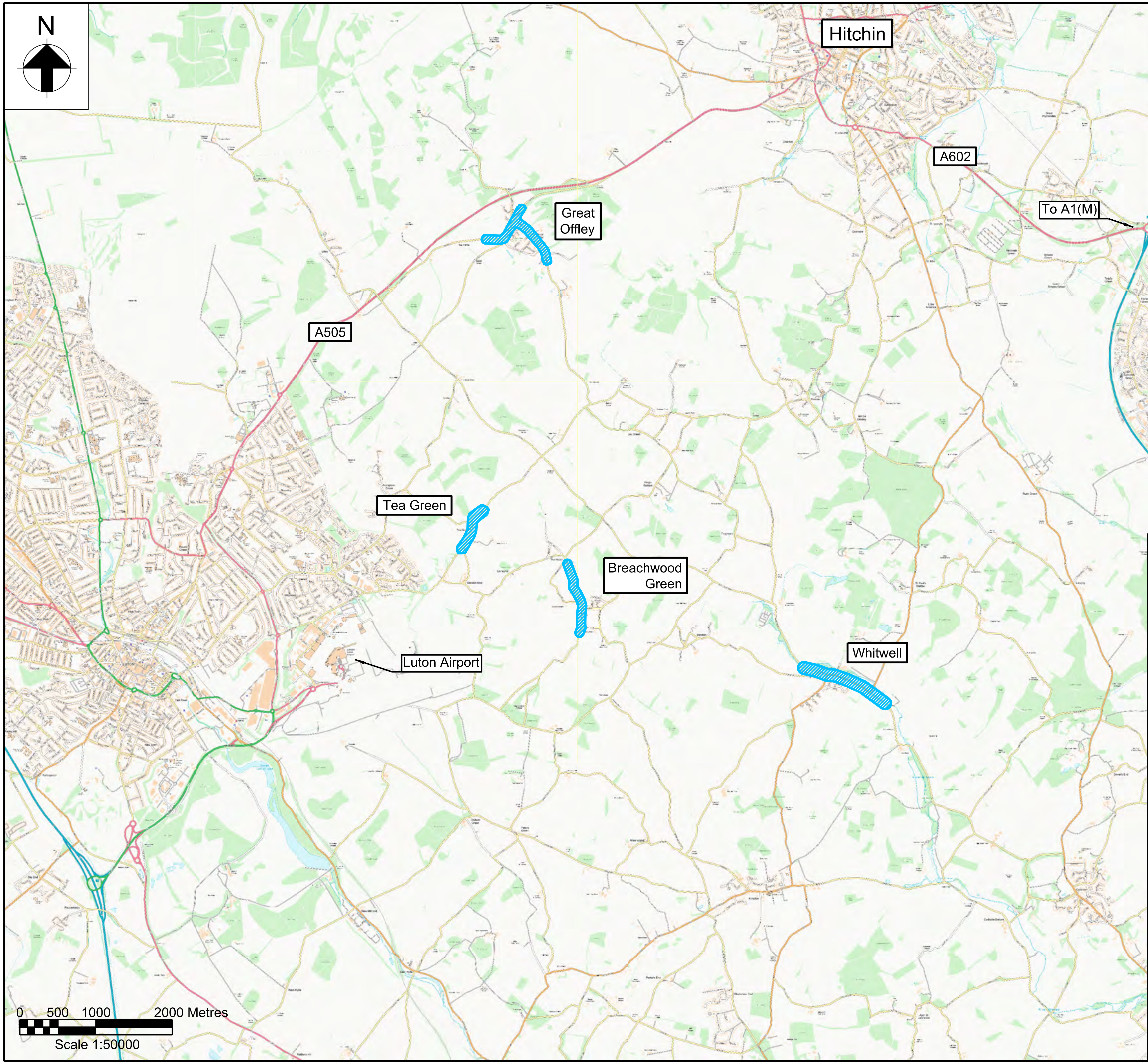
Drawing Title

HIGHWAY MITIGATION LOCATION PLAN

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:25000	A3
DCO Application Ref.	APFP Regulation	DCO Document Ref.			
TR020001	5(2)(o)	TR020001/APP/7.02			

Drawing Number	Revision
LLADCO-3C-ARP-SFA-SWI-DR-CE-0001	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



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KEY

Indicative locations of potential traffic management / traffic calming schemes

Revision History	Drawn	Checked	Approved	Date	Rev.
DCO Submission	NS	JR	RG	27/02/23	P01

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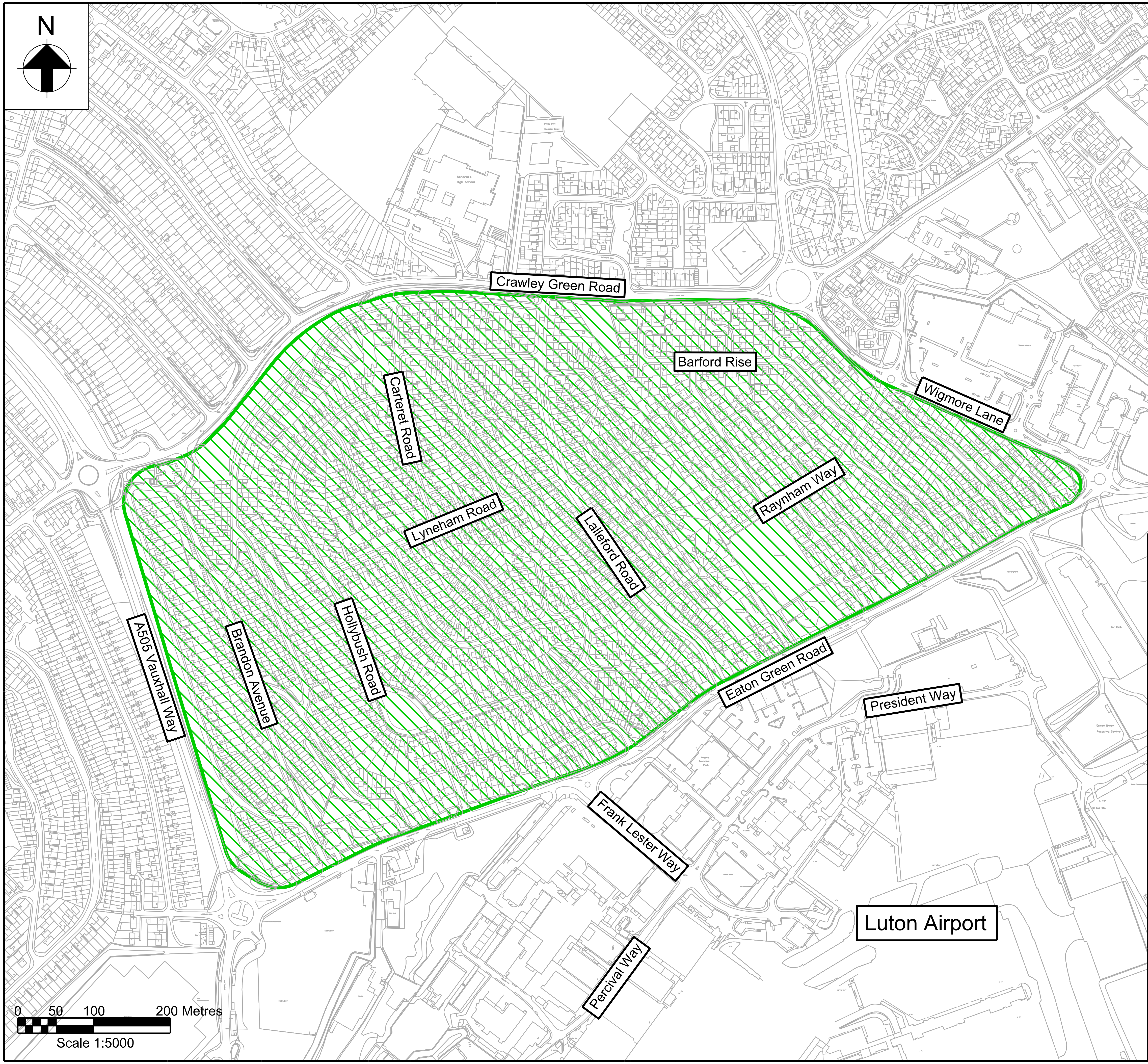
Drawing Title

POTENTIAL RURAL TRAFFIC MANAGEMENT LOCATIONS

Purpose of issue				Suitability	
DCO SUBMISSION				S6	
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:50000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-SWI-DR-CE-0002 Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number	P01



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KEY

Indicative area of potential residential parking controls

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

POTENTIAL AREA OF RESIDENTIAL PARKING RESTRICTIONS

Purpose of issue				Suitability	
DCO SUBMISSION				S6	
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:5000	A3

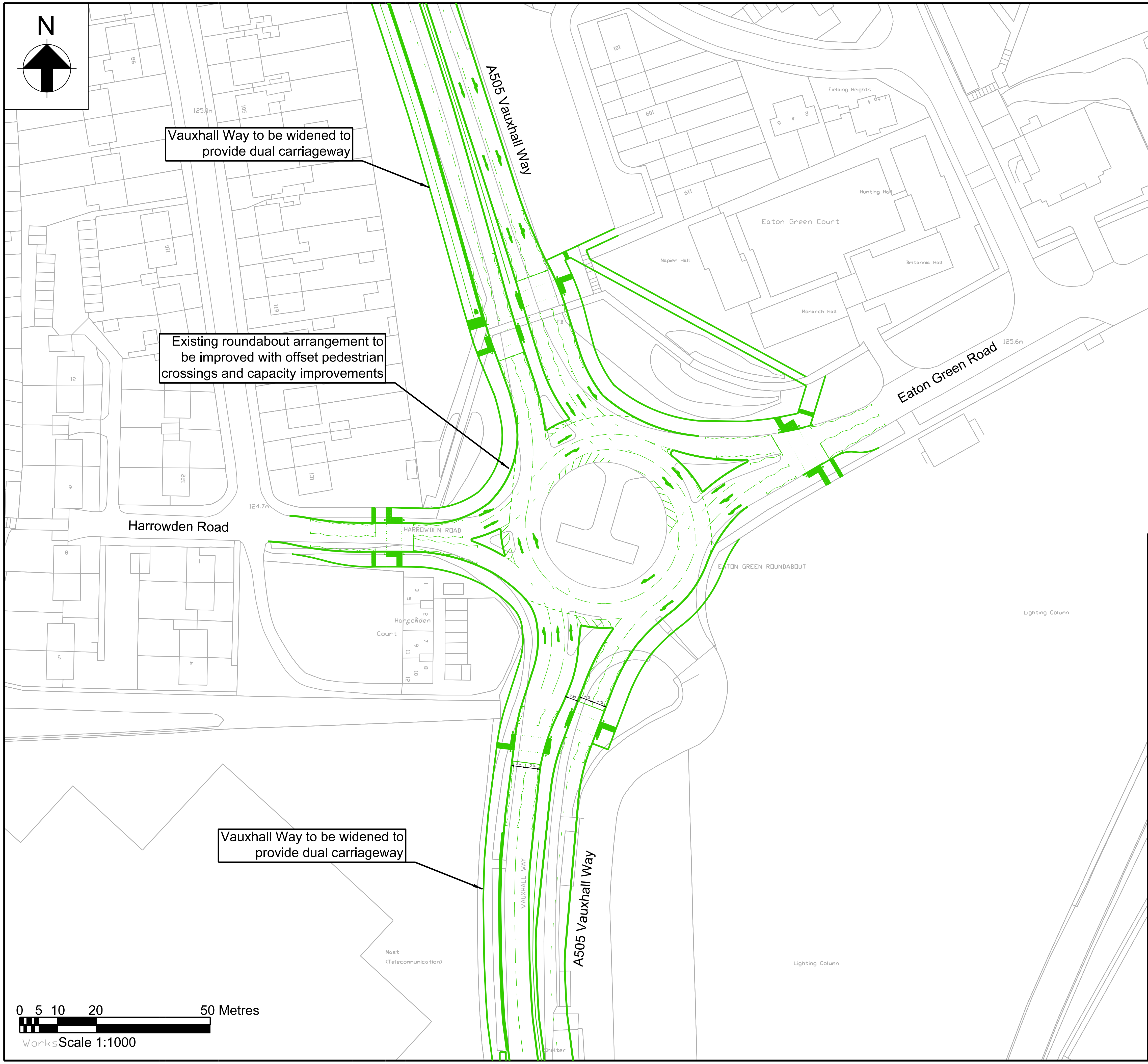
DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-SWI-DR-CE-0003	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number

Future Baseline- Assessment Phase 1

(No Airport Development)



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KEY

- Existing Mapping
- Proposed LBC Highway Layout (to be provided by LBC as part of East Luton Study)

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION VAUXHALL WAY / EATON GREEN ROAD FUTURE BASELINE

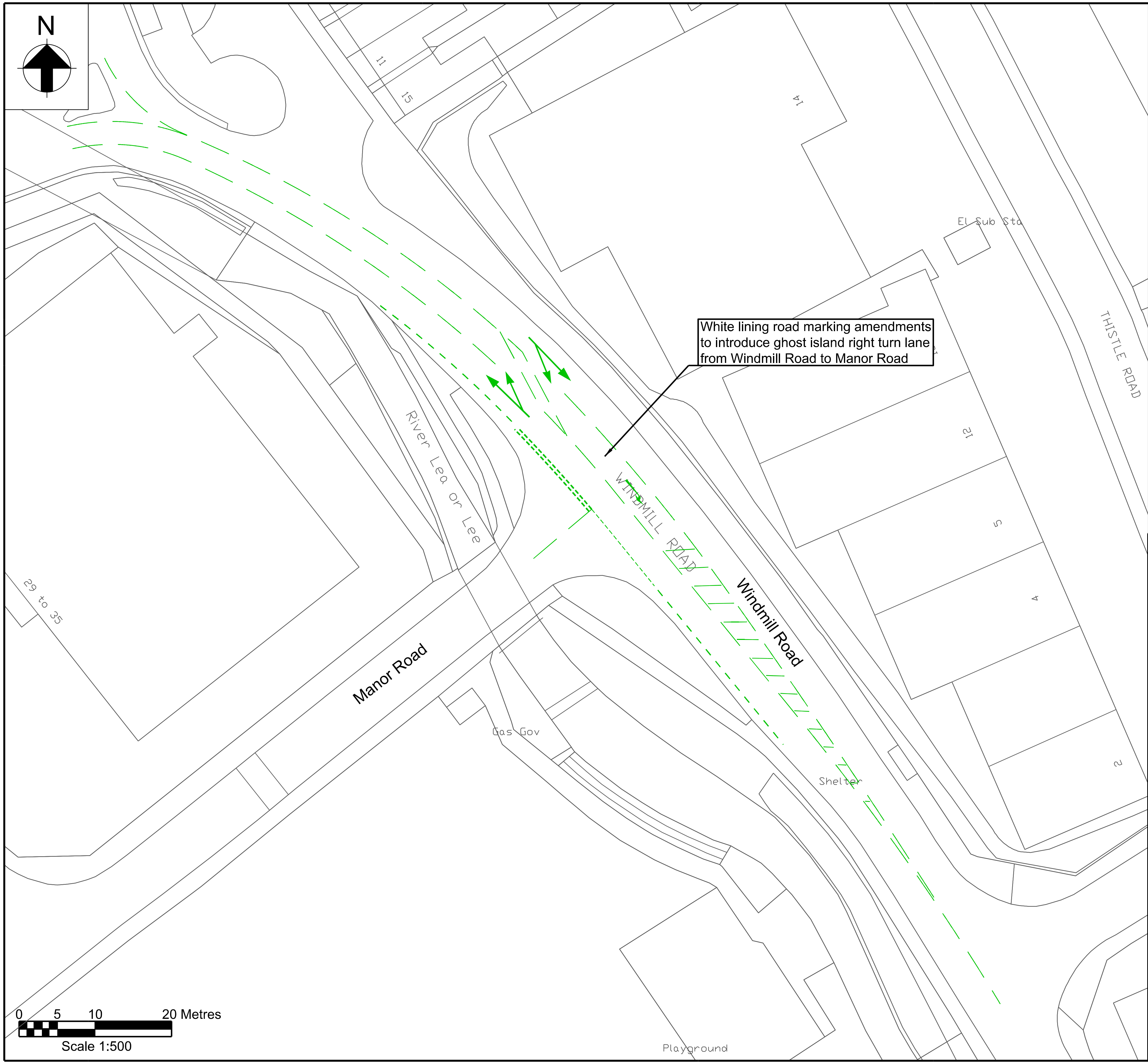
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	N.Scott	N.Scott	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0001	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



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Drawing Title

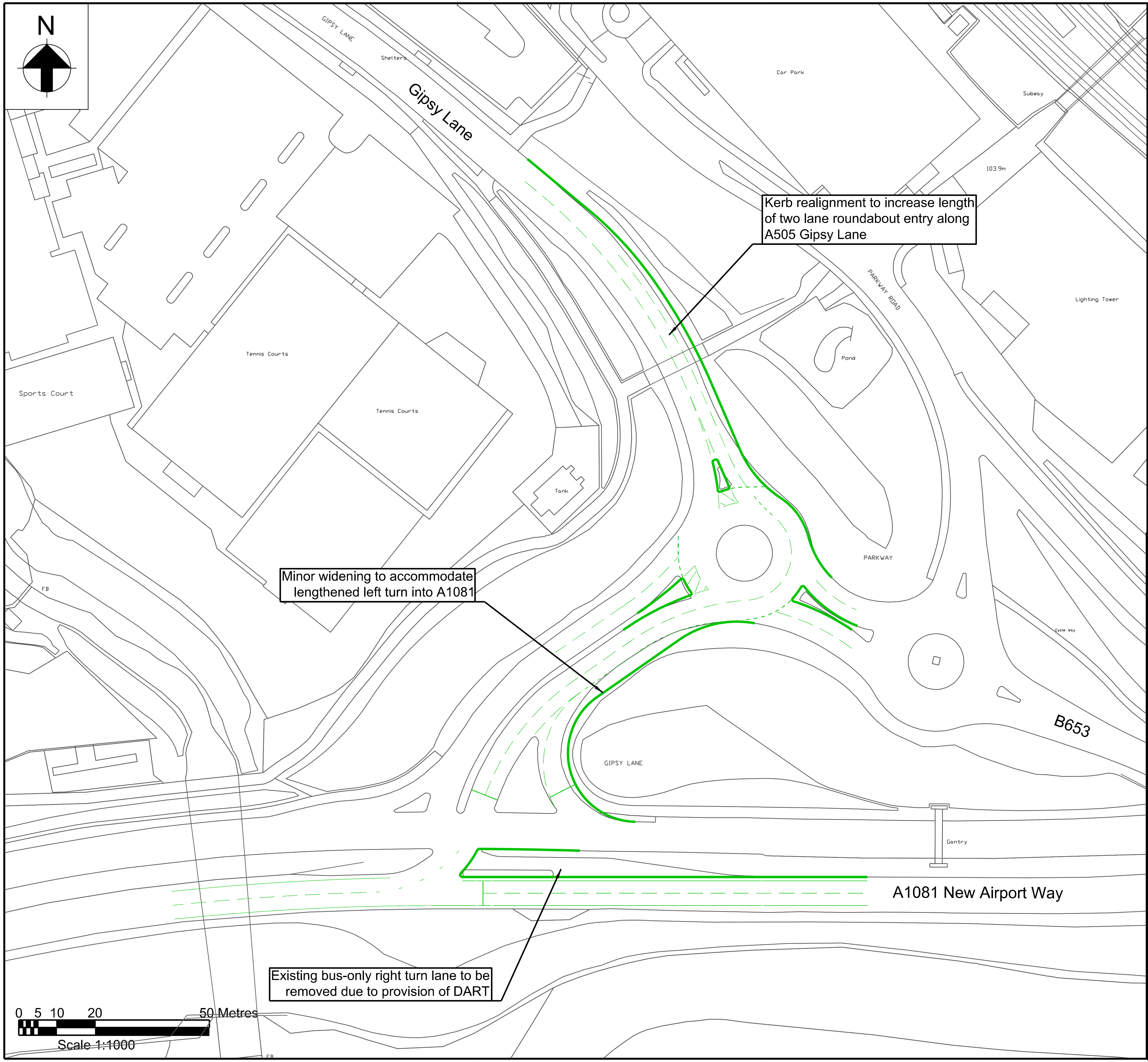
HIGHWAY MITIGATION WINDMILL RD / MANOR RD FUTURE BASELINE

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:500	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0002	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



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KEY

- Existing Mapping
- Proposed LBC Highway Layout (to be provided by LBC as part of East Luton Study)

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION
A1081 NEW AIRPORT WAY /
B653 / GIPSY LANE
FUTURE BASELINE

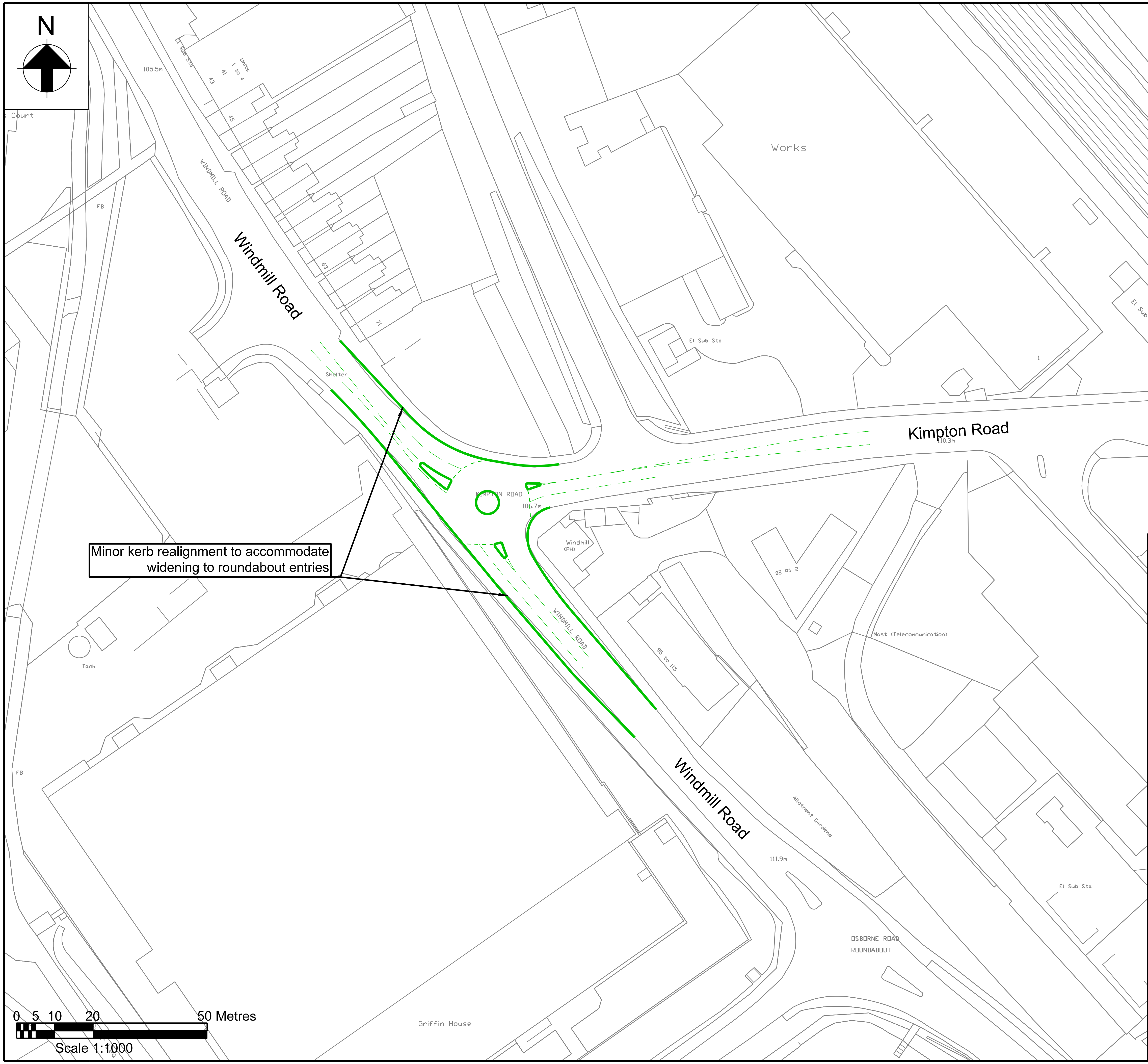
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0003	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



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KEY

- Existing Mapping
- Proposed LBC Highway Layout (to be provided by LBC as part of East Luton Study)

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION
WINDMILL RD / KIMPTON RD
FUTURE BASELINE

Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
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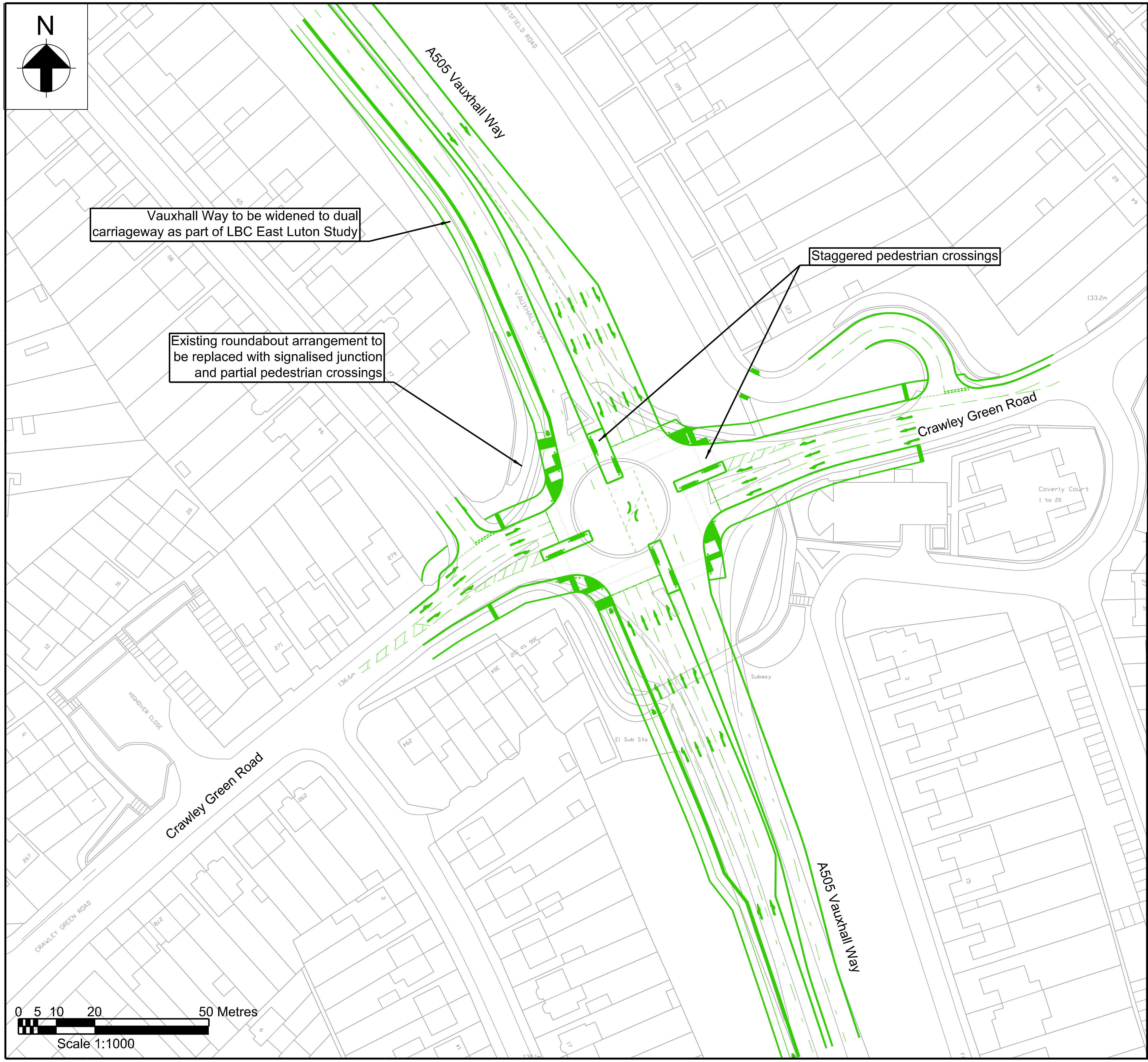
Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



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KEY

- Existing Mapping
- Proposed LBC Highway Layout (to be provided by LBC as part of East Luton Study)

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION
VAUXHALL WAY /
CRAWLEY GREEN ROAD
FUTURE BASELINE

Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
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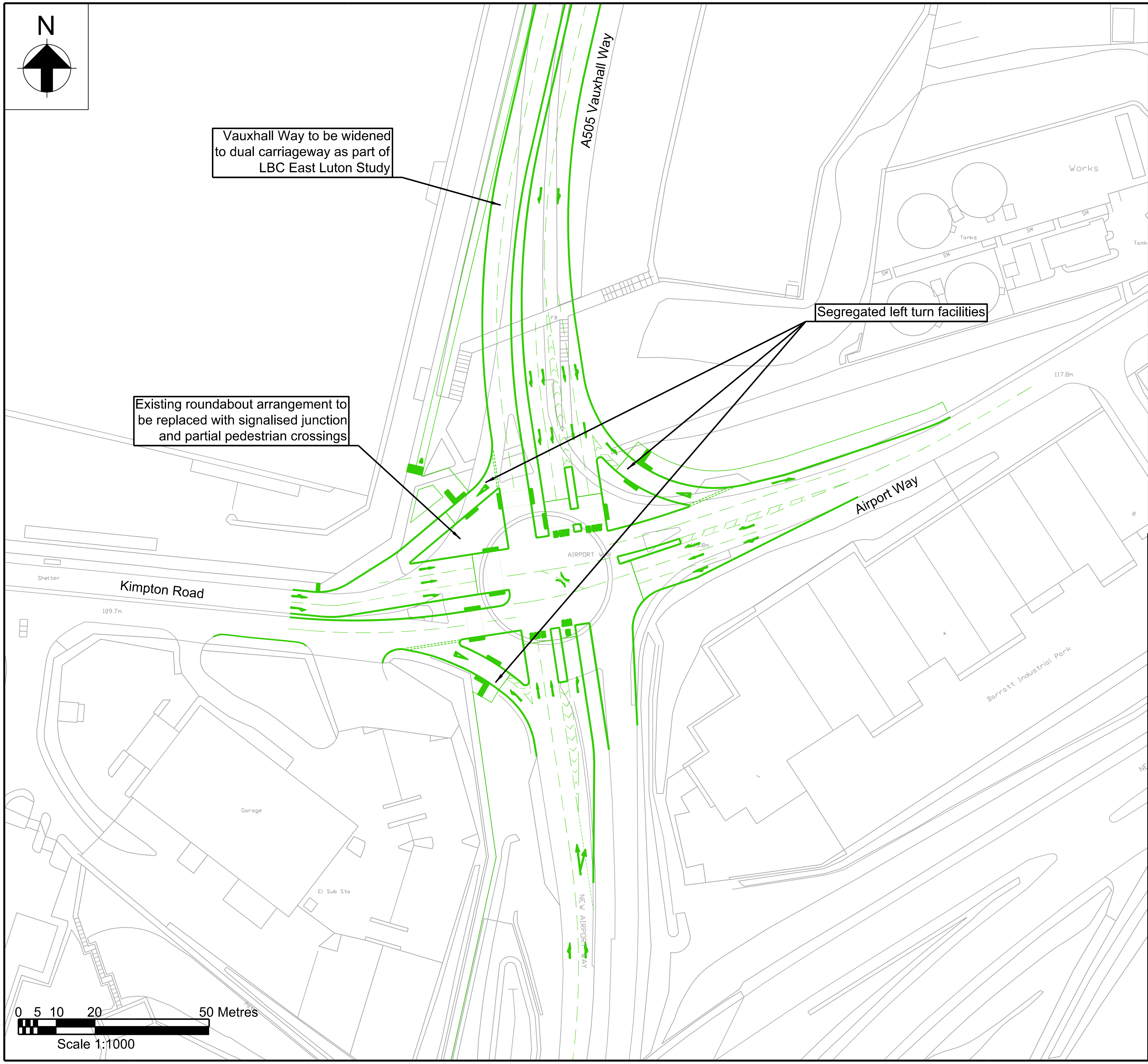
Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



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KEY

- Existing Mapping
- Proposed LBC Highway Layout (to be provided by LBC as part of East Luton Study)

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION VAUXHALL WAY / KIMPTON ROAD FUTURE BASELINE

Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

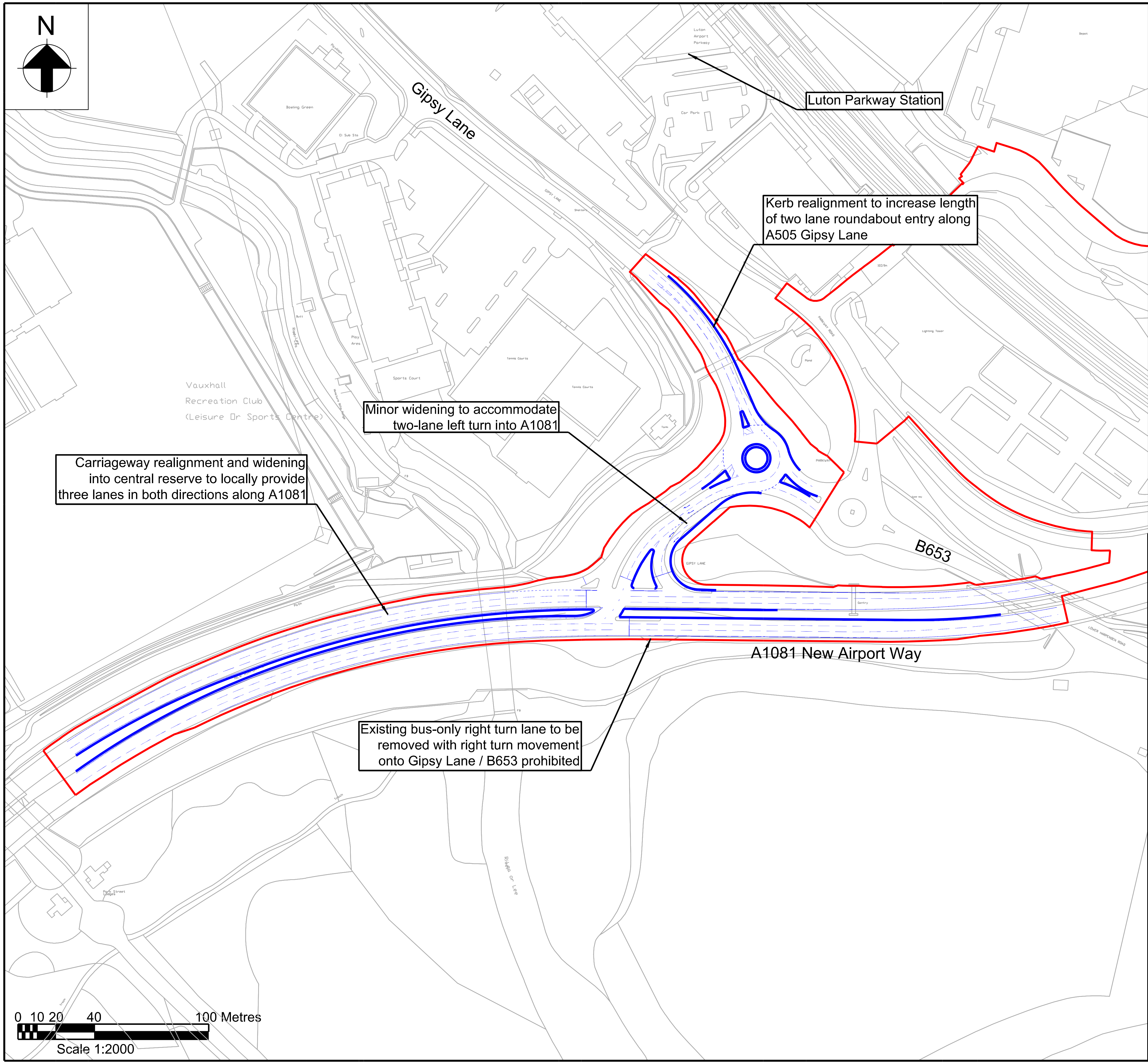
DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0035	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number

Assessment Phase 1

(With Airport Development)



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KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION A1081 NEW AIRPORT WAY / B653 / GIPSY LANE ASSESSMENT PHASE 1

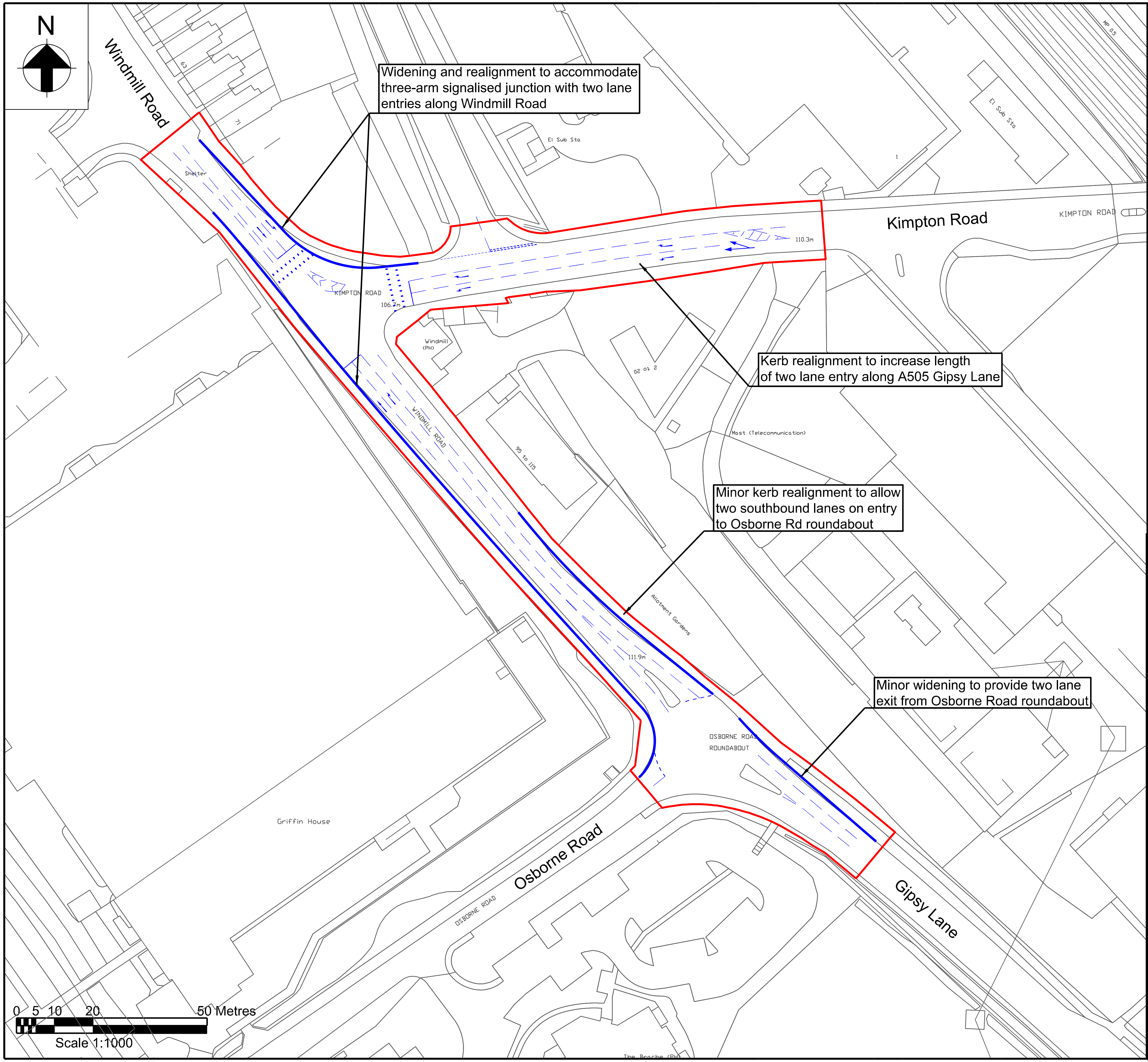
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:2000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0005	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



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KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

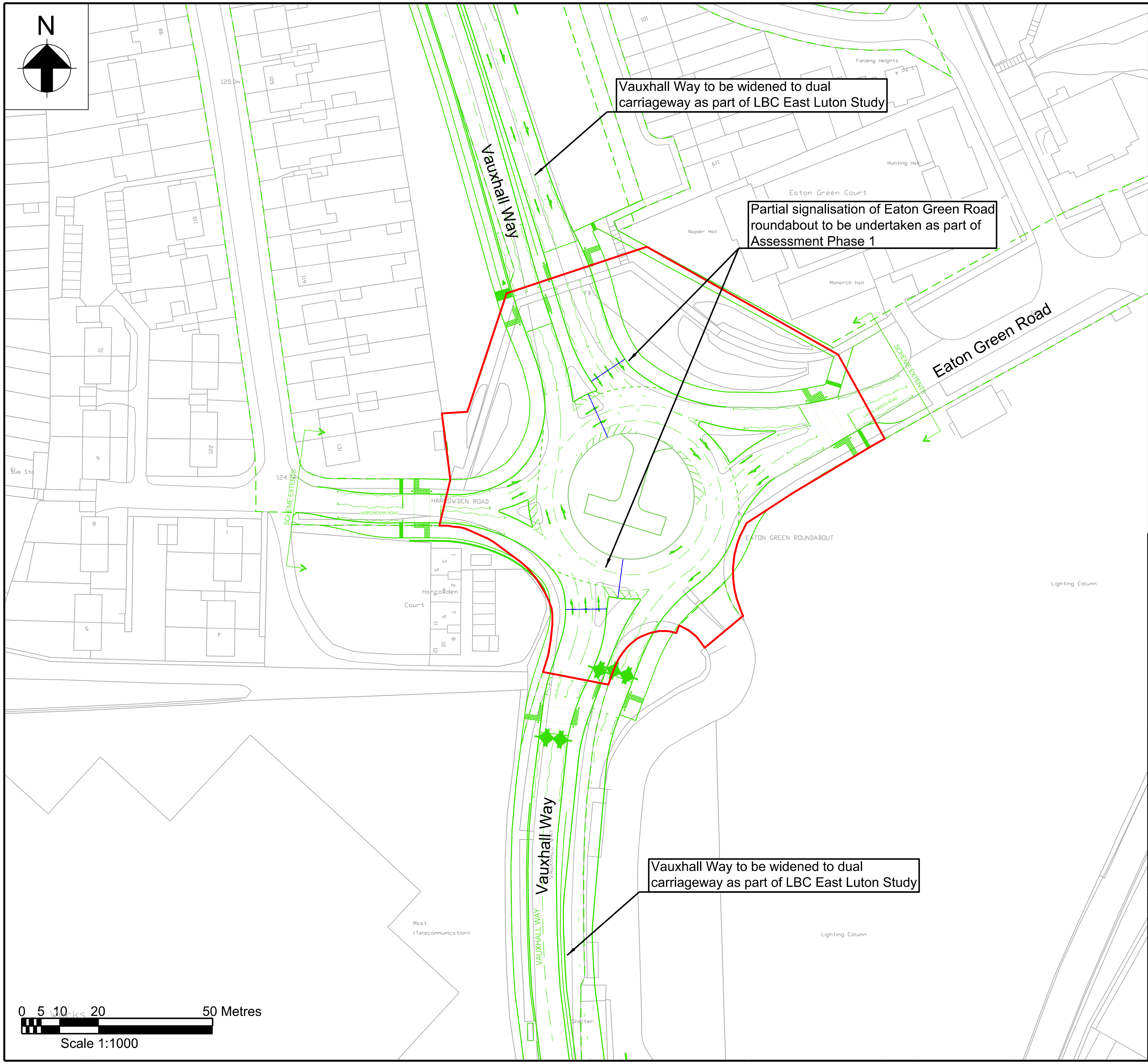
HIGHWAY MITIGATION WINDMILL RD / KIMPTON RD ASSESSMENT PHASE 1

Purpose of issue				Suitability	
DCO SUBMISSION				S6	
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0006	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



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KEY

- Existing Mapping
- Proposed Highway Layout
- Proposed LBC Highway Layout (provided by LBC as part of East Luton Study)
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
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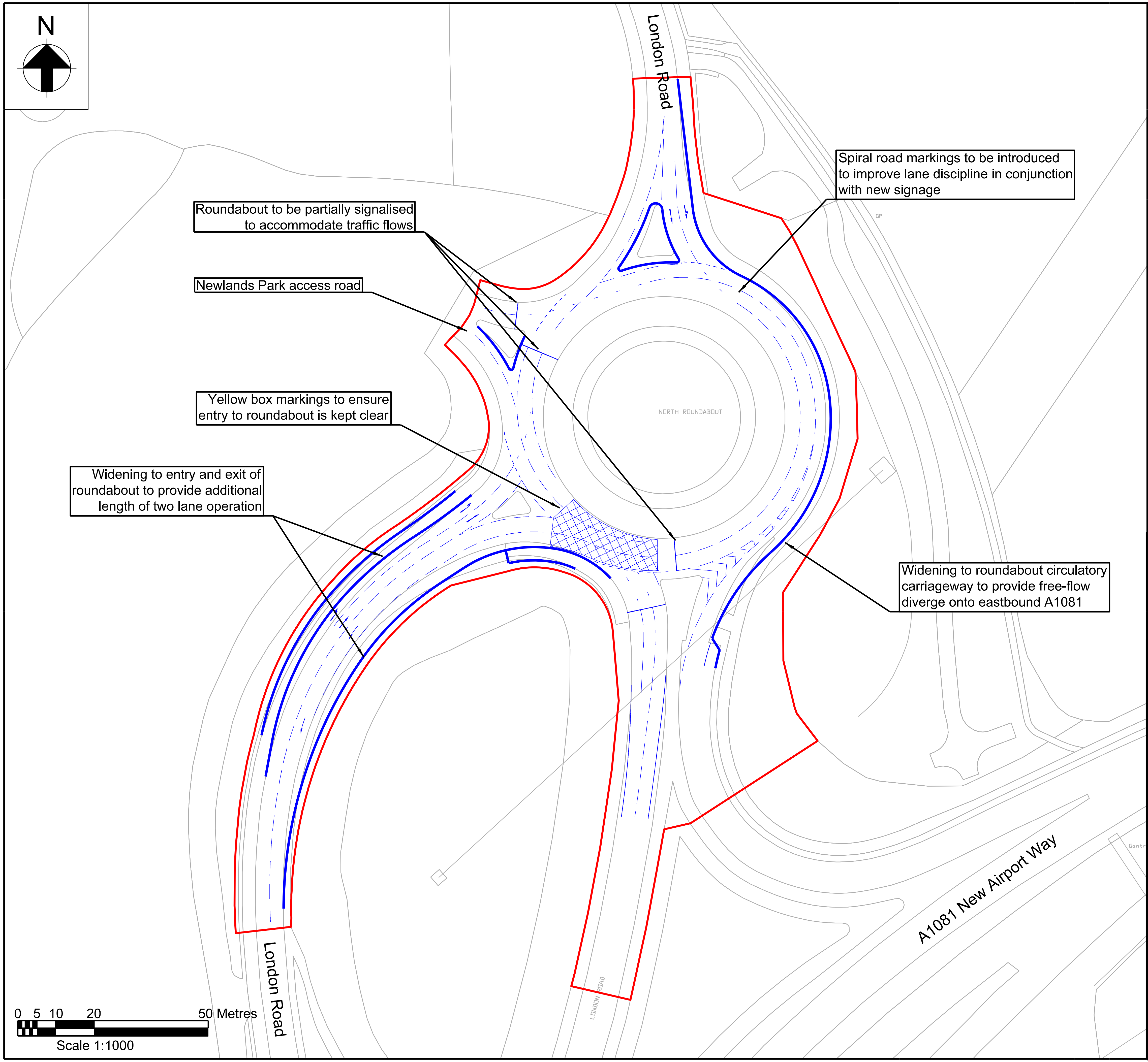
Drawing Title

HIGHWAY MITIGATION
A505 VAUXHALL WAY / EATON GREEN ROAD
ASSESSMENT PHASE 1

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn: N.Scott	Checked: J.Riat	Approved: R.Goodall	Date: 27/02/23	Scale: 1:1000	Size: A3
DCO Application Ref.: TR020001	APFP Regulation: 5(2)(o)		DCO Document Ref.: TR020001/APP/7.02		

Drawing Number: LLADCO-3C-ARP-SFA-HWM-DR-CE-0007 — Revision: P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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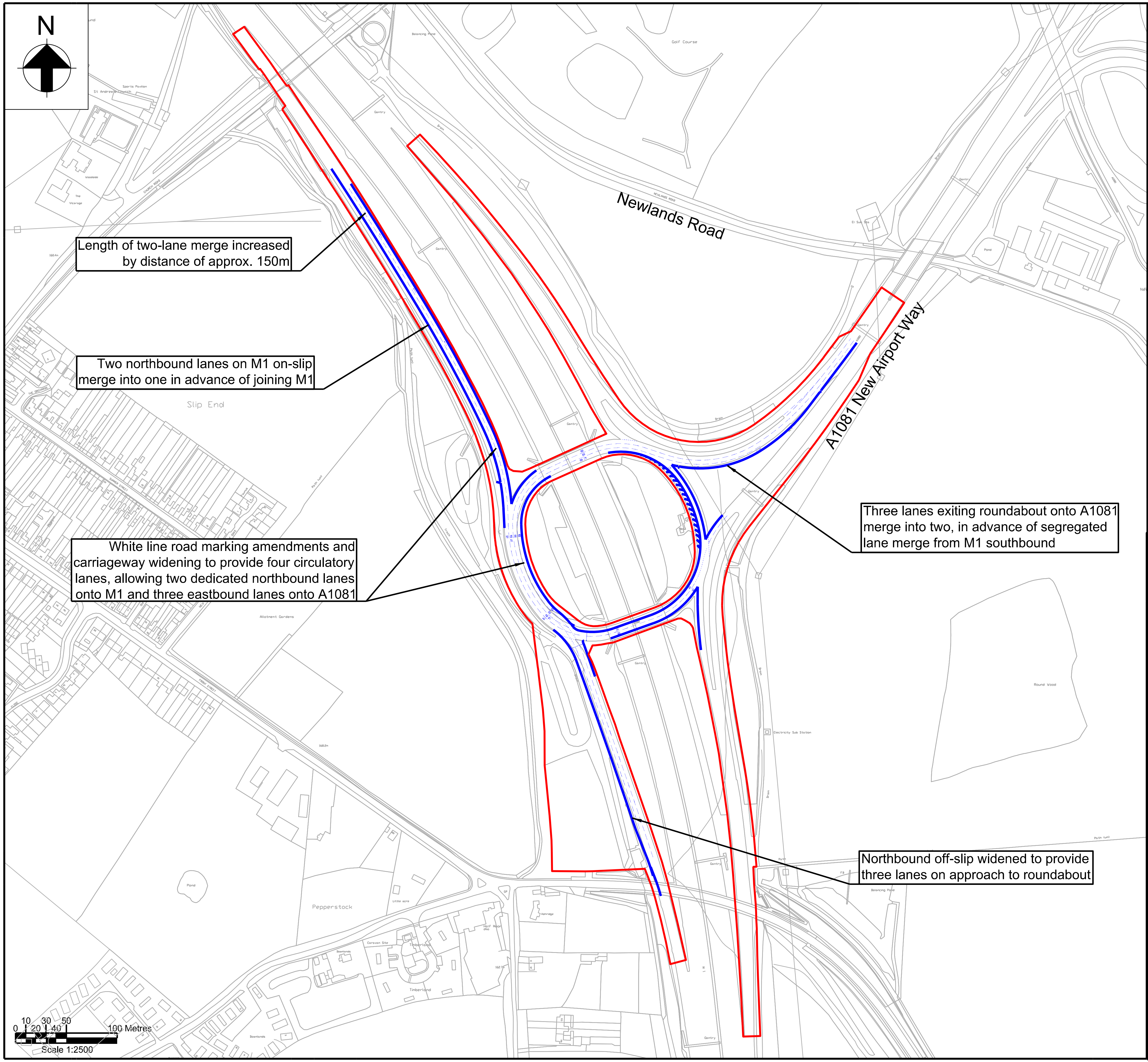
Drawing Title

HIGHWAY MITIGATION A1081 NEW AIRPORT WAY / LONDON ROAD (NORTH) ASSESSMENT PHASE 1

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0008	P01
Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number	



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

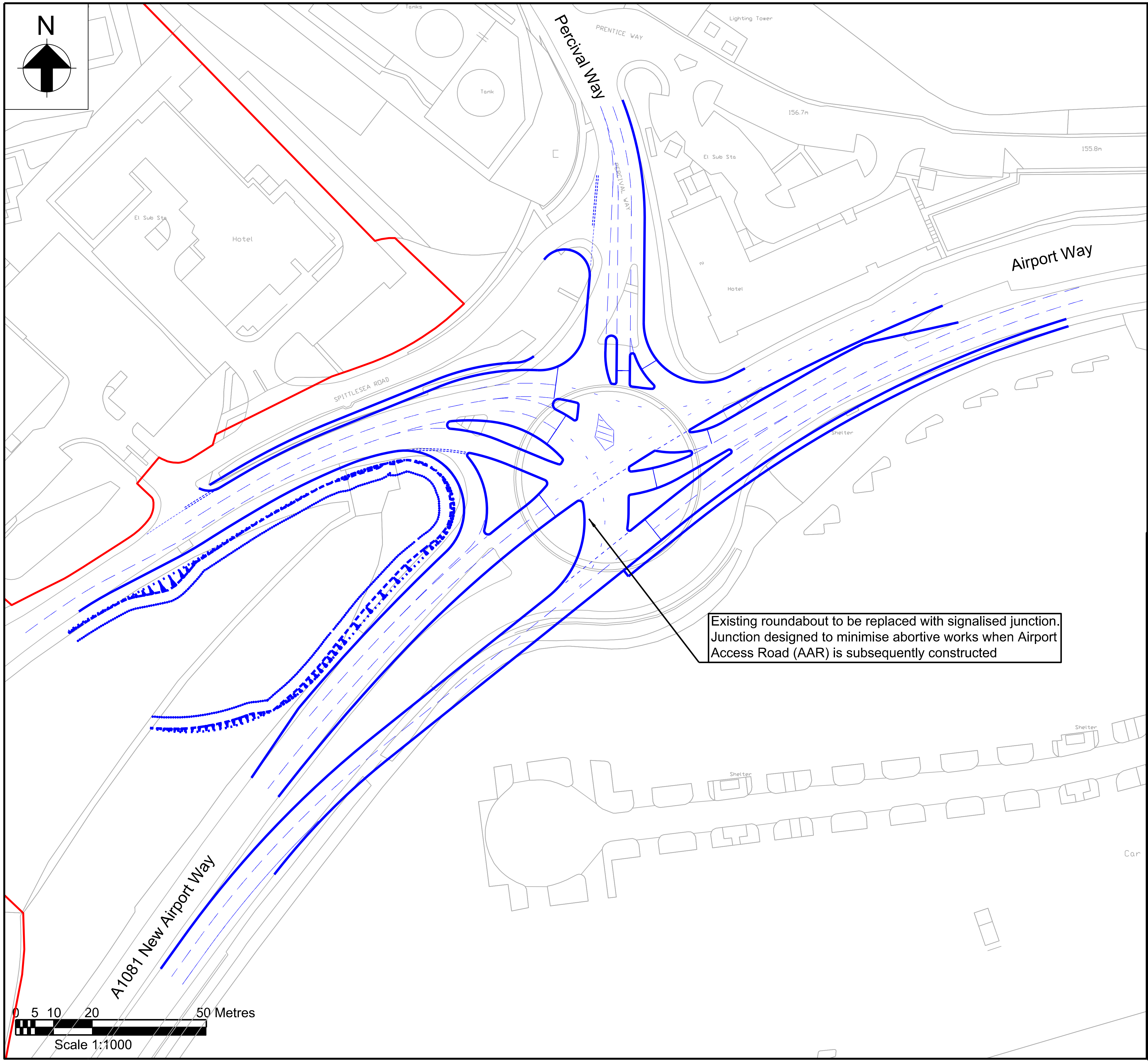
HIGHWAY MITIGATION M1 JUNCTION 10 ASSESSMENT PHASE 1

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:2500	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0009	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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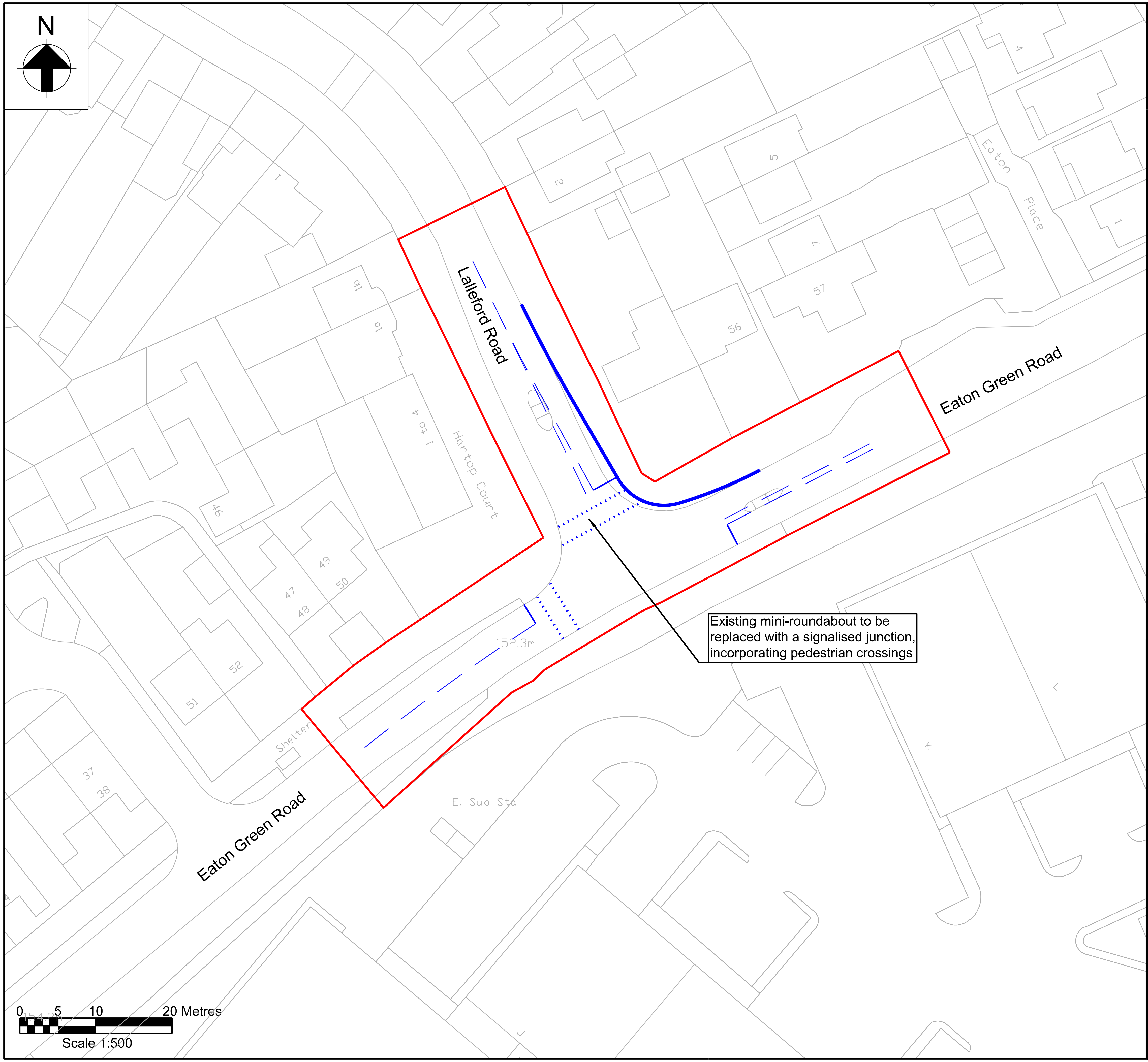
Drawing Title

HIGHWAY MITIGATION
A1081 NEW AIRPORT WAY / PERCIVAL WAY
ASSESSMENT PHASE 1

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn: N.Scott	Checked: J.Riat	Approved: R.Goodall	Date: 27/02/23	Scale: 1:1000	Size: A3
DCO Application Ref.: TR020001	APFP Regulation: 5(2)(o)	DCO Document Ref.: TR020001/APP/7.02			

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0010	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION EATON GREEN ROAD / LALLEFORD ROAD ASSESSMENT PHASE 1

Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:500	A3

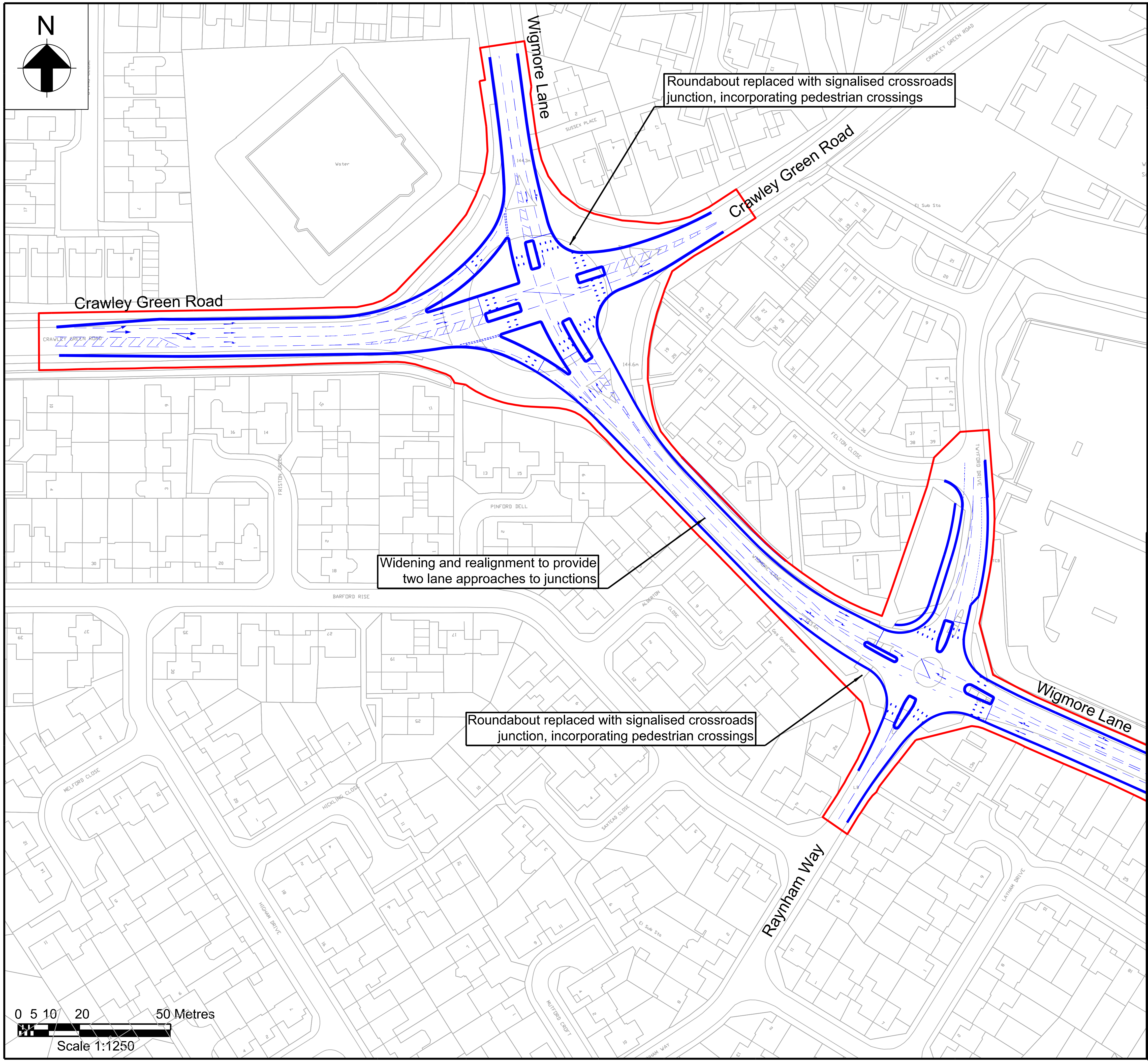
DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0011	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number

Assessment Phase 2a

(With Airport Development)



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

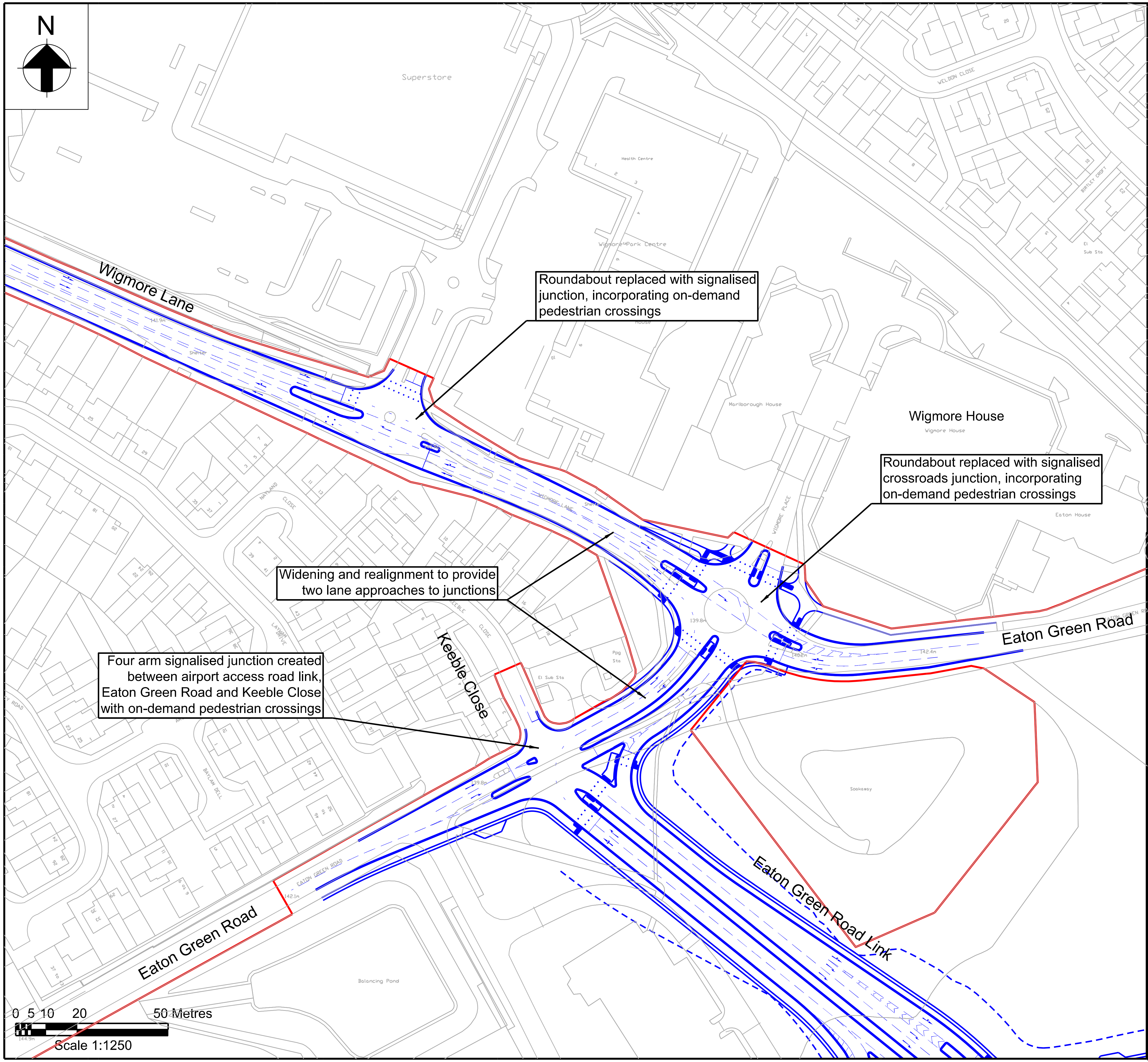
HIGHWAY MITIGATION WIGMORE LANE / CRAWLEY GREEN ROAD ASSESSMENT PHASE 2A

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1250	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0012	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION
WIGMORE LANE /
EATON GREEN ROAD
ASSESSMENT PHASE 2A

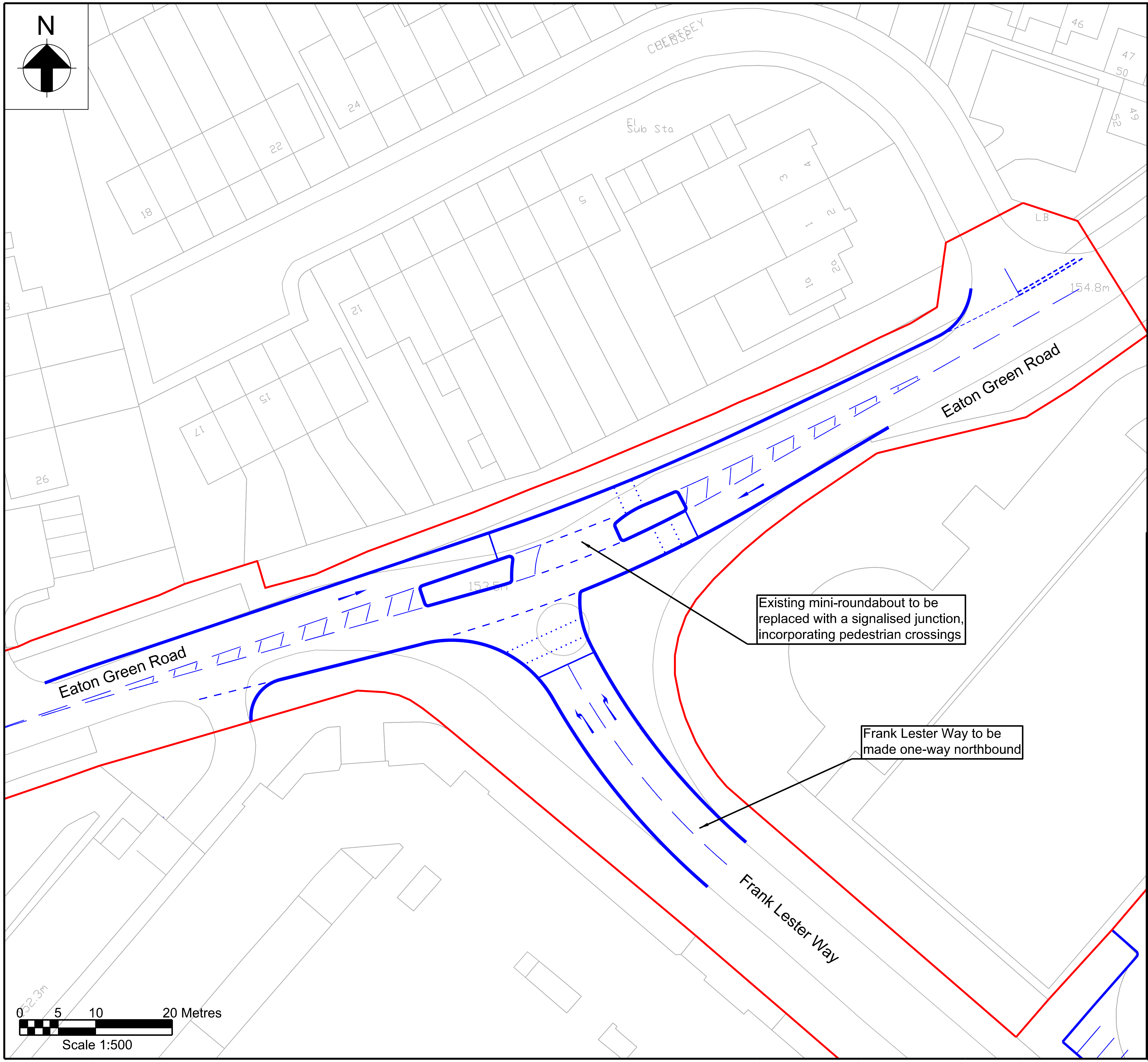
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1250	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0013	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION EATON GREEN ROAD / FRANK LESTER WAY ASSESSMENT PHASE 2A

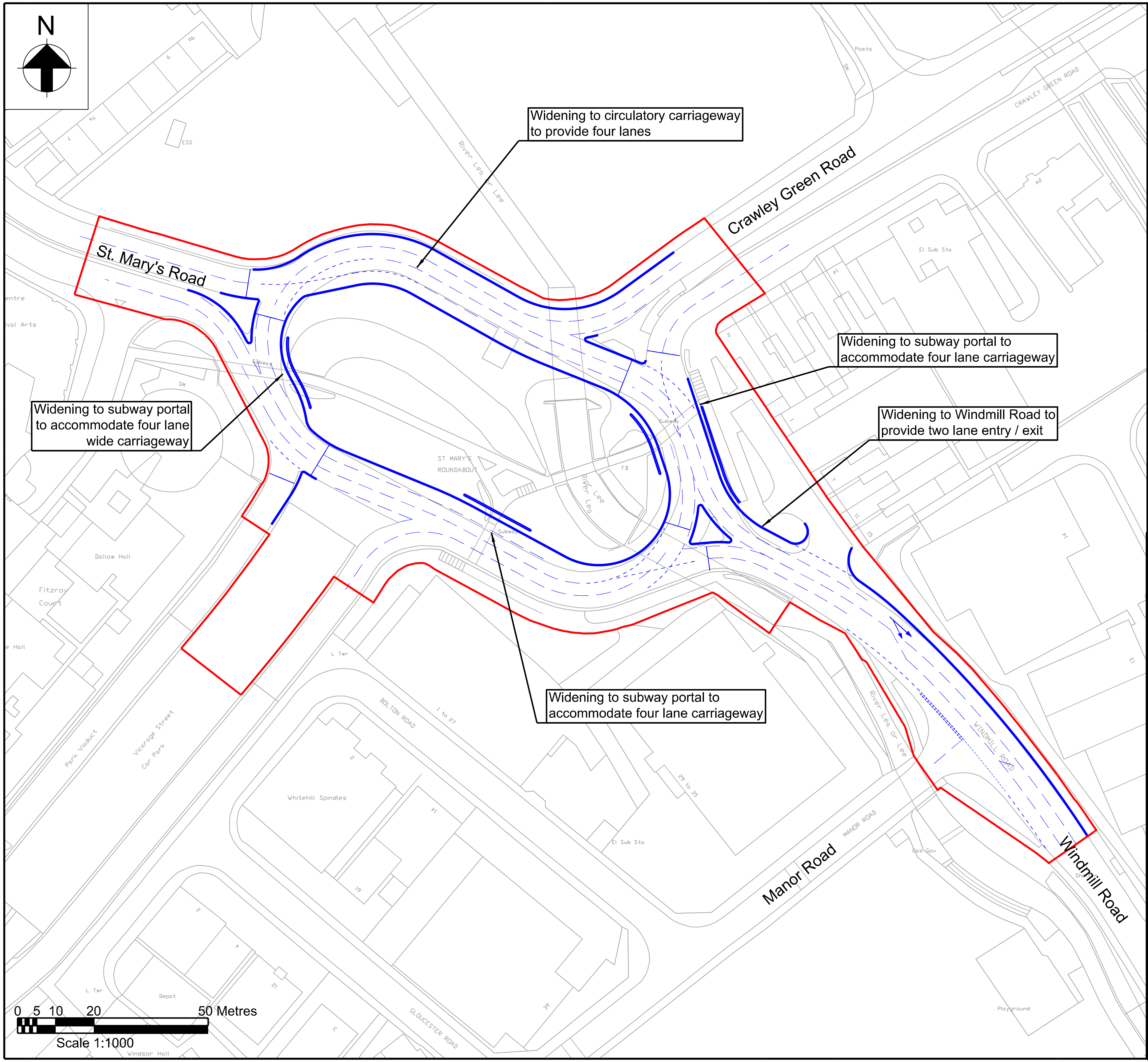
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:500	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0014	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

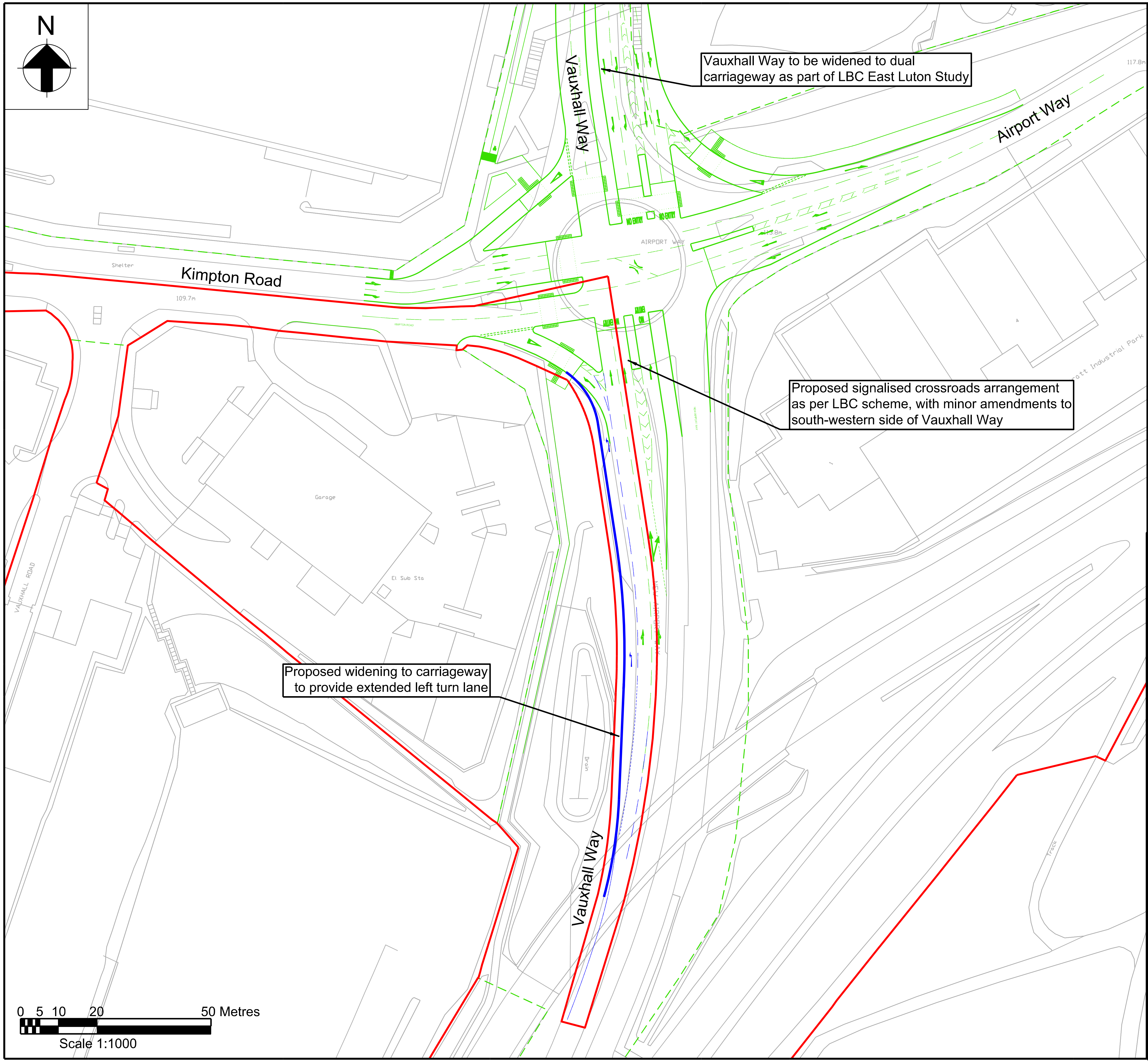
HIGHWAY MITIGATION WINDMILL RD / ST. MARY'S RD / CRAWLEY GREEN RD ASSESSMENT PHASE 2A

Purpose of issue				Suitability	
DCO SUBMISSION				S6	
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0015	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Proposed LBC Highway Layout (provided by LBC as part of East Luton Study)
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION A505 VAUXHALL WAY / KIMPTON RD ASSESSMENT PHASE 2A

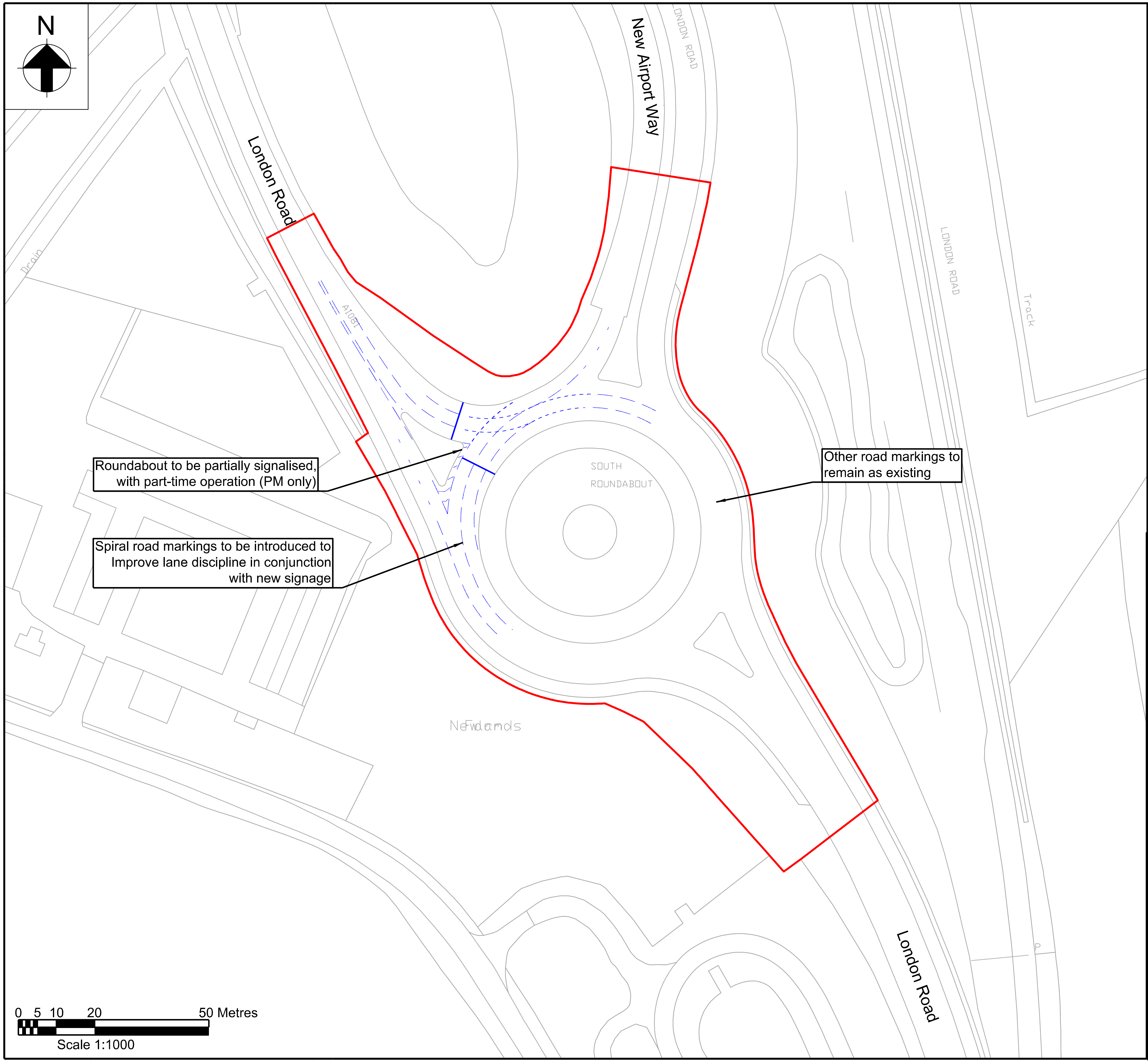
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0016	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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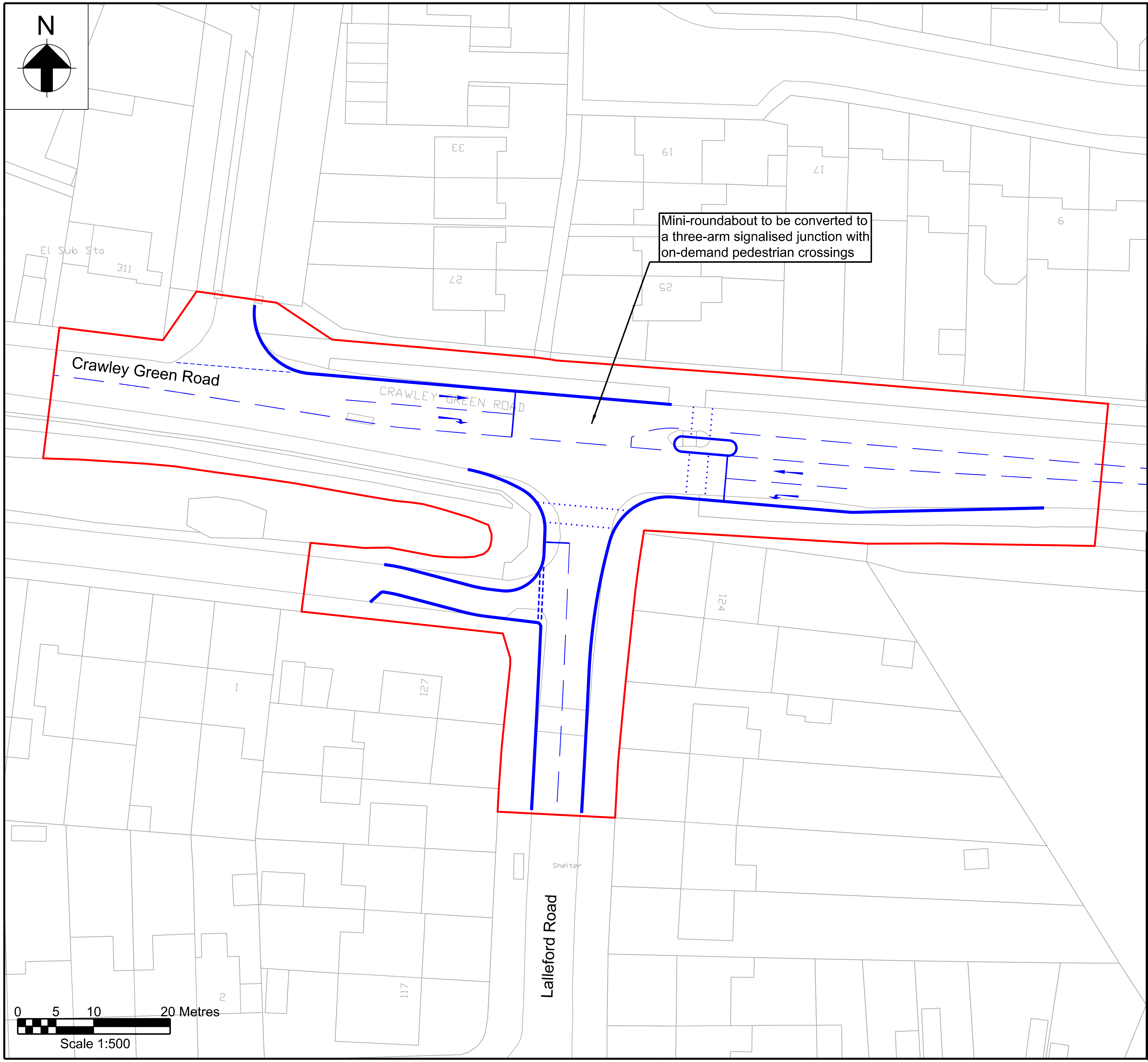
Drawing Title

HIGHWAY MITIGATION
A1081 NEW AIRPORT WAY /
LONDON ROAD (SOUTH)
ASSESSMENT PHASE 2A

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0017	P01
Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number	



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

DCO Submission	NS	JR RG	27/02/23	P01
Revision History	Drawn	Checked Approved	Date	Rev.

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Drawing Title

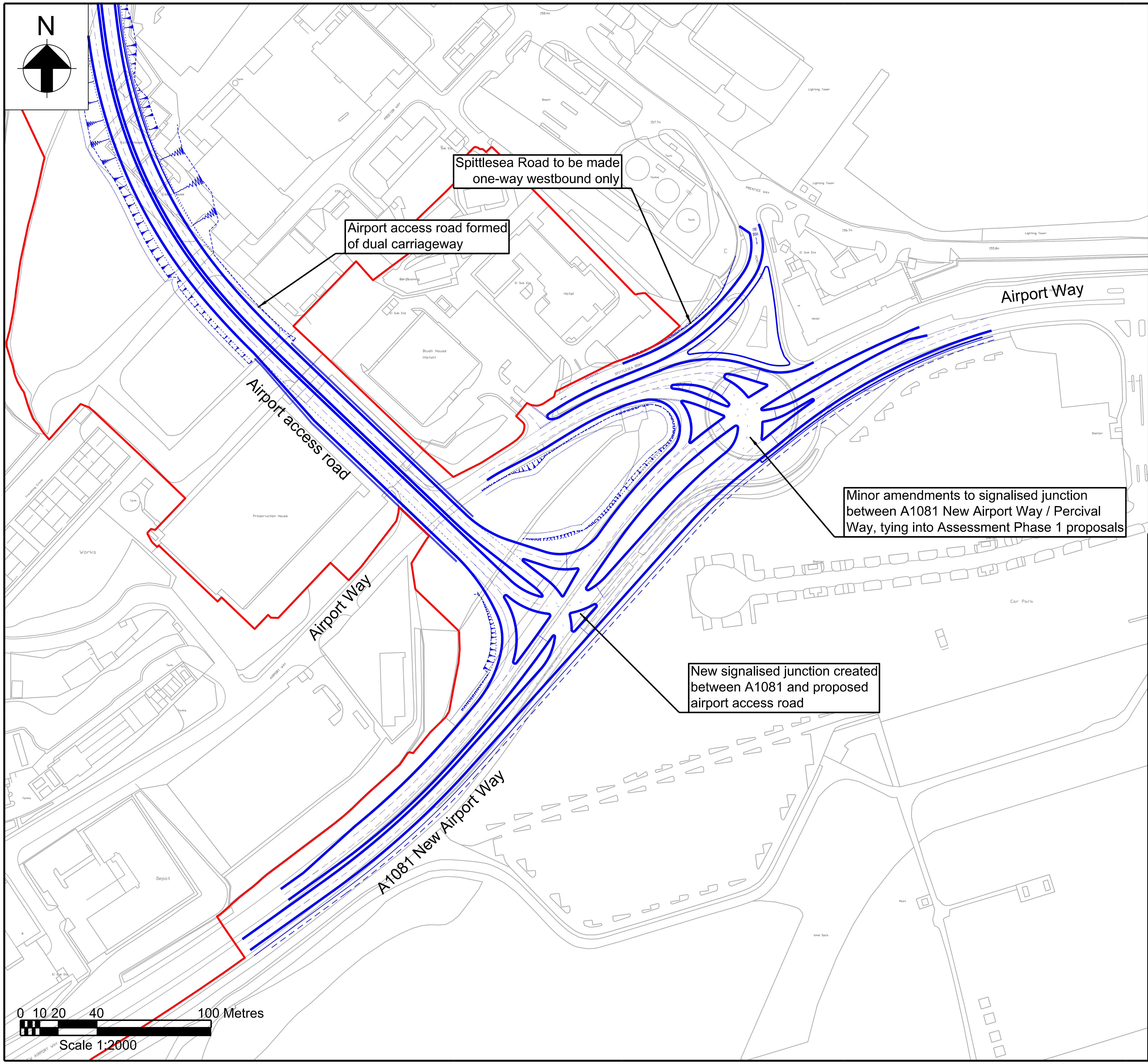
HIGHWAY MITIGATION CRAWLEY GREEN ROAD / LALLEFORD ROAD ASSESSMENT PHASE 2A

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:500	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0018	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

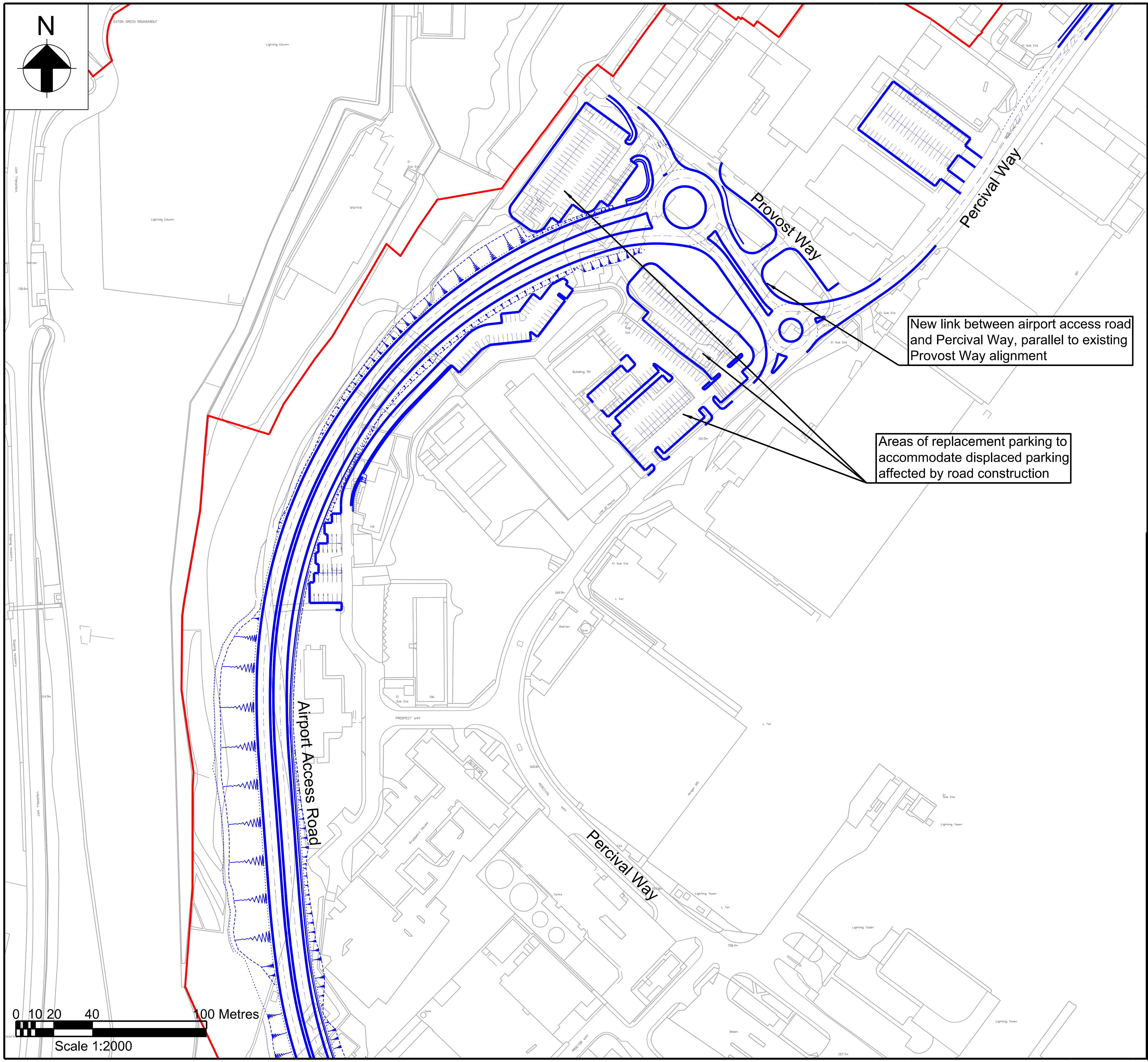
HIGHWAY MITIGATION A1081 NEW AIRPORT WAY / AIRPORT ACCESS RD ASSESSMENT PHASE 2A

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:2000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0019	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

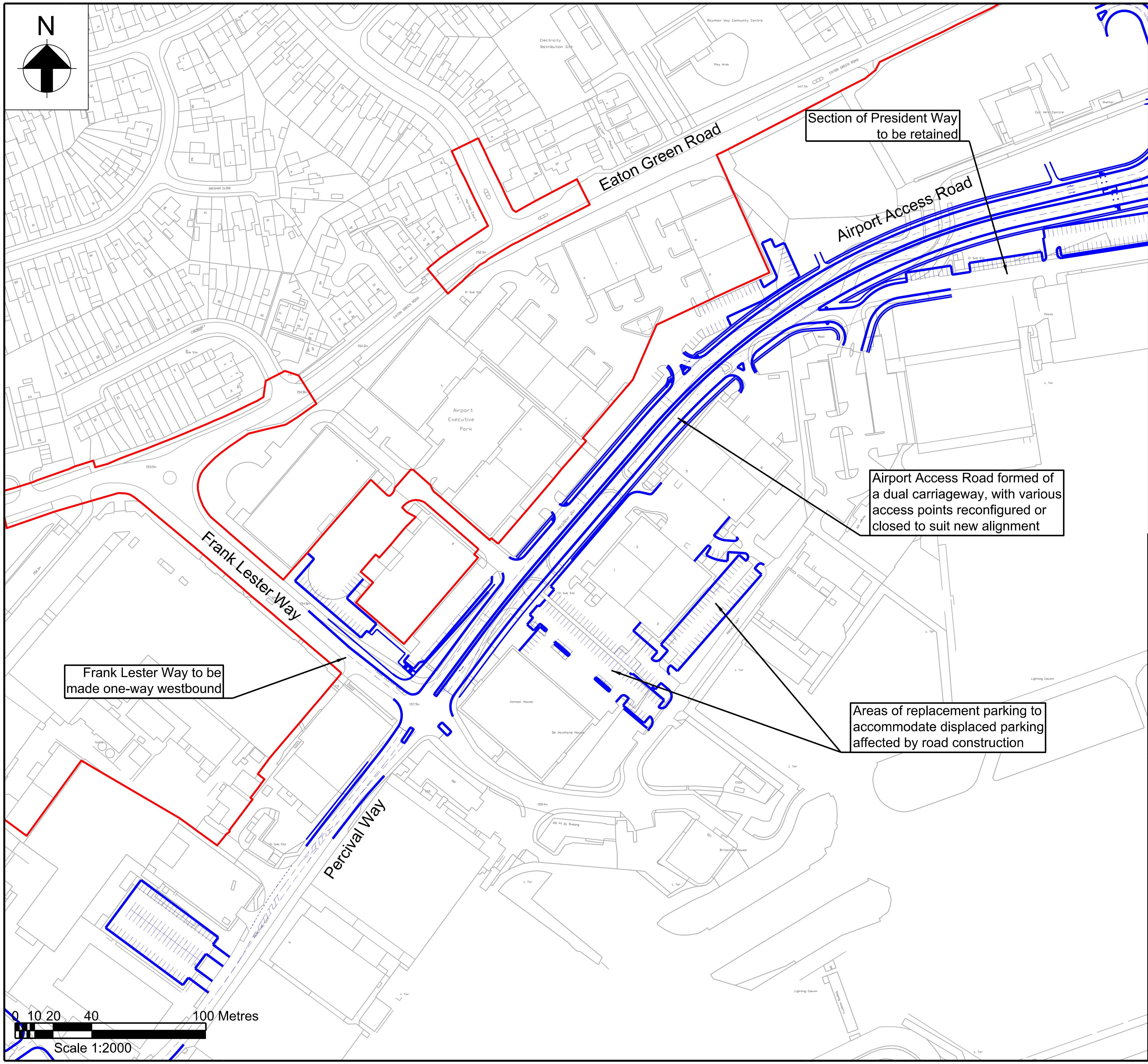
HIGHWAY MITIGATION
AIRPORT ACCESS ROAD /
PROVOST WAY
ASSESSMENT PHASE 2A

Purpose of issue				Suitability	
DCO SUBMISSION				S6	
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:2000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0020	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

DCO Submission	NS	JR RG	27/02/23	P01
Revision History	Drawn	Checked Approved	Date	Rev.

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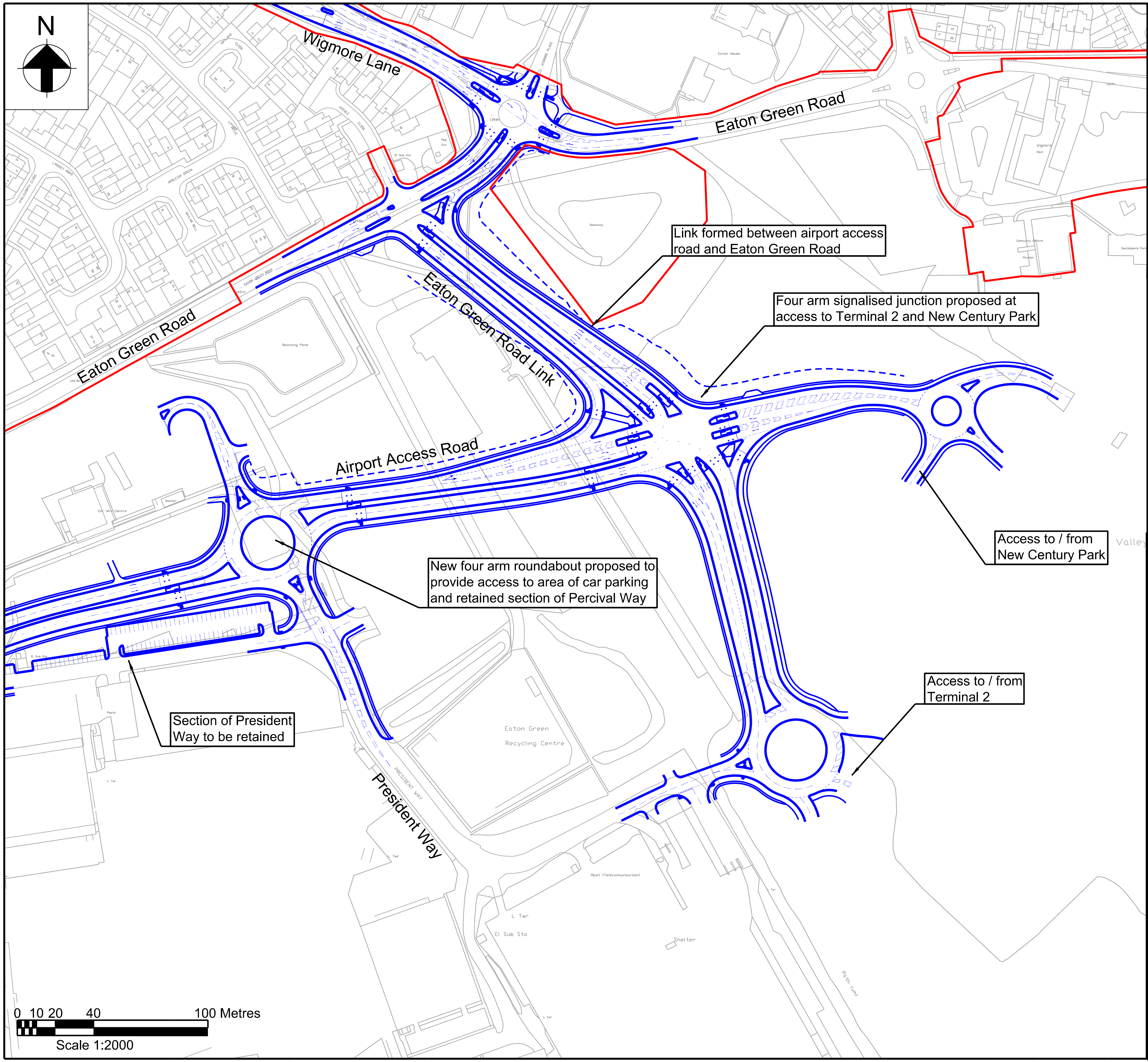
Drawing Title

HIGHWAY MITIGATION AIRPORT ACCESS ROAD / FRANK LESTER WAY ASSESSMENT PHASE 2A

Purpose of issue				Suitability	
DCO SUBMISSION				S6	
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:2000	A3
DCO Application Ref.	APFP Regulation	DCO Document Ref.			
TR020001	5(2)(o)	TR020001/APP/7.02			

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0021	P01
Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number	



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION
AIRPORT ACCESS ROAD / EATON GREEN RD LINK
ASSESSMENT PHASE 2A

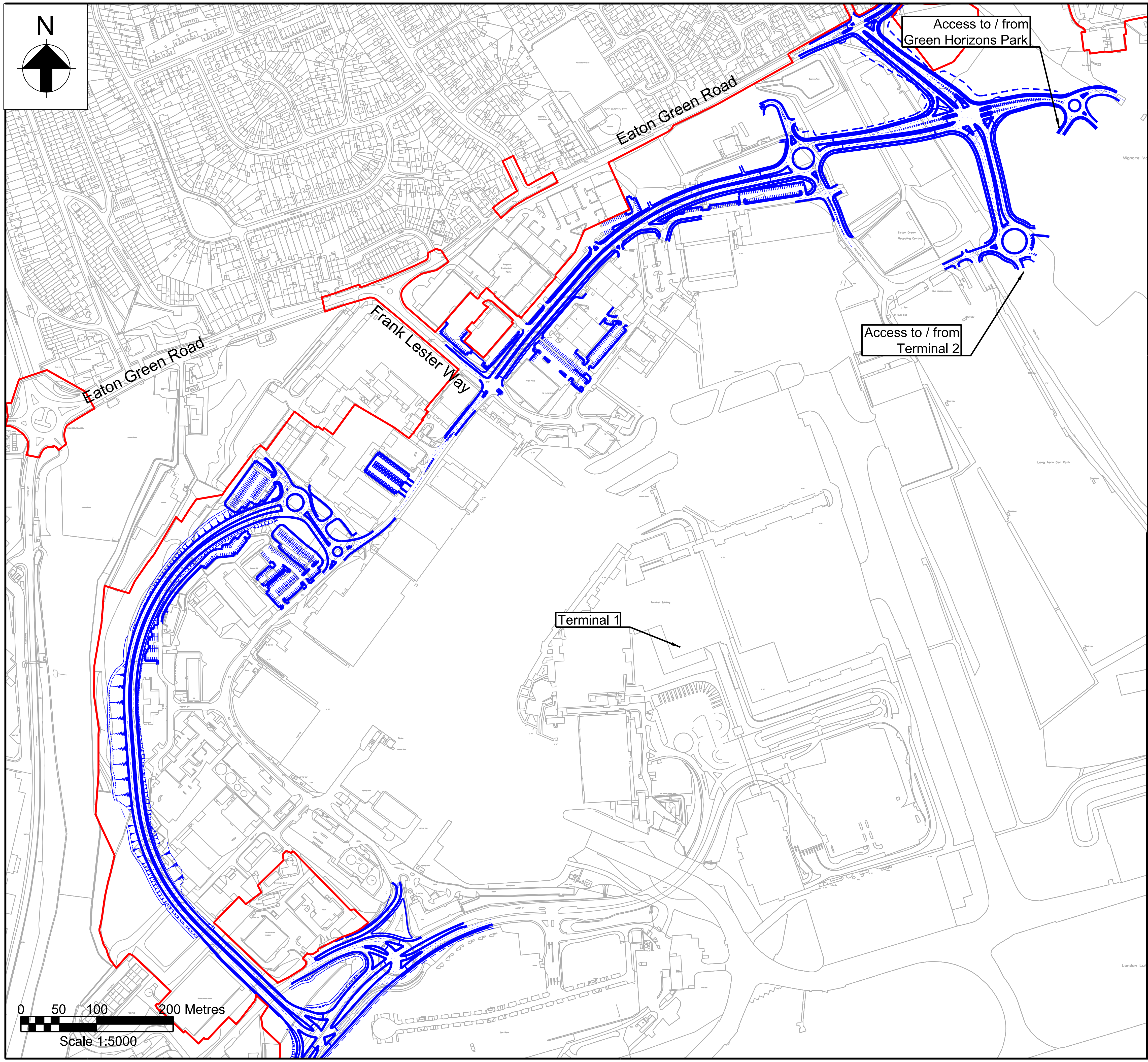
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:2000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0022	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION AIRPORT ACCESS ROAD ENTIRE ALIGNMENT ASSESSMENT PHASE 2A

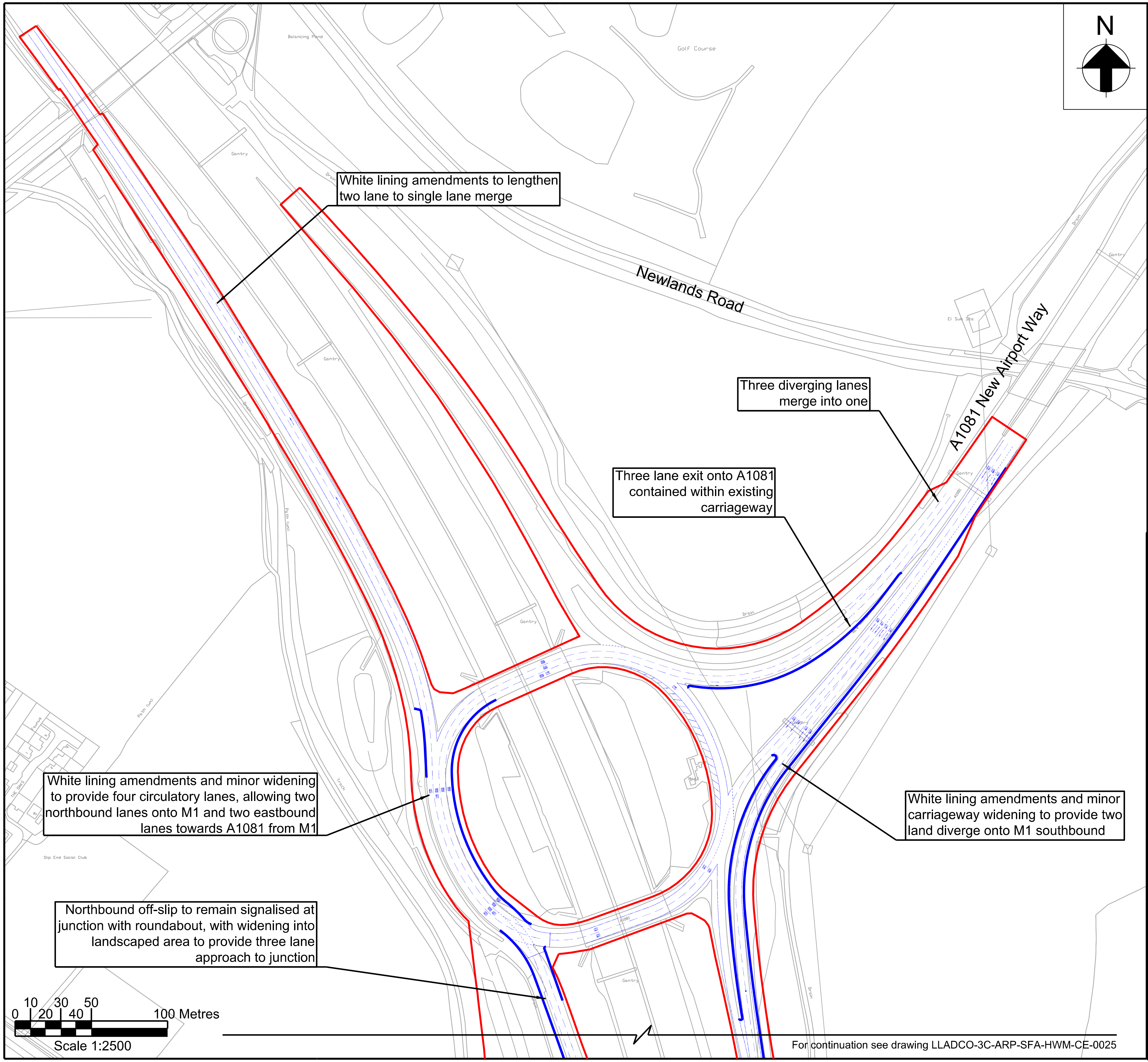
Purpose of issue					Suitability
DCO SUBMISSION					S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:5000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0023	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



For continuation see drawing LLADCO-3C-ARP-SFA-HWM-CE-0025

All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION M1 JUNCTION 10 ASSESSMENT PHASE 2A SHEET 1 OF 2

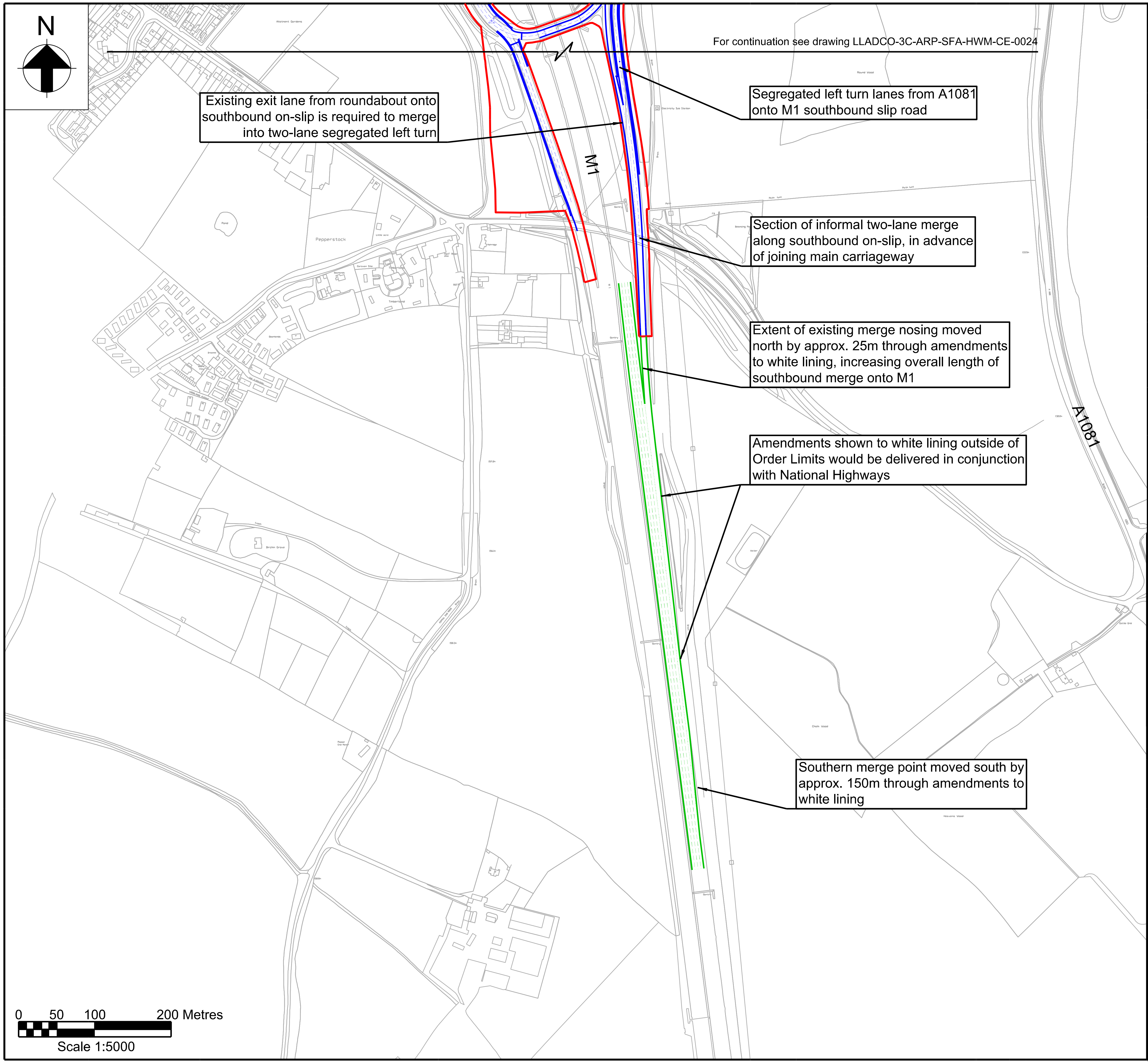
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:2500	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0024	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Proposed Highway Layout outside of Order Limits (to be undertaken by National Highways)
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION
M1 JUNCTION 10
ASSESSMENT PHASE 2A
SHEET 2 OF 2

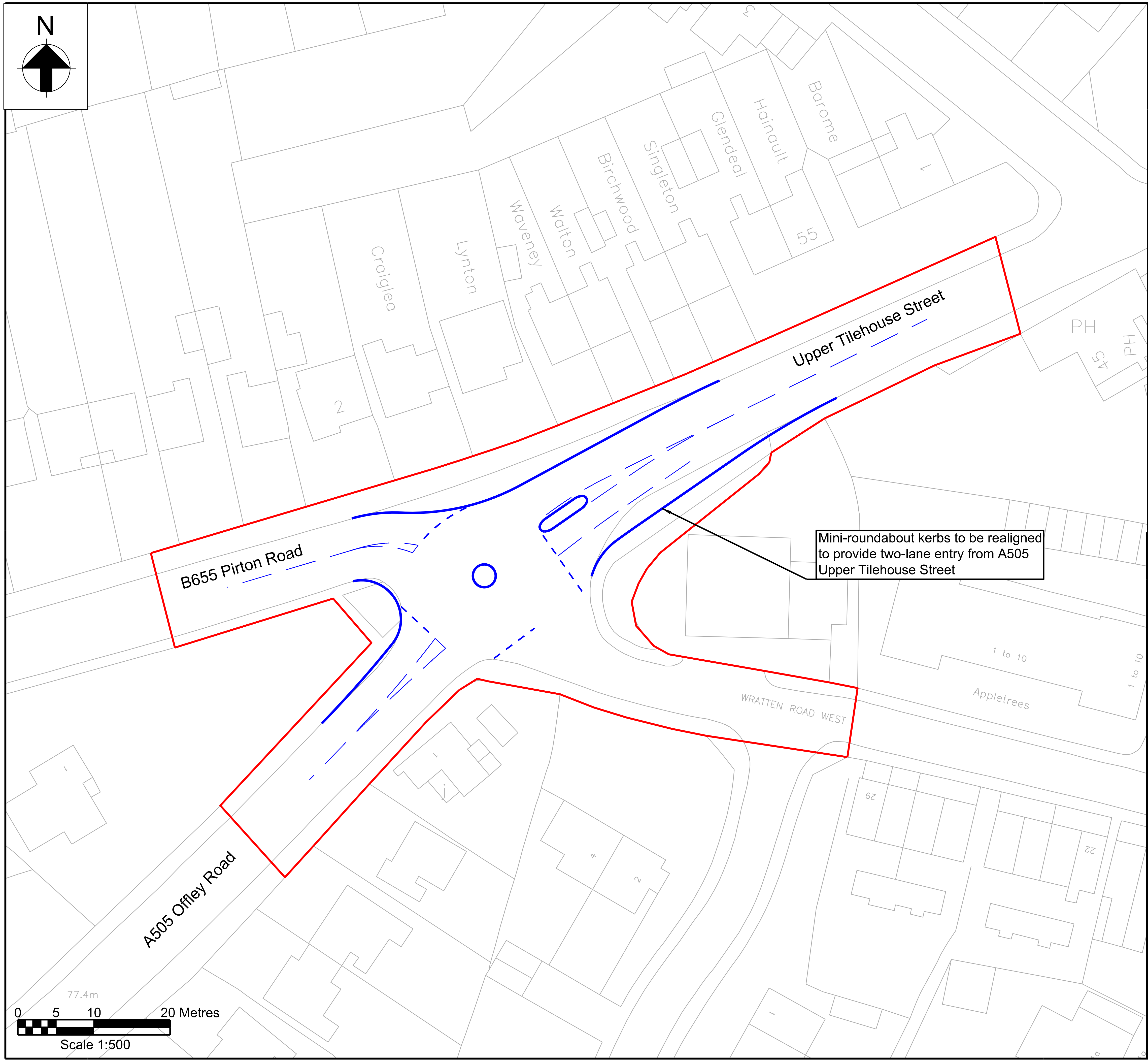
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:5000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0025	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION
A505 / UPPER TILEHOUSE ST
ASSESSMENT PHASE 2A

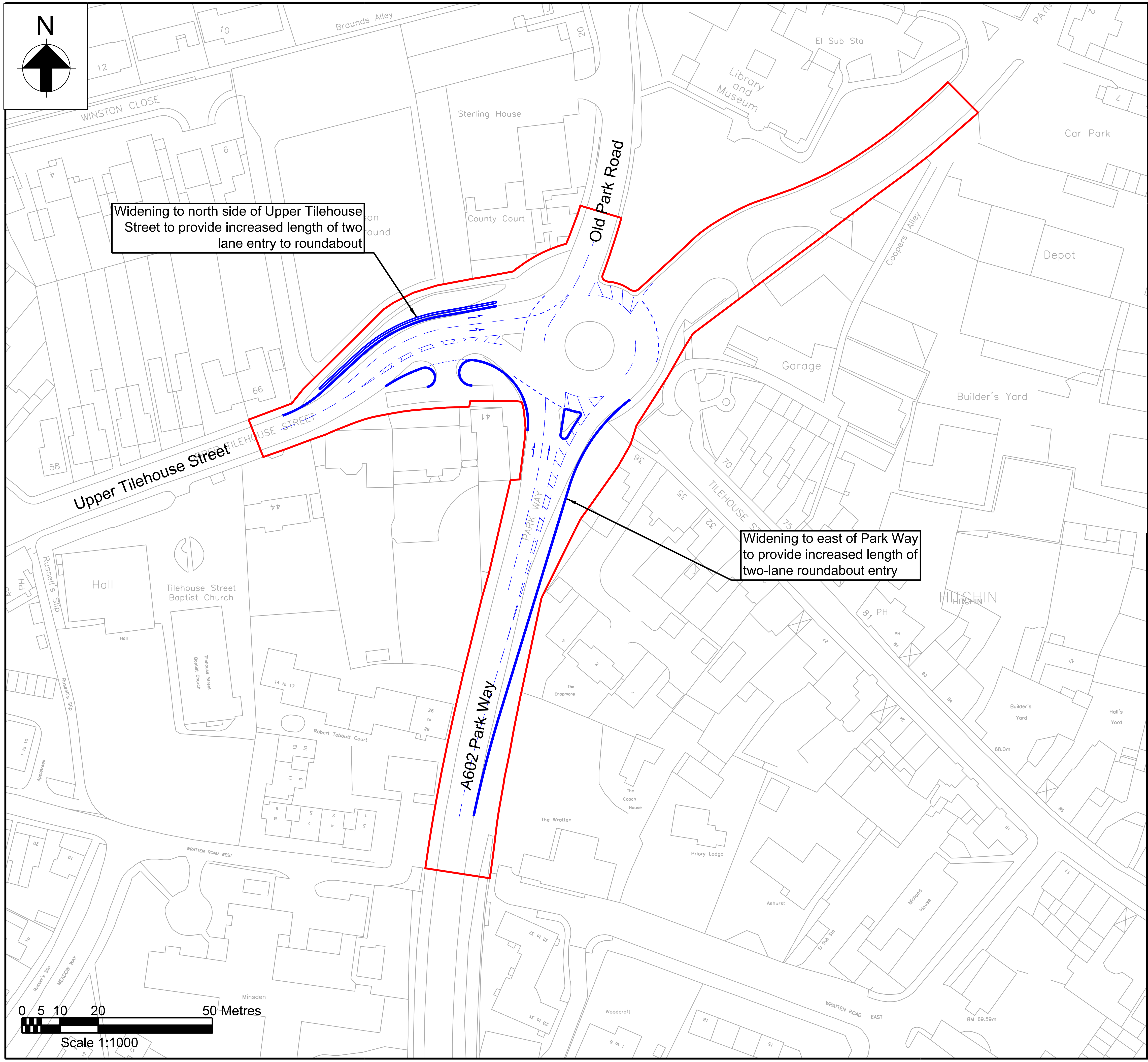
Purpose of issue	Suitability
DCO SUBMISSION	S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:500	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0026	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION
A505 UPPER TILEHOUSE ST / A602 PARK WAY
ASSESSMENT PHASE 2A

Purpose of issue				Suitability	
DCO SUBMISSION				S6	
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
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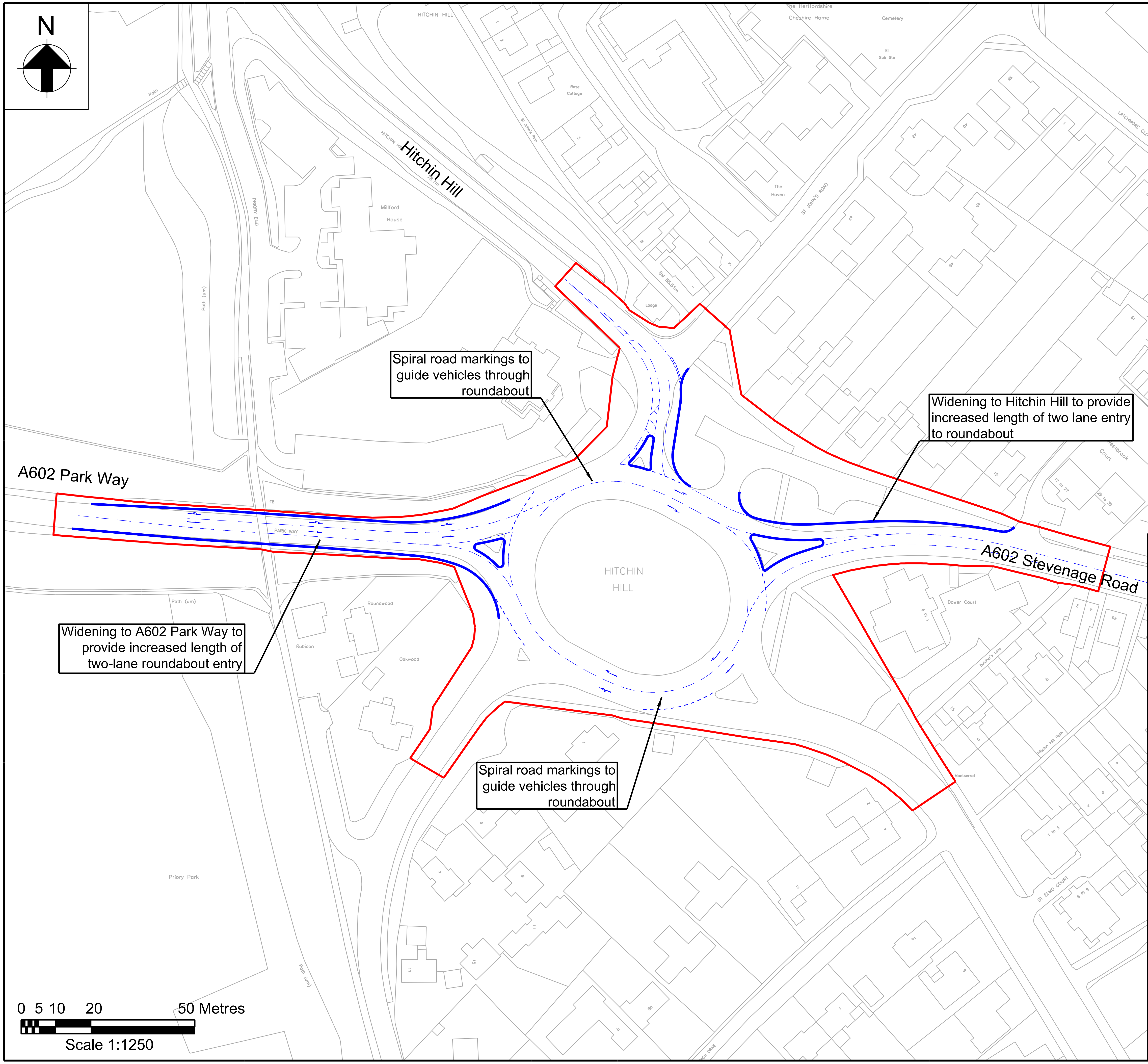
Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

DCO Submission	NS	JR RG	27/02/23	P01
Revision History	Drawn	Checked Approved	Date	Rev.

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Drawing Title

HIGHWAY MITIGATION A602 PARK WAY / STEVENAGE ROAD / HITCHIN HILL ASSESSMENT PHASE 2A

Purpose of issue				Suitability	
DCO SUBMISSION				S6	
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1250	A3

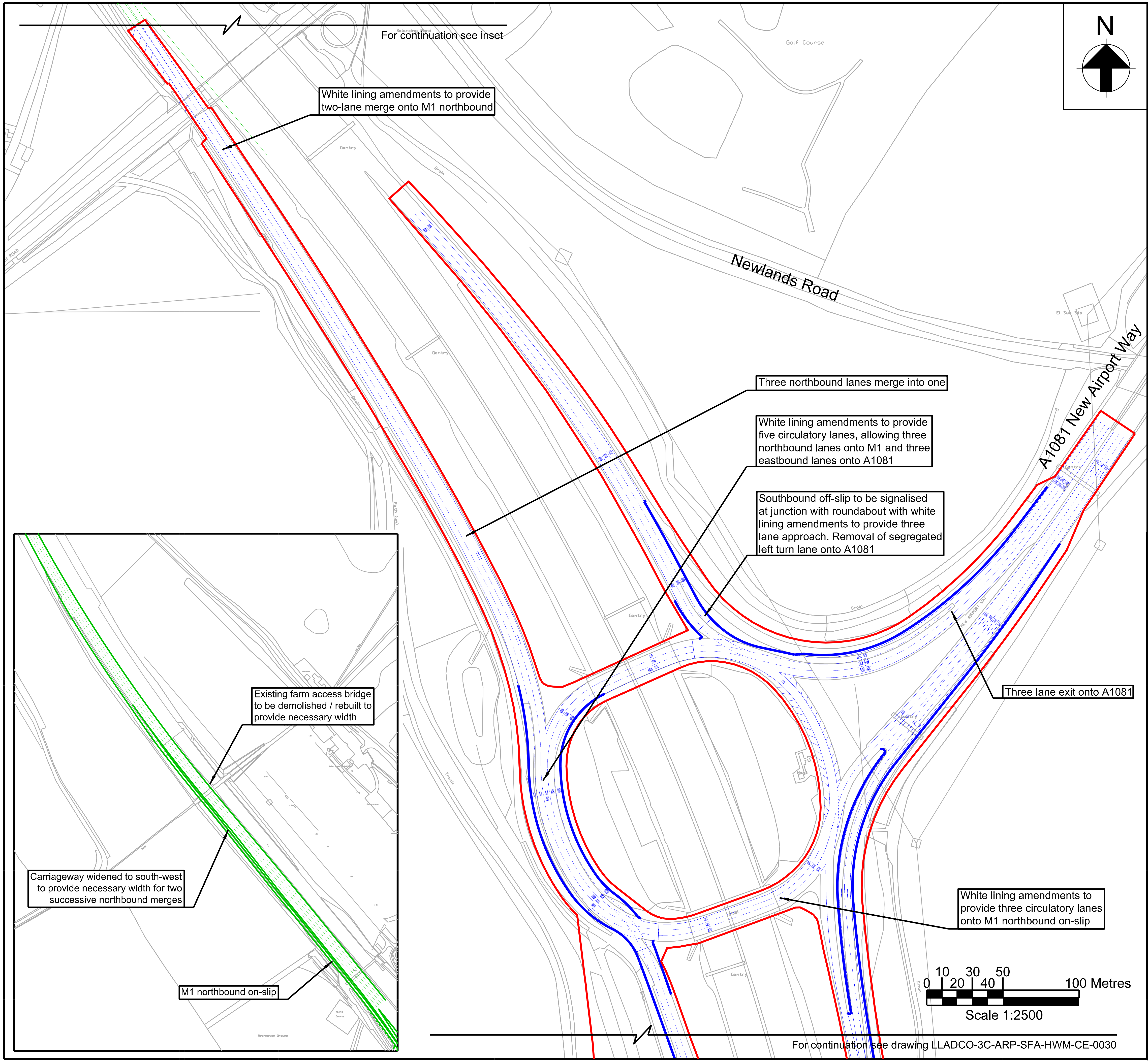
DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0028	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number

Future Baseline- Assessment Phase 2b

(No Airport Development)



For continuation see drawing LLADCO-3C-ARP-SFA-HWM-CE-0030

All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Proposed Highway Layout outside of Order Limits (to be undertaken by National Highways)
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION M1 JUNCTION 10 FUTURE BASELINE SHEET 1 OF 2

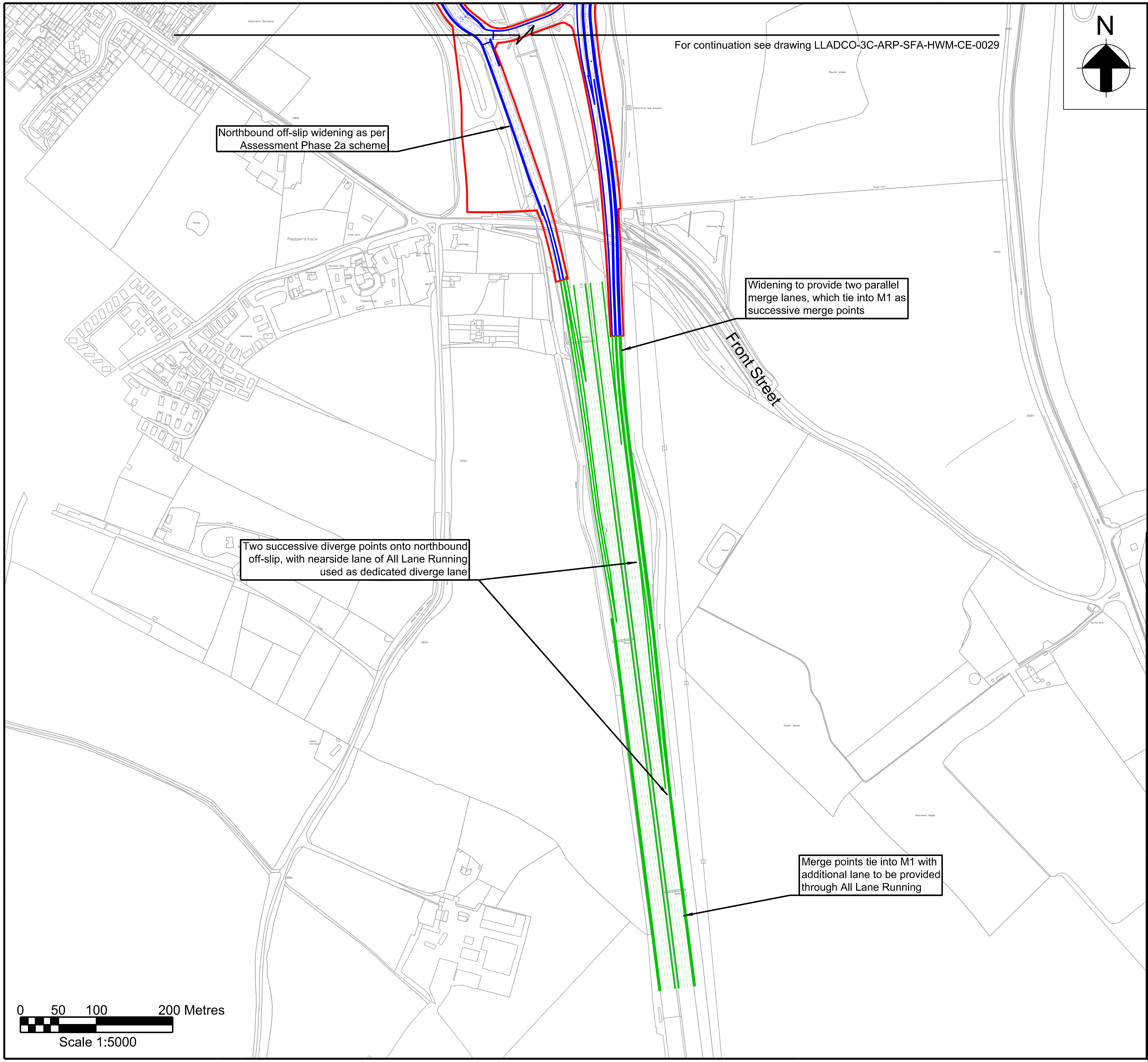
Purpose of issue					Suitability
DCO SUBMISSION					S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:2500	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0029	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Proposed Highway Layout outside of Order Limits (to be undertaken by National Highways)
- Order Limits

INDICATIVE LAYOUT

	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01
Revision History	Drawn	Checked / Approved	Date	Rev.

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Drawing Title

HIGHWAY MITIGATION M1 JUNCTION 10 FUTURE BASELINE SHEET 2 OF 2

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:5000	A3
DCO Application Ref.	APFP Regulation	DCO Document Ref.			
TR020001	5(2)(o)	TR020001/APP/7.02			

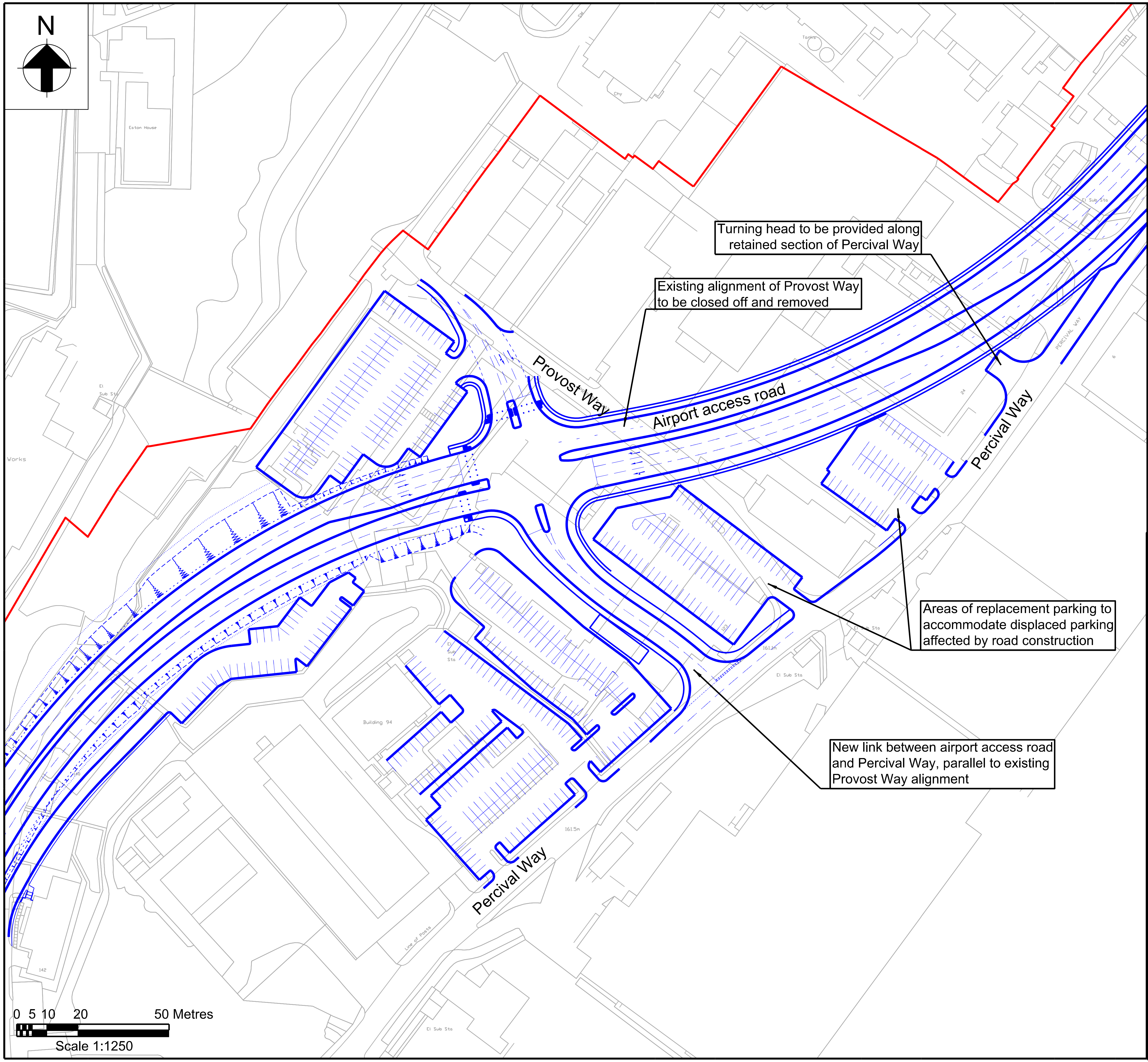
Drawing Number: LLADCO-3C-ARP-SFA-HWM-DR-CE-0030

Revision: P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number

Assessment Phase 2b

(With Airport Development)



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked	Approved	Date	Rev.
DCO Submission	NS	JR	RG	27/02/23	P01

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Drawing Title

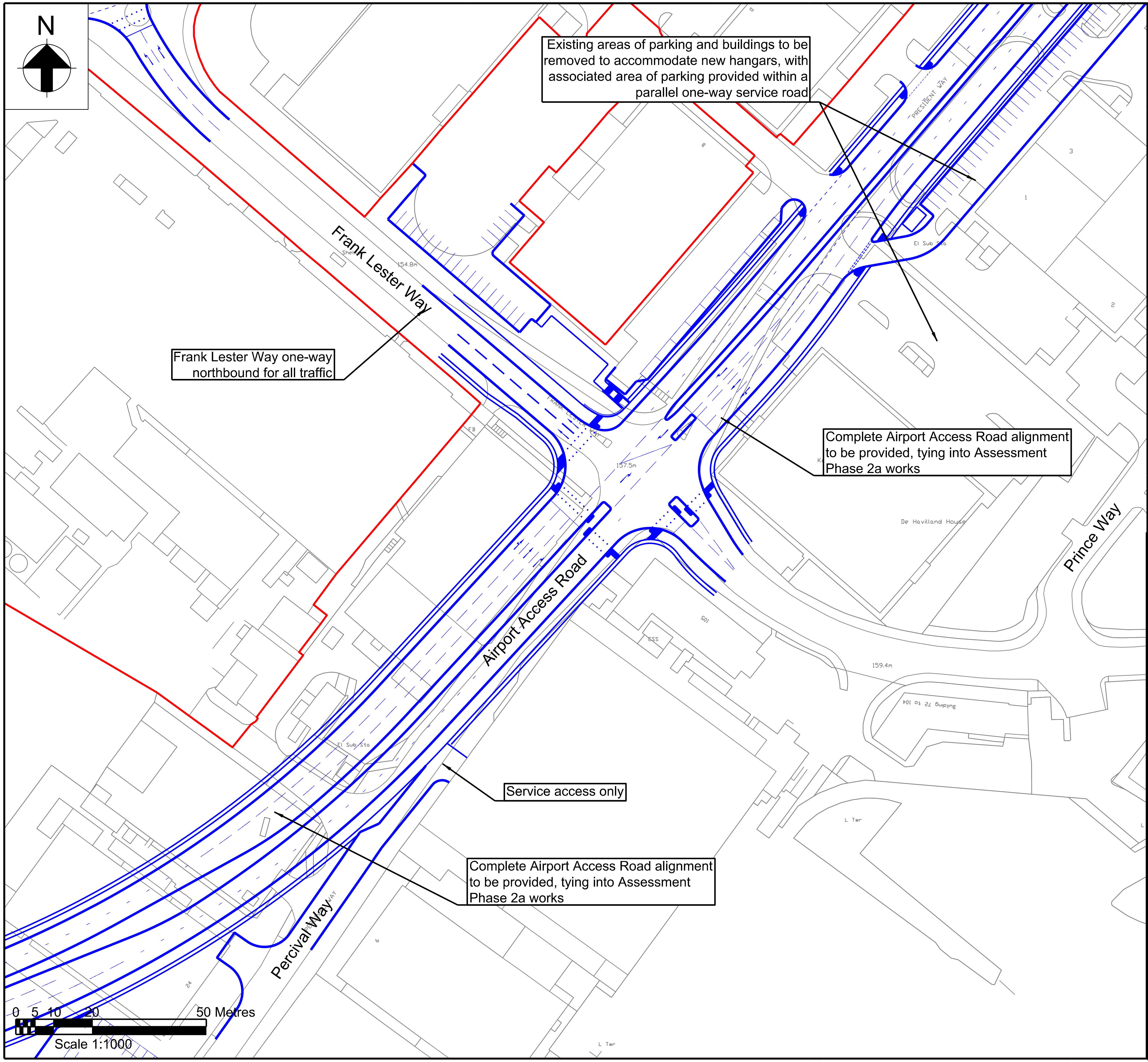
HIGHWAY MITIGATION
AIRPORT ACCESS ROAD /
PROVOST WAY
ASSESSMENT PHASE 2B

Purpose of issue				Suitability	
DCO SUBMISSION				S6	
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1250	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0031	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR RG	27/02/23	P01

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Drawing Title

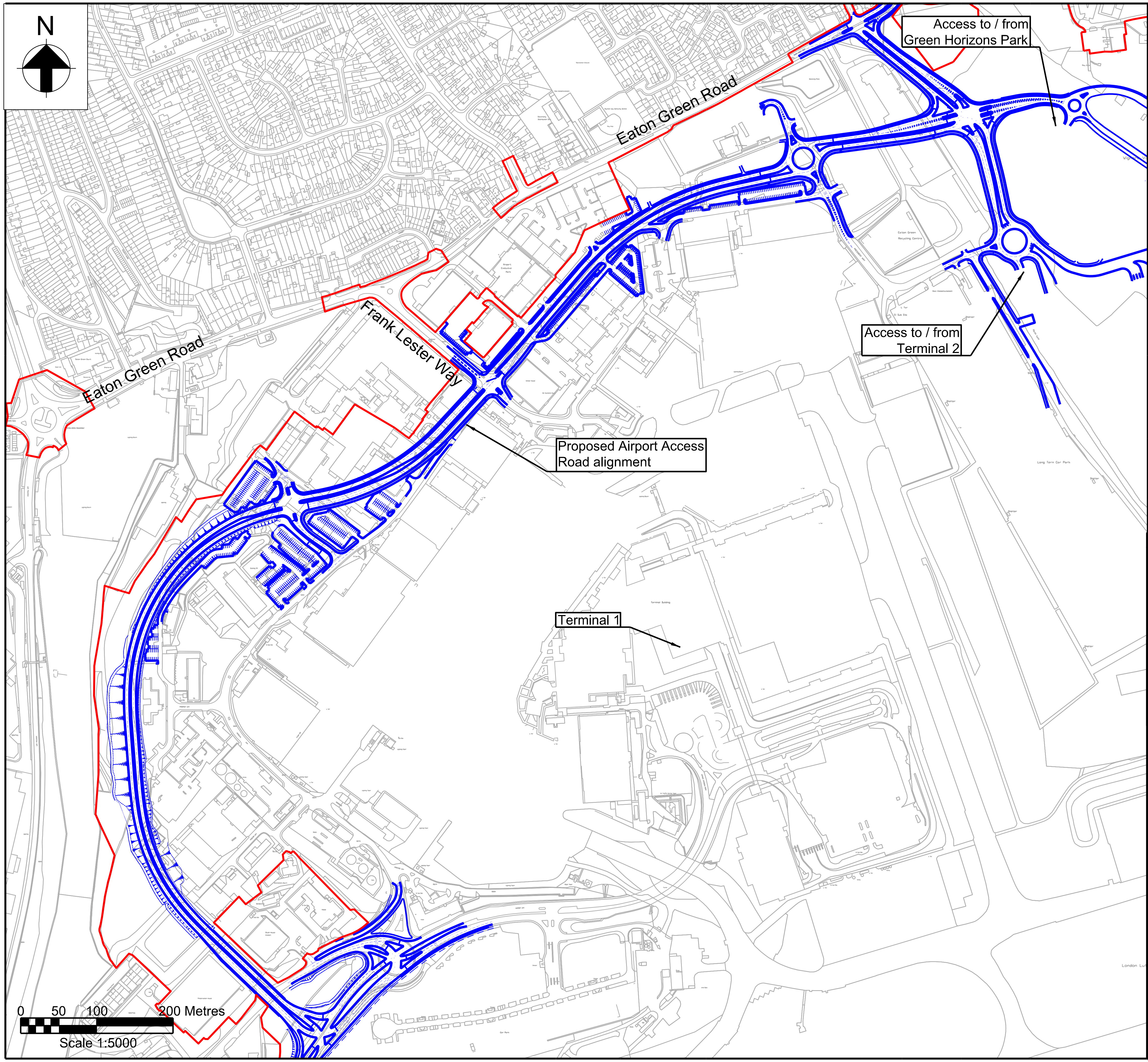
HIGHWAY MITIGATION AIRPORT ACCESS ROAD / FRANK LESTER WAY ASSESSMENT PHASE 2B

Purpose of issue					Suitability
DCO SUBMISSION					S6
Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:1000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0032	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

KEY

- Existing Mapping
- Proposed Highway Layout
- Order Limits

INDICATIVE LAYOUT

Revision History	Drawn	Checked / Approved	Date	Rev.
DCO Submission	NS	JR / RG	27/02/23	P01

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Drawing Title

HIGHWAY MITIGATION AIRPORT ACCESS ROAD FULL ALIGNMENT ASSESSMENT PHASE 2B

Purpose of issue					Suitability
DCO SUBMISSION					S6

Drawn	Checked	Approved	Date	Scale	Size
N.Scott	J.Riat	R.Goodall	27/02/23	1:5000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	5(2)(o)	TR020001/APP/7.02

Drawing Number	Revision
LLADCO-3C-ARP-SFA-HWM-DR-CE-0033	P01

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number

Appendix B: Strategic Modelling - Model Specification Report

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Strategic Modelling: Model Specification Report

21 September 2018

Report ref: LLADCO-2-AEC-00-00-SP-YT-0001

Contents

Tables

Figures

1 INTRODUCTION

1.1 Introduction

1.1.1 London Luton Airport Limited is preparing to secure the necessary consents to allow London Luton Airport to grow from the current permitted capacity of 18 million passengers per annum (mppa) to between 36 and 38mppa by 2042.

1.1.2 The Surface Access Strategy Position paper (July 2017) briefly discusses the key transport issues and constraints, and identifies:

- highway capacity problems exist at certain locations near the existing airport at peak times of the day;
- capacity at M1 Junction 10 and Junction 10a;
- M1 motorway lane capacity; and
- the need for consideration of a future public transport strategy.

1.1.3 This paper also discusses the existing strategic transport modelling tools developed in and around the Luton Airport area which can potentially be used to firstly understand the existing transport provision and constraints, secondly to understand the impact of growth on the highway and public transport network, and finally to develop and examine multi-modal interventions required to deliver the airport expansion as part of the Airport Masterplan.

1.1.4 A Vissim microsimulation model is being developed to assess the operation of the road network in the vicinity of Luton Airport, and this Model Specification Report details the development of a strategic modelling tool to work with this microsimulation model to provide an assessment of the transport networks with the proposed expansion.

1.1.5 The strategic modelling tool will be developed based on the existing Central Bedfordshire and Luton Transport Model (CBLTM), enhancing this model for the purposes of assessing the proposed expansion of Luton Airport.

1.1.6 The original version of the CBLTM was developed in 2009 by Halcrow (now CH2M) with a base year of 2009. In 2016 AECOM were commissioned to update this model to reflect a 2016 base year, which included the collection of new travel demand data (mobile network data and public transport ticket data). This 2016 base year version of the model has been used to assess Local Plans, development proposals, and route corridor strategies.

1.1.7 As defined within the Transport Assessment Scoping Report, the key objectives and outcomes for the strategic modelling are:

- to provide strategic growth forecasts for the microsimulation modelling (covering M1 Junction 10, the A1081 between the M1 and Luton Airport, and areas of southern Luton);
- to provide traffic flows for the Air Quality and Noise assessments of the traffic component of the scheme, to be reported in the Environmental Statement; and
- to provide a strategic assessment of the potential offsite pressure points on the transport network resulting from the proposed development.

1.2 Structure of Model Specification Report

1.2.1 The structure of this Model Specification Report follows that set out in Appendix F of WebTAG Unit M3.1; however this structure has been expanded to include discussion of the public transport assignment model and variable demand model included within CBLTM.

1.2.2 Throughout the document, a number of key assumptions have been highlighted in red boxes, and these are also summarised within Section 14.

1.2.3 Following this introduction, this Model Specification Report contains the following sections:

- Section 2: Proposed Uses of the Model and Key Model Design Considerations
- Section 3: Model Standards
- Section 4: Key Features of the Model
- Section 5: Data Sources and Data Collection
- Section 6: Highway Network Development
- Section 7: Highway Demand Development
- Section 8: Highway Model Calibration
- Section 9: Public Transport Demand Development
- Section 10: Public Transport Supply Model
- Section 11: Variable Demand Model

- Section 12: Forecasting
- Section 13: Indicative Programme
- Section 14: Key Assumptions

2 PROPOSED USES OF THE MODEL AND KEY MODEL DESIGN CONSIDERATIONS

2.1 Proposed Uses of the Model

2.1.1 The updated CBLTM suite will be required to assess the impacts on the transport network of the proposed Luton Airport expansion. At the time of writing, the assumed phasing of the airport expansion is:

- 2021 – 18 million passengers per annum
- 2023 – 21 million passengers per annum
- 2035 – 30 million passengers per annum
- 2042 – 38 million passengers per annum

2.1.2 As stated in paragraph 1.1.7, and as defined within the Transport Assessment Scoping Report, the key objectives and outcomes for the strategic modelling are:

- to provide strategic growth forecasts for the microsimulation modelling;
- to provide traffic flows for the Air Quality and Noise assessments of the traffic component of the scheme, to be reported in the Environmental Statement; and
- to provide a strategic assessment of the potential offsite pressure points on the transport network resulting from the proposed development.

2.1.3 It is expected that the strategic modelling will be potentially required to assess different growth assumptions for Luton Airport, alternative growth scenarios for Luton Borough and the surrounding areas, and offsite mitigation measures.

2.1.4 As part of the specification of the updated CBLTM suite, it has been assumed that charging policies (such as offsite road tolls) are not required to be assessed within the strategic modelling. As such, income segmentation within the model suite has been considered, but will not be represented.

2.1.5 The specification of the updated model is focussed on assessing the proposed expansion of Luton Airport, including testing alternative growth scenarios and infrastructure assumptions in the vicinity of Luton Airport. The model may not be suitable for testing schemes away from Luton Airport, such as East-West Rail and the Oxford to Cambridge Expressway. Representations of these schemes can be included in the model; however, there will be uncertainty around the modelling of their impact.

2.1.6 The corresponding Model Specification Report (issued March 2017) for the CBLTM, summarises the proposed use of the current CBLTM suite:

The CBLTM will provide an evidence base for current and future transport issues within the region. It is envisaged that the model will be used for development assessment and transport scheme prioritisation, to support business case development and to assess new public transport schemes[1].

A number of particular applications were discussed during the scoping exercise and a selection of these are listed below in Table 2.1 along with an explanation as to whether they could or could not be used by the model in its agreed scope.

[1] Subject to further local model validation as set out in Table 2.1

Table 2.1: List of Applications Considered During Scoping (Source: CBLTM Model Specification Report)

Application	Suitable	Notes
Prioritisation and solutions for the Local Plan and Local Transport Plan for CBC and LBC	Yes	
Development assessment for potential growth areas	Yes	
Development of Transport Business Cases. It is currently envisaged that the model will be used for the M1-A6 Link Business Case. AECOM is not aware of any other Transport Business Cases at this stage. The use of the model for other Business Cases is subject to further local model validation.	Yes	
Assessing high level strategic impact of proposed rail crossing closures or diversions.	Yes	
New public transport services of reasonably strategic scope.	Yes	CBLTM will be a strategic model capable of evaluating public transport services of that nature.
Improvements to stations and bus stops, across a moderate-sized area.	Yes	
Significant variations in service frequencies and time of reasonably strategic scope.	Yes	Significant variations are appropriate to model in CBLTM.
East-West rail impact on passengers at key locations in modelled area.	Yes	Sufficiently strategic impact located within core model area.
A421 Business Case (widening of section to the north of M1 Junction 13).	No	Outside the core modelled area where the network definition unsuitable for detailed analysis.
Any schemes not in the model study area, such as those in Milton Keynes or Bedford.	No	Outside the core modelled area where network definition unsuitable for detailed analysis
Evaluation of major rail schemes in a PDFH consistent approach.	No	PDFH is an elasticity-based approach that varies considerably from multi-modal modelling and is not suitable within this context; however, modelling outputs could be used in a PDFH consistent manner.

2.1.7 To date, the existing version of the CBLTM suite has been used:

- as part of the evidence base for the development of Local Plans;
- route strategic assessments; and
- Strategic Outline Business Case development (with model enhancements proposed as part of any potential Outline Business Case development).

2.1.8 The performance of the highway model included within the CBLTM suite is discussed in greater detailed within Section 7 and Section 8; however the following is Paragraph 7.3.19 of the CBLTM Local Model Validation Report (issued August 2017):

The CBLTM model passes WebTAG criteria for screenline / cordon validation, with 93%, 87% and 90% in AM, IP and PM respectively. However, individual link performance (70%, 78% and 73% respectively) should be reviewed in future applications of the CBLTM model and improved as required.

2.1.9 Paragraph 17.3.3 of the CBLTM Local Model Validation Report also states that:

It is recommended that the local performance of the model should be investigated prior to being applied for any specific application. In short, as a strategic model, CBLTM has strengths and weaknesses in terms of applicability that are dependent on the scale and nature of any potential application.

2.1.10 The requirements of the model for the Development Consent Order (DCO) process for the proposed Luton Airport expansion, including the provision of traffic forecasts for the noise and air quality assessments, are more stringent than those required for the uses of the model to date.

2.1.11 In order to improve the model to meet the expected requirements of the DCO process, a number of areas of the model development are proposed to be revisited. This is in part to improve the model performance against observed data, and also to incorporate latest industry best-practice.

2.2 Key Model Design Considerations

2.2.1 We assume that the updated CBLTM suite will be used to forecast non-airport travel demand in the vicinity of Luton Airport. Given the specific characteristics of airport-related travel, the forecasts for travel demand to / from Luton Airport (for employees, passengers and freight) will be generated outside the updated CBLTM suite, and will be an input into the model forecasts.

2.2.2 We assume that travel demand for the 2016 base year and forecast years for employee, passenger and freight to / from Luton Airport will be provided to AECOM for use within the strategic assessment of the proposed development. (See Section 12.4 for further discussion on airport travel demand forecasts.)

2.2.3 The forecasting approach adopted within CBLTM (using the trip-end model, CTripEnd, used within TEMPro) does not provide forecasts to airport passenger travel. It is therefore a requirement for this assessment for external airport passenger forecasts to be produced.

2.2.4 Trip generated by airport employees could be modelled using the standard forecasting approaches (by added any additional jobs to the trip-end model); however, this approach would not capture the specific characteristics (such as shift patterns) for airport employees. This approach would also not include the effects of any ‘soft’ policies (such as Travel Planning measures) adopted by Luton Airport to influence mode choice for airport employees. Given the importance of the forecasts for travel by Luton Airport employees, it is recommended that external forecasts for airport employees are produced.

2.2.5 The existing CBLTM focuses on the Central Bedfordshire and Luton Borough, with limited model detail outside these areas. The expected distribution of trips to / from Luton Airport includes movements to the south of the existing detailed model area (on the M1 towards London and the M25, and local routes towards Harpenden and St Albans), and also to the east (along the A505 towards Hitchin and the A1(M)).

2.2.6 It is therefore proposed to enhance the model detail within the CBLTM highway model to the south and east of Luton Airport to include key routes to / from the airport. This may include the use of Hertfordshire’s COMET transport model if permission to use data from this model is obtained from Hertfordshire County Council.

2.2.7 Another consideration in the specification of the updated CBLTM is the consistency with the microsimulation modelling. It is understood that the microsimulation models will have a base year of 2017, and will represent the AM Peak (08:00 to 09:00) and PM Peak (17:00 to 18:00) hours.

2.2.8 The existing CBLTM has a base year of June 2016, and without significant new demand data collection it is not recommended that the base year of the strategic model is updated to either October 2017 (to be consistent with the microsimulation modelling) or 2018 (as the current year).

2.2.9 The base year for the noise and air quality modelling will also be discussed; however it is unlikely that this will be consistent with the June 2016 base year adopted within CBLTM.

2.2.10 Retaining a 2016 base year for the strategic modelling will introduce an inconsistency between the strategic and microsimulation modelling, and between the strategic modelling and the noise / air quality assessment, which will need to be considered as part of the use of data from the strategic modelling.

2.2.11 It is anticipated that the strategic model will also include the AM Peak and PM Peak models as defined for the microsimulation models. Adopting alternative time period definitions within the strategic modelling will introduce further inconsistency between the two models.

2.2.12 In addition to this, wherever possible, consistency between the highway network links and zones represented within the microsimulation model and those included within the strategic model will be sought. It is expected that the microsimulation model will include additional zonal, and potentially network, detail to that contained within the strategic model.

3 MODEL STANDARDS

3.1 Modelling Principles and Guidance

3.1.1 The existing CBLTM has been developed in-line with the Department for Transport's Web Transport Analysis Guidance[2] (WebTAG), using the latest available guidance at the time of the model's development. This includes reference to the following units of WebTAG:

- Unit M1.2: Data Sources and Surveys
- Unit M3.1: Highway Assignment Modelling
- Unit M3.2: Public Transport Assignment Modelling
- Unit M2: Variable Demand Modelling
- Unit M4: Forecasting and Uncertainty
- TAG Data Book

3.1.2 Since the development of the CBLTM (in late 2016 / early 2017), some updates to WebTAG have been published, and this update to the model suite will follow the latest available guidance. This includes:

- the March 2017 version of WebTAG Unit M2 on variable demand modelling;
- the May 2018 version of WebTAG Unit M4 on forecasting; and
- the use of the May 2018 WebTAG data book (containing assumptions on values of time, operating costs, etc.).

3.1.3 In addition to WebTAG, reference will be made to supplementary guidance and industry best practice. This is expected to include the Design Manual for Roads and Bridges (DMRB) and the Traffic Appraisal Manual (TAM).

3.2 Validation Criteria and Acceptability Guidelines

3.2.1 For the highway assignment model, the performance of the base year modelled flows and speeds will be judged against observed data based on the criteria set out within WebTAG Unit M3.1.

[2] https://www.gov.uk/guidance/transport-analysis-guidance-webtag

3.2.2 For screenline flows, the modelled flow should be within 5% of the observed screenline total for all, or nearly all, screenlines (WebTAG Unit M3.1, Table 1). As part of this:

- screenlines should contain at least five count locations;
- the performance should be reported both including and excluding high flow routes (such as motorways); and
- the performance should be reported for calibration and validation screenlines separately, by vehicle type and by time period.

3.2.3 For individual link flows, 85% or more of links should meet one of the two criteria set out in Table 3.1. The results of this comparison should be reported for total vehicle flows and car vehicle flows, but not for goods vehicles unless sufficiently accurate count data have been collected.

Table 3.1: Link Flow Validation Criteria (WebTAG Unit M3.1, Table 2)

Criteria	Description
Flow Criteria	Individual flows within 100 vehicles/hr of counts for flows less than 700 vehicles/hr
	Individual flows within 15% of counts for flows less between 700 and 2,700 vehicles/hr
	Individual flows within 400 vehicles/hr of counts for flows more than 2,700 vehicles/hr
GEH Criteria	GEH less than 5, where: $$GEH = \sqrt{\frac{(M-C)^2}{(M+C)/2}}$$ M is the modelled flow, and C is the observed flow.

3.2.4 For highway modelled journey times, WebTAG Unit M3.1, Table 3 states that modelled journey times along the defined routes should be within 15% (or 1 minute if higher) of the observed journey times for 85% or more of the journey time routes.

3.2.5 For the public transport assignment model, the base year modelled flows will be assessed against the criteria set out within WebTAG Unit M3.2. Section 7 of WebTAG Unit M3.2 states that:

- modelled screenline flows should be within 15% of observed data for at least 95% of defined screenlines; and

- for individual links the modelled flows should be within 25% of observed data, except where the observed flows are particularly low (for example, less than 150 passengers per hour).

3.2.6 As part of the calibration and validation of both the base year highway and public transport assignment models, the accuracy of the observed surveys for both highway traffic volumes and public transport passengers will be considered. For example, the highway link flow or journey time validation criteria may be adjusted where there is a greater level of variability in the observed data.

3.2.7 Whilst we will work towards achieving the criteria for highway and public transport assignment validation set out within WebTAG, we cannot guarantee any particular level of calibration or validation. It is noted that the standards set out in WebTAG are guidelines against which to assess a highway model, and they do not set out criteria stating when a model is, and is not, fit for purpose.

3.2.8 Any areas of the model which fall below the criteria set out within WebTAG will be investigated, and the implications on the forecasting for the proposed Luton Airport expansion discussed with the client.

3.2.9 For the variable demand model, a number of base year realism tests will be undertaken, based on the guidance detailed in WebTAG Unit M2, Section 6.4. These realism tests are discussed in Section 11.7.

3.3 Convergence Criteria and Standards

3.3.1 The forecasts produced by the CBLTM suite are required to be stable to enable the impact of changes in assumptions between scenarios (such as airport traffic, network infrastructure and housing growth) to be identified. The stability of the model forecasts is measured through the convergence of the model.

3.3.2 There are a number of levels of convergence within the model suite. Firstly there is the convergence of the individual assignment models, and also the convergence of the variable demand model. We will seek to achieve the highest possible levels of convergence to improve the stability of the model forecasts for future years.

3.3.3 WebTAG Unit M3.1, Section 3.3 details a number of acceptable convergence levels for a highway assignment model, with particular emphasis on the $\%Gap$ measure of convergence. These guidelines should be seen as minimum standards that should be aimed for in the development of a highway model, and if tighter levels of convergence are achievable these should be adopted.

3.3.4 Table 4 of WebTAG Unit M3.1 details the acceptable base year model convergence statistics, and this is reproduced in Table 3.2.

Table 3.2: Highway Assignment Convergence (WebTAG Unit M3.1, Table 4)

Criteria	Description
Delta and $\%Gap$	Less than 0.1% or at least stable with convergence fully documents and all other criteria met
Percentage of links with flow change less than 1%	Four consecutive iterations greater than 98%
Percentage of links with cost change less than 1%	Four consecutive iterations greater than 98%
Percentage change in total user costs	Four consecutive iterations less than 0.1% (Stochastic User Equilibrium assignment only)

3.3.5 We have assumed that crowding of public transport services will not be represented within the public transport assignment model. This means that there is no feedback between the public transport travel demand and travel costs, and therefore convergence does not need to be considered for the public transport model.

3.3.6 The convergence of the variable demand model will be measured against the criteria set out in WebTAG Unit M2, Section 6.3, and this is discussed within Section 11.6.

4 KEY FEATURES OF THE MODEL

4.1 Introduction

4.1.1 The structure of the model will be based on the existing structure of the CBLTM. This model will be enhanced for the purposes of assessing the proposed expansion of Luton Airport, focussing on the representation of travel demand to / from the airport and increasing the model detail to the south and east of Central Bedfordshire and Luton Borough within western Hertfordshire.

4.1.2 The current CBLTM has a base year of June 2016, and as part of this enhancement it is not proposed to change the base year of the model.

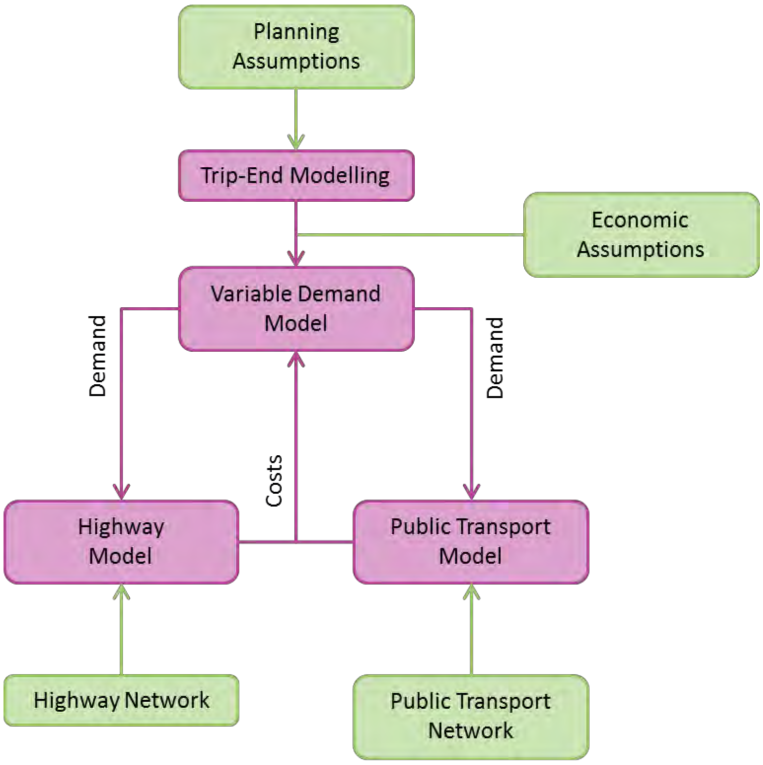
4.2 Structure of Model Suite

4.2.1 The current and proposed CBLTM suite contains:

- a highway assignment model;
- a public transport assignment model;
- a variable demand model; and
- a trip-end forecasting tool (based on the DfT's CTripEnd software).

4.2.2 When producing a model forecast, all of these elements of the CBLTM suite are used, using user-defined inputs and passing information between the individual components of the suite. Figure 4.1

Figure 4.1 Overview of Model Suite

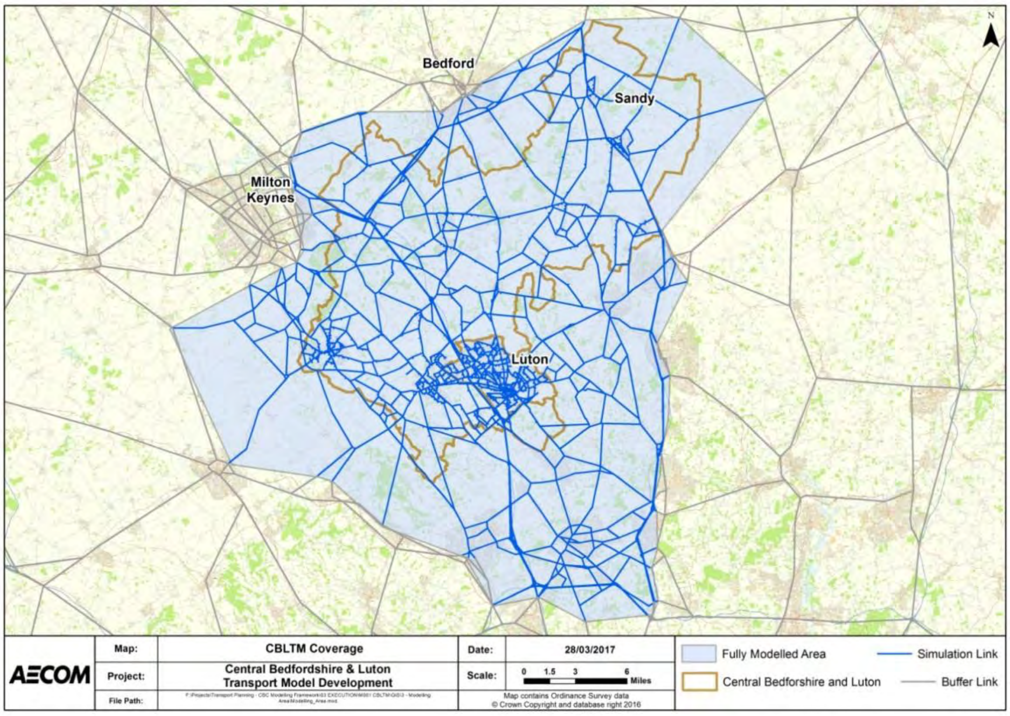


4.3 Spatial Coverage: Fully Modelled and External Areas

4.3.1 The existing Fully Modelled Area for the CBLTM has been defined based on the extent of the simulation network included in the highway model. This is shown in Figure 4.2. The existing Fully Modelled Area covers all of Central Bedfordshire and Luton Borough, and also includes some of the neighbouring districts.

4.3.2 The existing Fully Modelled Area includes areas to the south of Luton Airport, including Harpenden, St Albans, the M1 / M25 Junction, and areas to the east up to and including the A1 / A1(M) from the M25 in the south to the A421 in the north.

Figure 4.2 Existing CBLTM Fully Modelled Area



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4.3.3 As discussed in Section 4.4, whilst these areas to the south and east of Luton Airport are included within the Fully Modelled Area, the level of detail included within the existing CBLTM in these areas is lower than that included within Central Bedfordshire and Luton Borough.

4.3.4 It is therefore proposed to retain the existing Fully Modelled Area; however, to enhance the model to provide additional zone and network detail within the Fully Modelled Area in locations to the south and east of Luton Airport.

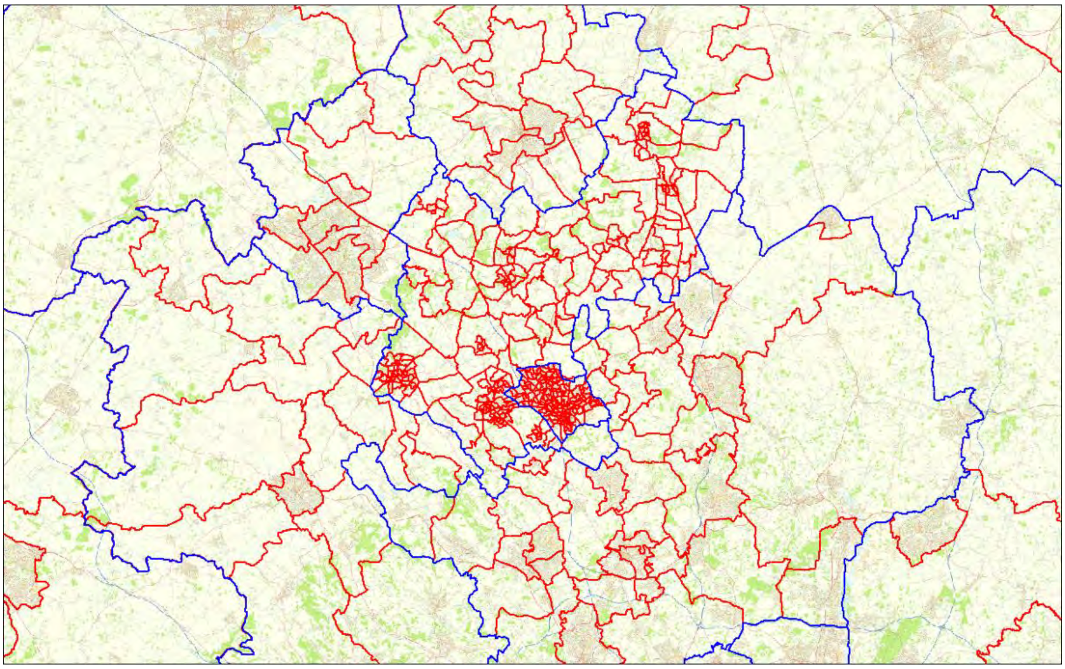
4.3.5 The existing CBLTM suite includes representation of all Great Britain, although the level of detail included within the model decreases with distance from Central Bedfordshire and Luton Borough. In terms of the external areas of the model, outside the Fully Modelled Area, we assume that the existing zone and network detail will be retained.

4.4 Zone Structure

4.4.1 The existing CBLTM suite zone system covers all of Great Britain, with less detail further away from Central Bedfordshire and Luton Borough. In total there are 520 geographical zones within the model, and 50 'spare' development zones with no fixed geographical location. This zone system is adopted by all elements of the model suite.

4.4.2 Figure 4.3 provides an overview of the existing CBLTM zone system within Central Bedfordshire and Luton Borough, and the surrounding areas. This figure shows that the level of detail within Central Bedfordshire and Luton Borough is significantly greater than in neighbouring areas.

Figure 4.3 Existing CBLTM Zone System – Overview



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4.4.3 Given the location of Luton Airport to the south-east of Luton Borough, near the border with Hertfordshire, it is proposed that additional zone detail will be added to the model to the south and east of Luton Airport, including areas around Harpenden and St Albans to the south, and Hitchin to the east.

4.4.4 We assume that these areas will continue to have less zone detail than that included within Central Bedfordshire and Luton Borough.

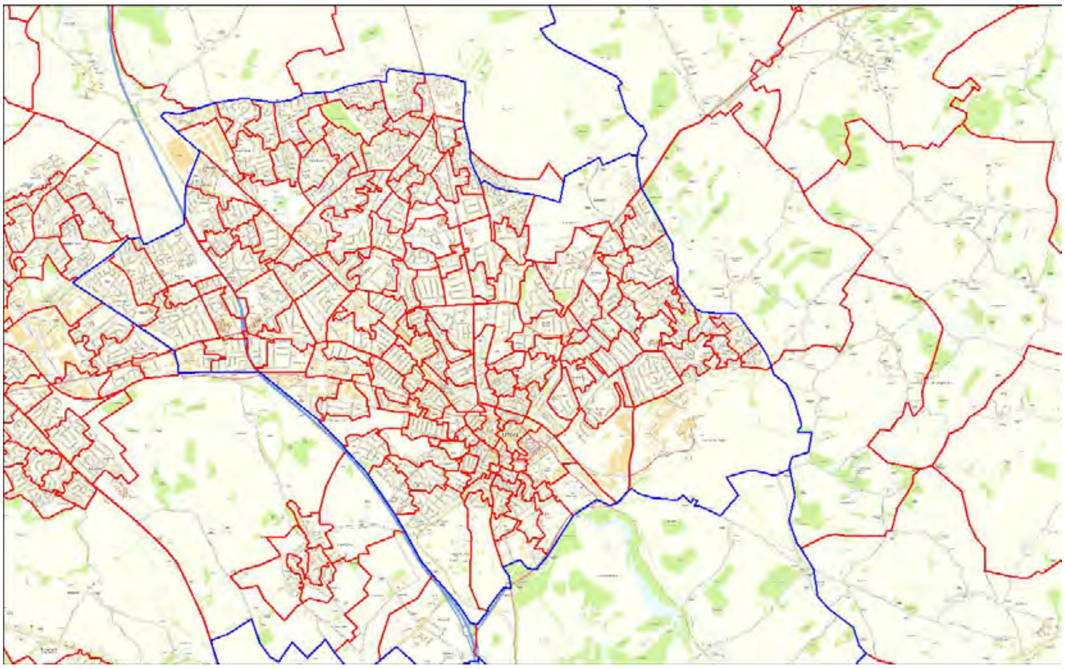
4.4.5 Additional zone detail within other areas of Hertfordshire (such as Stevenage and Hatfield) will be added if it is considered that additional zone detail would improve route options to / from Luton Airport.

4.4.6 Figure 4.4 provides further detail on the zone system contained within the existing CBLTM suite within Luton

Borough. This shows that the zone system provides significant detail within Luton, containing around 150 zones within this area.

4.4.7 It is noted that currently Luton Airport is represented by a single model zone. It is proposed that this zone is disaggregated to allow identification of the different land-uses around the airport. This will include the terminal, the short-, mid- and long-stay car parks, and other key attractors such as the employment along Percival Way. It is also proposed to include a number of 'spare' zones at the airport to allow flexibility in representing different options for the proposed expansion of Luton Airport.

Figure 4.4 Existing CBLTM Zone System – Luton Borough



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4.4.8 Consideration of key known developments in the vicinity of Luton Airport will also be considered as part of the review of the zone system. For example, a zone representing the proposed Century Park development to the east of Luton Airport will be included, and zone detail to the north-east of Luton Airport Parkway station will be considered.

4.4.9 Within the Local Model Validation Report for the existing CBLTM, a number of zones within Central Bedfordshire and Luton Borough have assignment trip-ends above the 200 to 300 trips per hour suggested by WebTAG (Unit M3.1, §2.3.11). As part of the enhancement to the zone system, zones with over 300 trips per hour in the vicinity of Luton Airport will be reviewed and disaggregated where required.

4.4.10 Where disaggregation of the existing CBLTM zone system takes place, this will consider other zone systems from which data may be required as part of the model development. These include:

- 2011 Census Output Areas and Workplace Zones;
- district and county boundaries;
- National Trip-End Model (NTEM) zoning; and
- other model zone systems, such as the Hertfordshire COMET model.

4.4.11 Consistency with these boundaries will be sought within the enhancement of the existing CBLTM zone system; however there may be areas (particularly non-residential areas) where Census geography does not provide enough detail to accurately represent the loading of traffic to / from the network. In these cases, natural boundaries will be used to subdivide Census geography into model zones.

4.5 Representation of Time Periods

4.5.1 Within the existing highway assignment model, the peak hours within the AM Peak and PM Peak are represented along with an average interpeak hour. The definition of these hours has been based on analysis of local count data, identifying the individual peak hour within the AM and PM Periods.

4.5.2 The definition of the AM Peak (08:00 to 09:00) and PM Peak (17:00 to 18:00) hours within the existing CBLTM highway model is consistent with those defined for the microsimulation model (based on an independent review of traffic survey data), and therefore it is not proposed to change the definition of the highway modelled hours.

4.5.3 It should be noted that the AM Peak and PM Peak hours represented within the highway model may not represent the peak hours for airport-related highway demand. The definition of the highway model peaks hours is based on the hours where the aggregate traffic volumes on the network area highest, including both airport and non-airport traffic.

4.5.4 It is considered likely that the peak movements for Luton Airport passengers will fall outside the peak hours defined based on aggregate traffic volumes across the network. The peak hours as defined by airport passenger movements will not be assessed within the CBLTM suite.

4.5.5 As crowding is not represented within the public transport model, the assignment represents average hours within the AM Peak, interpeak and PM Peak periods. It is not proposed to change the definition of time periods within the public transport model.

4.5.6 The variable demand model represents an average weekday, split into four periods: AM Peak; interpeak; PM Peak; and off-peak. With the exception of the off-peak period, these periods are aligned with those defined for the highway and public transport assignment models.

4.5.7 Within the variable demand model, an estimate of off-peak travel demand and costs will be required. Travel demand for the off-peak period will be developed, and will be assigned on a copy of the interpeak networks to provide an estimate of travel costs. These off-peak assignment models will not be calibrated or validated, and therefore should not be used to extract flows or speeds for this time period.

4.5.8 In summary, Table 4.1 provides an overview of the time periods proposed to be represented by the model components.

Table 4.1: Proposed Time Period Definitions (Average June Weekday, Monday to Thursday)

Period	Highway Assignment	Public Transport Assignment	Variable Demand Model
AM Peak	08:00 to 09:00	07:00 to 10:00 (average hour)	07:00 to 10:00
Interpeak	10:00 to 16:00 (average hour)	10:00 to 16:00 (average hour)	10:00 to 16:00
PM Peak	17:00 to 18:00	16:00 to 19:00 (average hour)	16:00 to 19:00
Off-peak	n/a	n/a	19:00 to 07:00

4.6 Demand Segmentation

4.6.1 Within the existing highway assignment model contained within the CBLTM, a number of assignment user classes are represented. These are:

- car commuting;
- car business;

- car 'other';
- light goods vehicles (LGVs); and
- heavy goods vehicles (HGVs).

4.6.2 As part of the enhancements to the CBLTM highway assignment model, it is not proposed to change the definition of the assignment user classes or add further user classes.

4.6.3 Consideration of additional user classes for airport users (passengers, employees and freight) was considered. Additional assignment user classes would increase the model run times (by an estimated 60%), both in terms of forecast model runs and the during the calibration process.

4.6.4 Travel demand for Luton Airport passengers, employees and freight will be included within the assignment, with these trips having an origin or destination at one of the Luton Airport model zones. Airport-related traffic will be the only demand with an origin or destination at these zones, allowing for trips to / from Luton Airport to be isolated within the assignment results.

4.6.5 In terms of the allocation of airport-related trips to the highway assignment user classes, it is proposed that airport employees are added to the 'car commuting' user class, airport passengers are added to the 'car business' user class (due to their high value of time), and airport freight demand is added to the LGV and HGV user classes as appropriate.

4.6.6 It is not proposed to include a specific taxi user class for trips to / from Luton Airport, with travel to / from Luton Airport via taxi considered in the same way as other highway airport passenger trips.

4.6.7 As discussed in Paragraph 2.1.4, we assume that charging policies are not to be tested within the strategic modelling, and therefore income segmentation of the car commuting and car 'other' assignment user classes is not proposed.

4.6.8 Within the public transport assignment model, travel demand is currently segmented by mode between rail and bus users, and not by trip purpose. As with the highway model, airport-related trips can be identified based on the trip origin / destination, and therefore additional airport-related user classes within the public transport model are not proposed.

4.6.9 Mixed-mode public transport trips (rail and bus trips) are not explicitly modelled within the CBLTM. Travellers making these journeys are included within the demand matrices as they are based primarily on ticket data; however the legs of their journeys are not linked. Based on analysis of the National Travel Survey, around 5% of access to rail is made by bus within the East of England, and therefore this simplification is not thought to be significant.

4.6.10 Within the context of Luton Airport, the existing shuttle bus between Luton Airport Parkway station and the terminal is represented as a “rail” service (with an appropriate travel time) so as not to be considered a mixed-mode journey within the model. In forecasting, this service will be replaced by the DART (Direct Air Rail Transit), which will also be coded as a rail service.

4.6.11 Within the variable demand model, travel demand is segmented by trip purpose, with the existing CBLTM suite representing commuting, employers’ business (combined home-based and non-home-based), ‘other’ (combined home-based and non-home-based), LGV and HGV.

4.6.12 We proposed to extend this representation of travel demand to explicitly represent home-based and non-home-based travel for employers’ business and ‘other’ trips, resulting in the following trip purposes represented within the variable demand model:

- commuting;
- home-based employers’ business;
- non-home-based employers’ business;
- home-based ‘other’;
- non-home-based ‘other’;
- LGV; and
- HGV.

4.6.13 The base year demand matrices will be developed including a representation of home-based and non-home-based trips, and therefore including this distinction does not increase the scope of the matrix development tasks. Changes will be required to the variable demand model to separate home-based and non-home-based; however, these updates are not significant in scope, will improve the model’s forecasting, and will simplify the demand model implementation.

4.6.14 Within the variable demand model, car ownership levels will be represented, with no-car owning households not able to choose highway within the mode choice element of the choice structure.

4.6.15 As discussed, on the assumption that charging policies will not be tested as part of the strategic modelling, income segmentation has not been proposed within the variable demand model.

4.7 Software Platform

4.7.1 The existing highway assignment model contained within the CBLTM has been implemented within SATURN version 11.3.12U. As part of the update to the highway assignment model, we will seek to adopt the latest available version of the SATURN software.

4.7.2 Both the public transport and variable demand models contained within the CBLTM suite use Emme 4. As with the highway assignment model, it is proposed to make use of the latest available version of Emme at the time of model development for these elements of the model suite.

5 DATA SOURCES AND DATA COLLECTION

5.1 Introduction

5.1.1 A number of data sources were collated as part of the development of the existing CBLTM suite, and the majority of these will be retained within the enhanced model to assess the proposed Luton Airport expansion.

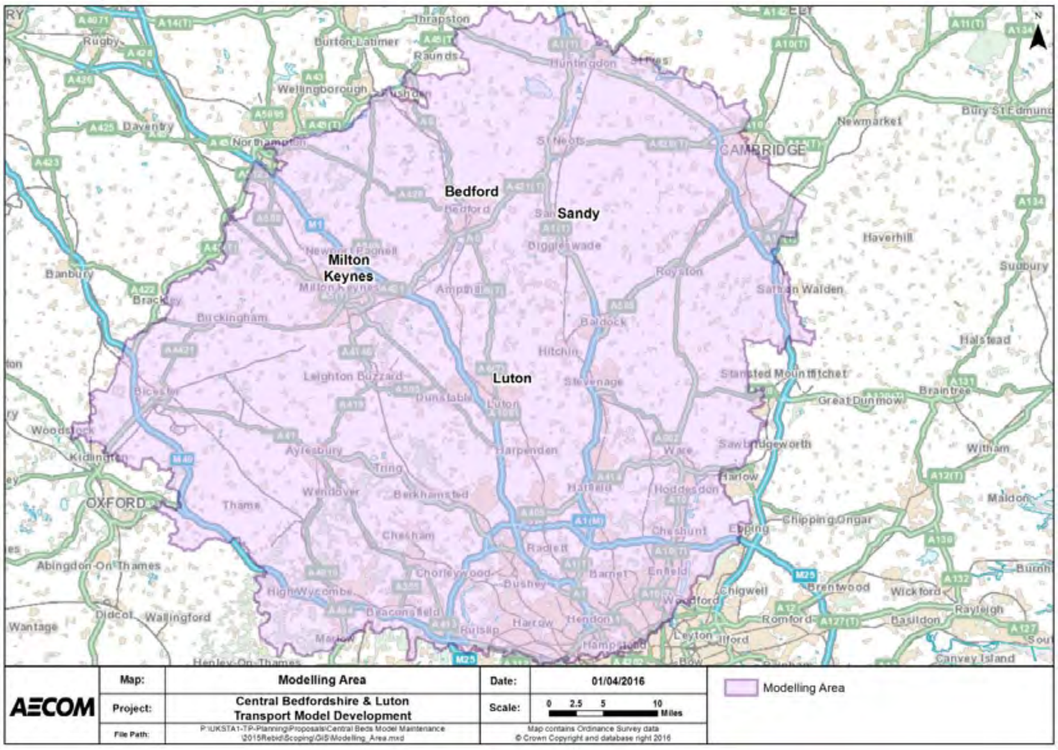
5.1.2 The data collected as part of the development of the CBLTM did not focus on travel in the vicinity of Luton Airport, and therefore further data collection is proposed to supplement the existing data sources with further data on travel in and around Luton Airport.

5.2 Existing CBLTM Highway Demand Data

5.2.1 As part of the development of the 2016 base year highway models contained with the existing CBLTM, mobile network data were obtained from Telefonica covering the period between mid-April and mid-May 2016, excluding weeks containing bank holidays and school holidays. This data have been processed to represent an average weekday (Monday to Thursday) within this period.

5.2.2 The collected mobile network data included trips which intercepted a defined mobile network cordon (shown in Figure 5.1). This cordon area includes an area significantly larger than Central Bedfordshire and Luton Borough, broadly bounded by the North Circular to the south, the M11 / A14 to the east, the A14 / A45 to the north and the M40 to the west.

Figure 5.1 CBLTM Mobile Network Cordon



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5.2.3 It is not proposed to obtain new mobile network data as part of this enhancement to CBLTM, given the coverage of the original data and that the 2016 base year is to be retained. The processing of this mobile network data will be reviewed as part of this model enhancement to take account of the latest best practice relating to the processing of mobile network data, and this is discussed in Section 7.

5.2.4 In addition to the mobile network data, demand data for external-external movements which do not intercept the mobile network cordon have been sourced from Highways England's South East Regional Traffic Model (SERTM).

5.3 Existing Highway Count Surveys

5.3.1 Traffic count survey data were collected as part of the 2016 base year CBLTM model calibration and validation exercise. Three sources of count data were used, and these are:

- TRADS data available from WebTRIS;
- count data obtained from Central Bedfordshire Council (CBC) and Luton Borough Council (LBC); and

- bespoke data collected for the CBLTM development in 2016.

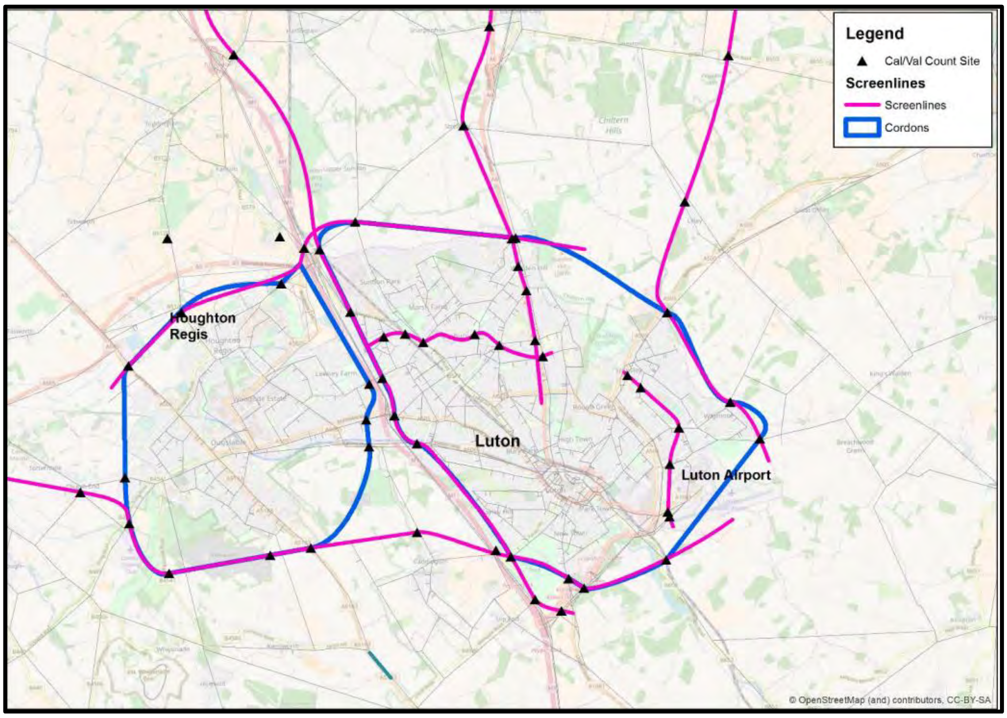
5.3.2 These data include both Automatic Traffic Count (ATC) data and Manual Classified Count (MCC) data. As defined within WebTAG Unit M3.1, the ATC data were used to define the total vehicle flow at a given site, with the MCC data used to provide estimates of the vehicle type proportions.

5.3.3 It should be noted that some of the ATCs collated as part of the development of the CBLTM highway model did not include data for at least two weeks as recommended by WebTAG. The location of these sites, and those with significant observed variation in traffic volumes, will be reviewed and additional surveys conducted where required.

5.3.4 Figure 5.2 shows the location of traffic surveys, and how these have been used to generate screenlines and cordons within Luton Borough. This shows that there is a:

- a cordon of the Luton urban area (calibration);
- a cordon of the Dunstable urban area (calibration);
- a north-south screenline to the west of Luton Airport (validation); and
- two screenlines to the north of Luton, one north-south and extending outside Luton along the A6 (validation), and one east-west in orientation within Luton (calibration).

Figure 5.2 Existing CBLTM Screenlines and Cordons – Luton Borough



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5.3.5 Arup undertook additional traffic surveys in Autumn 2017 as part of the data collection exercise for the microsimulation model. The appropriateness and relevancy of this data to strategic modelling will be reviewed.

5.3.6 In addition to this, we will seek permission to use traffic counts collected by Hertfordshire as part of the development of their county-wide transport model, COMET. These counts would be used to create additional screenlines to the south of Luton Airport, and potentially to the east of the airport.

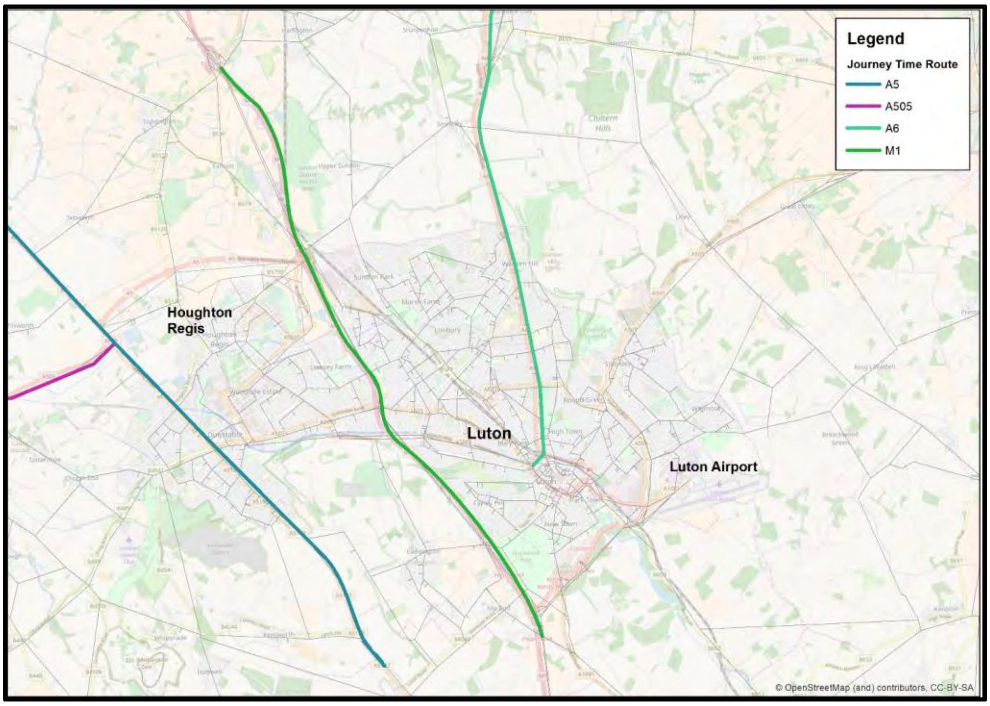
5.4 Existing Highway Journey Time Surveys

5.4.1 In addition to traffic count survey data, observed journey time data were collected and obtained from the Trafficmaster database (March to June 2015) for use in the validation of the existing CBLTM highway model. Journey time routes were used to validate modelled journey times against this observed data.

5.4.2 The Trafficmaster data have been used to define observed journey time data for a number of routes within Central Bedfordshire and Luton Borough. Figure 5.3 shows the journey time routes defined within Luton Borough. These include:

- the M1 between Junctions 10 and 12;
- the A6 to the north from Luton town centre; and
- the A5 through Dunstable.

Figure 5.3 Existing (Trafficmaster) CBLTM Journey Time Routes – Luton Borough



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5.4.3 As Figure 5.3 indicates, the coverage of observed journey time data within Luton is limited within the existing CBLTM; therefore additional journey time data routes will be defined in order to ensure sufficient coverage of key routes in the vicinity of the airport.

5.5 Existing CBLTM Public Transport Demand Data

5.5.1 Electronic ticket machine (ETM) data were collected from two bus operators, Arriva and Centrebus in Central Bedfordshire and Luton Borough. Between them they cover around 73% of bus services that operate in Central Bedfordshire and Luton Borough.

5.5.2 The data in principle cover all passenger boardings, including concessions, use of return tickets, and use of smartcards and other passes, as well as actual ticket sales.

5.5.3 All ETM data have been provided for three months from March to May 2016.

5.5.4 For rail travel, LENNON (Latest Earnings Nationally Networked Over-Night) rail ticket data obtained from the Association of Train Operating Companies (ATOC) for the whole country was used.

5.5.5 LENNON data contain tickets (including season tickets) sold by type, issuing station, origin station and destination station. The LENNON data were provided for the month of March 2016.

5.6 Existing CBLTM Public Transport Count Surveys

5.6.1 The Office of Rail and Road (ORR) publishes annual statistics on usage of all railway stations in Great Britain. These data are based primarily on LENNON ticket sales data, and were used to validate and confirm processing of the LENNON data. They are not strictly independent counts.

5.6.2 One set of single on-board bus passenger counts along four links at four sites within the model area were carried out in September 2016. Those locations are:

- Ampthill Road (Flitwick);
- Stanbridge Road (Leighton Buzzard);
- Biscot Road (Luton); and
- Barton Road (Luton).

5.7 Proposed Highway Data Collection

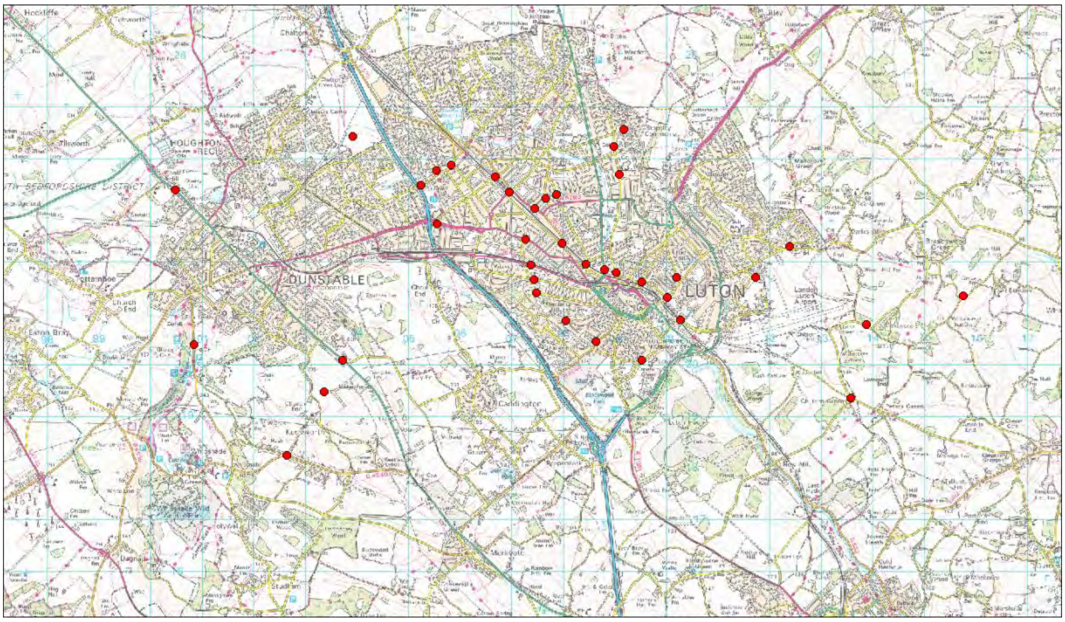
5.7.1 A data collection exercise will be undertaken to expand the existing count data set. This count data will be focused on capturing movements to / from Luton Airport, including the strategic road network.

5.7.2 A review of the available data around Luton Airport has been undertaken to make best use of available data, and locations have been identified where collecting new count data is required to define a number of new screenlines and cordons.

5.7.3 Both ATC data, to define total vehicle flows, and MCC data, to define vehicle splits, will be collected as part of this data collection exercise. It is anticipated that these data will be collected in two phases: firstly in early July 2018; and secondly in mid-September 2018.

5.7.4 During the two-week period between 9th and 20th July 2018, prior to the school summer holidays, a total of 38 automatic traffic counts have been undertaken within Luton and the surrounding area. The location of these traffic surveys is shown in Figure 5.4.

Figure 5.4 Location of July 2018 Traffic Surveys



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5.7.5 Given that these additional data are expected to be undertaken in July / September 2018, the count data will need to be adjusted to represent June 2016. This will make use of long-term count data available within Central Bedfordshire and Luton Borough.

5.7.6 The existing journey time data from Trafficmaster provide limited coverage for routes to / from Luton Airport. It is therefore proposed to add a number of new journey time routes to the validation of base year modelled travel times using the existing Trafficmaster dataset. It is expected that these will include:

- the extension of the existing M1 journey time route to the south towards the M25, and to the north towards the A421 / Milton Keynes;
- the A1081 between the M1 and Luton Airport;

- the A505 between Luton Airport and Hitchin;
- the A1081 to the south of Luton Airport through Harpenden and towards St Albans; and
- key routes within Luton such as the A505 between Luton town centre and Luton Airport, and Hatters Way between Luton and Dunstable.

5.7.7 The existing journey time data are based on Trafficmaster data covering March to June 2015. We will seek to update the observed Trafficmaster journey time data to correspond with the June 2016 base year of the model, which will require the reprocessing of journey time data for the existing journey time routes using the updated observed data.

5.7.8 If the existing March to June 2015 Trafficmaster data are retained for the journey time validation, this 2015 data set will be used to extract journey time data for the additional journey time routes.

5.8 Proposed Public Transport Data Collection

5.8.1 We are not proposing to collect any additional public transport data for the purpose of this enhancement to the CBLTM suite. We do however proposed to make use of the CAA Luton Airport passenger survey and the Luton Airport Employee Travel survey to validate the existing base year public transport demand to / from the airport.

5.9 Luton Airport Base Year Travel Demand

5.9.1 As part of the review of the existing base year highway and public transport travel demand matrices, the representation of trips to / from Luton Airport will be considered.

5.9.2 For passenger demand, the Luton Airport Passenger Survey conducted by the CAA (Civil Aviation Authority) provides information on the ultimate origin / destination of passengers within the United Kingdom, their mode of travel, and the time of day of their journey to / from Luton Airport.

5.9.3 For airport employees, London Luton Airport Operations Limited (LLAOL) has undertaken a travel survey of existing employees. It is understood that tabulations of these data are available; however these may not include sufficient detail to enable their use directly within the base year models. We will explore with Luton Airport if more detailed information can be made available from this survey, and consider how this information can best be used as part of the enhancement to CBLTM.

5.9.4 We are not aware of similar data for freight demand to / from Luton Airport, capturing information on goods traffic at the airport. If information is available on freight demand at Luton Airport, this information will be used as part of the development of the base year highway demand matrices.

5.10 Other Data Sources

5.10.1 As part of the enhancement of the CBLTM suite, reference will be made to a number of other available data sources. These data sources will provide additional information not captured in the existing data sets (such as information on average vehicle occupancies), and will also provide independent checks on the processing of the model data.

5.10.2 It is expected that these additional data sources will include:

- the 2011 Census data and the 2016 mid-year population estimates;
- TEMPro v7.2;
- National Travel Survey (NTS) data; and
- information on freight demand from the Continuing Survey of Road Goods Transport (CSRGT) data and the DfT's Base Year Freight Matrices (BYFM).

6 HIGHWAY NETWORK DEVELOPMENT

6.1 Introduction

6.1.1 The highway network represents the supply side of the highway modelling process and is primarily formed of links and nodes that represent on-street conditions. The network will be represented using SATURN, which is a congested highway assignment software package, and will use the standard Wardrop's principle of user equilibrium.

6.2 CBLTM Highway Network Development

6.2.1 The existing 2016 base year highway network used within CBLTM has been developed from the previous 2009 base year model. As part of the update to a 2016 base year, the following tasks were undertaken as part of the development of the highway networks:

- implementing schemes that were introduced between 2009 and 2016;
- included impact from roadworks which significantly affected traffic in June 2016;
- coded signal timings at certain locations provided by CBC and LBC; and
- corrections and ad-hoc revisions to the existing network.

6.2.2 It was noted in the existing CBLTM Local Model Validation Report (LMVR) that there were discrepancies between some of the existing coding and that it is "*highly recommended that a systematic review of the network be undertaken as part of future base year calibration work*".

6.2.3 It is also noted within the existing LMVR that no coding manual exists for the current CBLTM highway model, setting out standard assumptions for the coding of different junctions.

6.3 Highway Network Review

6.3.1 The first stage in reviewing and enhancing the existing CBLTM highway network coding will be to develop a network coding manual. This will ensure accuracy and consistency of coding across the network by different network coders. This will be based on similar coding manuals developed by AECOM, and will set out the assumptions and standards to be adopted for network coding.

6.3.2 The coding manual will provide best practice and guidance on, but not limited to, the following items:

- global network and assignment parameters;
- simulation junction saturation flows by junction type, turn geometry and turn movement;
- coding of signal stages and timings;
- modelling of flared approaches to junctions;
- the application of fixed, cruise speeds or variable speed-flow curves to links, and the standard assumptions for each approach; and
- centroid connector coding in the simulation and buffer areas.

6.3.3 A full and in-depth network review of the existing simulation coding will be undertaken based on the coding manual within Luton Borough, Dunstable, to the south and east of Luton Airport within Hertfordshire, and on the Strategic Road Network. Network outside these areas (for example, within Central Bedfordshire away from Dunstable and the buffer network) will not be reviewed.

6.4 Highway Network Checks

6.4.1 A series of checks will be systematically performed on the reviewed network to ensure network integrity and consistency with the network coding manual. These checks will include:

- A random selection of network coding, focussing on routes to / from Luton Airport, will be reviewed in detail by an independent and experienced SATURN modeller. This review will be undertaken periodically during the network review, with findings from the reviews being fed back to the coding team.
- A review and documentation of all ‘serious warnings’ and ‘warnings’ produced by SATURN at nodes to be reviewed.
- Using an initial assignment, review the model route choice of traffic through the reviewed network, identifying potential coding errors before the calibration of the base year highway model.

- Using the 2016 network and forecast year demand, ‘stress tested’ the networks to identify any locations where excessive delays or blocking back may occur, potentially leading to poor convergence of the overall model suite.

6.5 Network Expansion

6.5.1 In addition to the existing network detail, the following network enhancements will be made to the network where required:

- additional network detail around Luton Airport;
- additional network detail outside Central Bedfordshire and Luton Borough to the south and east of Luton Airport;
- a review of the zone connector coding within these areas, and updates where zone definitions have been updated; and
- existing traffic signal coding will be retained; however, sense-checking of the assumptions at traffic signals will be undertaken. It is not proposed to collate new observed traffic signal staging and timings.

6.5.2 The network detail will, where possible, be consistent with that included within the microsimulation model network (shown in Figure 6.1), to allow for the transfer of data between the two models.

Figure 6.1 Extent of Microsimulation Modelled Network

Source: Arup

6.6 Capacity Restraint Approach: Junction Modelling and Speed-Flow Relationships

6.6.1 There are two distinct network areas or types in the highway model:

- the "inner" or simulation network in which considerable junction-based data have been included; and
- the "outer" or buffer network which surrounds the simulation network and only contains link-based data.

6.6.2 The extent of the simulation network coding contained within the existing CBLTM highway model (where detailed junction coding is represented) is shown in Figure 4.2. Outside this area, buffer network coding has been implemented, where individual junctions are not modelled in detail.

6.6.3 Within the simulation area speed flow curves are used to model congestion on longer links (typically greater than 500 metres) such as motorways where delays tend to be dictated by conditions on the link rather than the junction. Junction modelling will be used to model delays and blocking back in urban areas such as Luton Town Centre, Dunstable and Leighton Buzzard where links are typically shorter in length.

6.6.4 The buffer network uses fixed, cruise speeds, which may vary by time period, and will change over time when forecasting[3].

[3] Within the buffer network there is a mismatch between the level of network detail and the travel demand included within the assignment matrices. The assignment matrices contain all travel, whereas only strategic links are represented within the buffer network.

The primary function of the buffer network is to ensure that trips access the simulation network at the right location and also to enable the routeing of longer distance (external) trips. No speed-flow curves are applied within the buffer network coding, and this external network is not proposed to be reviewed as part of this model enhancement.

6.6.5 As part of forecasting, the fixed cruise speeds coded within the buffer network will be reduced over time to reflect increasing levels of congestion outside the modelled area, using forecast speed changes from the National Transport Model. This is required to provide consistency between the forecast changes in the cost of travel between the simulation and buffer network areas of the model. A discrepancy between the two parts of the model may lead to an over- or underrepresentation in growth of external traffic within the variable demand model.

6.7 Assignment Methodology

6.7.1 The CBLTM highway model assignment method currently uses Wardrop's principle of user equilibrium and this will be maintained for the CBLTM enhancement. The SATURN manual states that Wardrop's principle of traffic equilibrium could be stated as:

Traffic arranges itself on congested networks such that the cost of travel on all routes used between each O-D pair is equal to the minimum cost of travel and all unused routes have equal or greater cost.

6.7.2 Wardrop's equilibrium is a widely used and standard assignment methodology for congested highway networks and will be maintained for the 2016 CBLTM update.

This leads to high assigned volumes on the buffer network, which would generate significant (and unrealistic) delays if speed-flow relationships were applied within the buffer network.

7 HIGHWAY DEMAND DEVELOPMENT

7.1 Introduction

7.1.1 This section sets out the process by which the existing highway prior matrices (i.e. those before the application of matrix estimation) have been developed, and the proposed methodology for enhancing these matrices for use in the assessment of the proposed Luton Airport expansion.

7.1.2 This section includes discussion on the derivation of highway travel demand to / from Luton Airport in the 2016 base year model.

7.2 CBLTM Highway Demand Development

7.2.1 The existing highway prior matrices for car traffic have been developed primarily using mobile network data provided by Telefonica (known as O2 in the UK). Synthetic demand matrices have been used to infill short-distance trips and to provide splits of travel demand by purpose. Demand data from South-East Regional Traffic Model (SERTM) have also been used for freight demand and for external-external trips not captured within the mobile network data.

7.2.2 The Local Model Validation Report (LMVR), issued August 2017, for the existing CBLTM details a number of verification tasks which have been undertaken to understand the mobile network data provided for the model development. These checks identified a number of limitations with the data set, such as the capturing of short-distance trips, the identification of rail and HGV trips, and the performance of these matrices against observed screenline flows.

7.2.3 As detailed within the LMVR, these issues are common with the use of mobile network data given that this source of travel demand data is relatively new to the industry, and taking into account the mobile network infrastructure (i.e. the location and density of mobile network masts). A number of processes have been applied to the mobile network data in an attempt to address the limitations of the data, and these are detailed within the LMVR.

7.2.4 Table 7.1 provides a summary of the performance of the existing highway prior matrices against observed screenline flows as reported within the LMVR after informed adjustments and corrections have been made to the data.

7.2.5 WebTAG Unit M3.1, Section 8.2 states that an assignment of the prior matrices should result in modelled flows within 5% of observed flows on 'all or nearly all' screenlines, and in instances where this criteria is not met, adjustments to the prior matrices should be considered.

7.2.6 The existing performance of the highway prior matrices reported in the LMVR is below the standards set out in WebTAG, and significantly so in the interpeak and PM Peak models.

Table 7.1: Summary of Prior Matrix Screenline Performance (CBLTM LMVR, Tables 19 to 21)

Time Period	Screenlines Meeting WebTAG Criteria
AM Peak Hour	19 out of 30 (63%)
Interpeak Hour	11 out of 30 (37%)
PM Peak Hour	8 out of 30 (27%)

7.3 Highway Demand Refinements: Non-Airport Demand

7.3.1 Given the performance of the existing highway prior matrices, and the advances in the understanding and processing of mobile network data since the development of the existing CBLTM, it is proposed to reprocess the Telefonica mobile network data for this model enhancement.

7.3.2 The objective of this reprocessing of the mobile network data is to improve both the performance of the highway prior matrices (as shown in Table 7.1) and the performance of the calibrated highway model, particularly in terms of flow validation (as shown in Table 8.2).

7.3.3 This reprocessing of the data will include the lessons learnt from the development of the existing CBLTM and our use of mobile network data for a number of other recent applications.

7.3.4 The following provides an overview of the proposed stages of work to reprocess the mobile network data:

- Define and setup matrix verification tests, considering trip-rates, trip-lengths, purpose and time period splits
- Consider the spatial accuracy of the mobile network data to define a sector system in which the data are to be processed
- Address any trip rate biases identified as part of the verification

- Remove bus, rail and freight demand from the mobile network data using information from the public transport model, SERTM and other data sources
- Augment missing or unreliable trip records, such as short-distance trips
- Disaggregate data to model trip purpose using synthetic matrices
- Disaggregate data from defined sector system to model zones using synthetic matrices
- Revisit verification tests based on data excluding public transport and freight, and with unreliable records augmented
- Consider further constraints (such as controls on trip rates) based on the outcome of the updated verification tests
- Convert data to origin / destination, peak hour matrices for assignment onto the highway network

7.3.5 As part of this data processing and verification, information from the National Travel Survey (NTS) data will be used throughout. Information from the 2011 Census and TEMPro v7.2 data will also be used as part of this process.

7.3.6 The NTS data will also be used to derive trip-length profiles used as part of the development of synthetic matrices. These synthetic matrices will also use trip-ends from the base year trip-end model (see Section 12.3 for further details) and trip distances from the existing CBLTM highway assignment.

7.3.7 There is a general lack of observed data regarding freight demand within transport modelling, and we will therefore consider the strengths and weaknesses of the available data sources. For light goods vehicles (LGVs) we propose to consider the use of Trafficmaster Origin-Destination data[4] and the LGV demand developed for the SERTM.

7.3.8 For heavy goods vehicles (HGVs) we propose to consider information available with the CSRGT data and the DfT's BYFM data, and the matrices developed as part of the SERTM.

7.3.9 With the available data sets reviewed and processed, the mobile network data, synthetic matrices and other data sources (such as SERTM highway demand, Trafficmaster OD data and CSRGT data) will be merged. It is not expected that this merging process will be a binary choice for all movements, taking a single data source for a given movement within the

[4] Given the sample captured within the Trafficmaster Origin-Destination dataset, this data source is not considered suitable for developing car or HGV travel demand.

matrix, but will be combine the different estimates based on the relative confidence in the data sources for individual movements.

7.3.10 The performance of these merged matrices against screenline flows will be reviewed, and adjustments to the matrices applied to improve the performance against screenline flows. In applying any adjustments to the matrices, the impact of these changes on the matrix verification tests will be assessed to ensure that these changes do not distort the highway demand data.

7.3.11 The demand model contained within the CBLTM suite operates using all-day, production / attraction, person demand. The highway demand developed using the process outlined above will also be developed at this level to ensure consistency with the demand model, and factors derived to convert these matrices to assignment hour, origin / destination, vehicle matrices. These factors include from-home / to-home proportions for home-based trips, vehicle occupancy assumptions, and peak hour factors for the AM Peak and PM Peak hours.

7.4 Highway Demand Refinements: Luton Airport Demand

7.4.1 Travel demand to / from Luton Airport will be included within the highway matrices developed using the processes detailed in Section 7.3; however there will be uncertainties with these estimates. This includes the allocation of commuting trips to Luton Airport compared with other workplaces in the vicinity of the airport, and the treatment of non-UK residents, or “roamers”, within the mobile network data.

7.4.2 Therefore it is proposed that the highway travel estimates produced by the processes detailed in Section 7.3 for travel to / from Luton Airport will be replaced with alternative data sources. It is assumed that base year highway travel demand matrices (for passengers, employees and freight) will be provided to AECOM within the required timescales set out in Section 13.

8 HIGHWAY MODEL CALIBRATION

8.1 Introduction

8.1.1 The CBLTM highway model was calibrated based on the Department for Transport's WebTAG Unit M3.1 acceptability guidelines for calibration and validation on individual counts, screenlines and journey time acceptability guidelines.

8.1.2 The CBLTM was calibrated for the whole of the 'core' modelled area which incorporated Central Bedfordshire and Luton Borough. The 2016 CBLTM model was not built with a particular emphasis on trips to and from Luton Airport.

8.1.3 As part of this model enhancement:

- the simulation network coding around Luton Airport will be reviewed and updated,
- additional count data will be collected to provide further screenlines and cordons within Luton;
- additional journey time routes will be defined focussing on routes to / from Luton Airport; and
- the prior matrices will be rebuilt.

8.1.4 We assume that matrix estimation will be required to improve the model performance against the available traffic survey and journey time data.

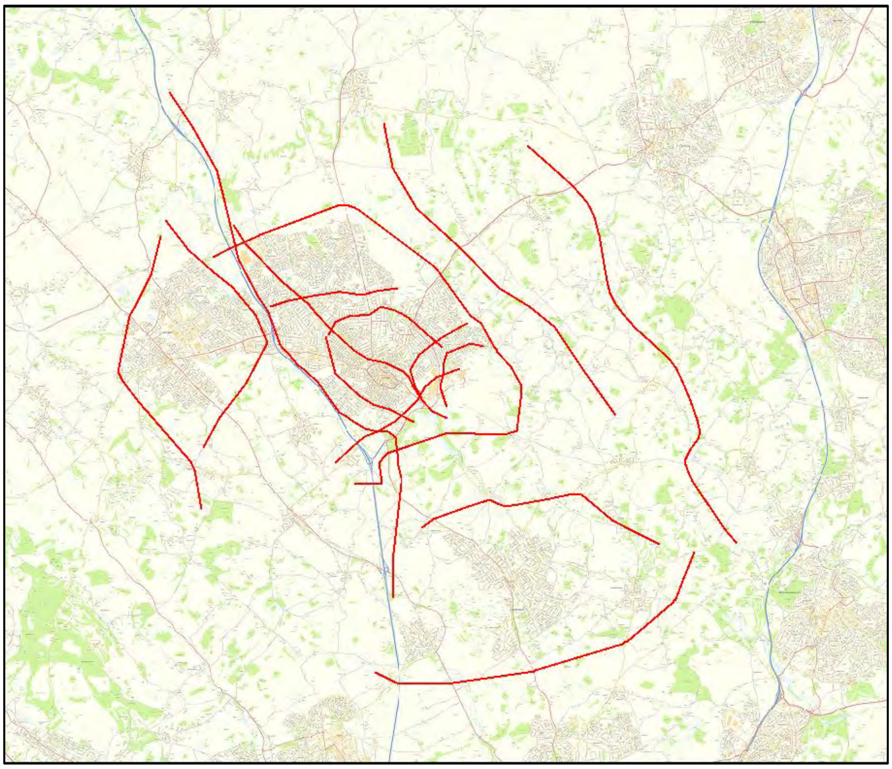
8.2 Highway Calibration and Validation Data Sets

8.2.1 The additional count data to be collected as part of this model enhancement will be supplementary to the existing screenlines and cordons defined within the CBLTM highway model. The screenlines and cordons defined for this model enhancement will replace those defined in the existing CBLTM highway model within Luton Borough.

8.2.2 Screenlines defined elsewhere within the highway model will be retained within the model calibration; however their performance will not be the focus of this model calibration exercise.

8.2.3 Based on the expected traffic survey data to be collected, Figure 8.1 shows the proposed location of the additional screenlines to be added to the model calibration and validation data sets.

Figure 8.1 Proposed Additional Screenlines



Map contains Ordnance Survey data © Crown copyright and database right 2018

8.2.4 It is anticipated that the screenlines to the south and east of Luton Airport will make use of traffic surveys undertaken as part of the development of Hertfordshire's COMET transport model; however if access to these data is not granted, we will seek to undertake traffic surveys at the required locations to construct screenlines to the south of the airport.

8.2.5 Of the counts required to construct the screenlines shown in Figure 8.1:

- around 50% of these counts will be undertaken in July / September 2018 as part of this update to CBLTM;
- around 17% will be taken from the traffic counts undertaken by Arup as part of the development of the microsimulation model;
- around 20% will be taken from the existing CBLTM dataset; and
- around 13% will be taken from Hertfordshire's COMET model, assuming permission to make use of these data is granted.

8.2.6 The defined screenlines will be allocated to the calibration and validation datasets as part of matrix estimation. It is expected that around two-thirds of the screenlines will be allocated to the calibration dataset, with the remaining third of screenlines defined as validation.

8.2.7 Where possible, the screenlines allocated to the validation dataset will be located between calibration screenlines. For example, the most easterly screenline (to the west of Hitchin) and the Luton Cordon may be classified as calibration, with the screenline between these (to the west of Lilley) may be classified as validation.

8.2.8 In addition to the traffic survey data, journey time routes will be defined to validate the modelled speeds against observed data. As discussed in Section 5.4, additional routes to those defined within the existing CBLTM highway model are proposed, along with an update to the observed Trafficmaster data from 2015 to 2016 observed data.

8.3 Highway Assignment Calibration and Validation

8.3.1 The overarching aim of the model calibration is to minimise the changes to the prior matrices through matrix estimation, if a matrix estimation process is applied. The aim is to improve the quality of the networks and prior matrices such that matrix estimation has less work to do in order to match the observed count and journey time data sets

8.3.2 Prior to the application of matrix estimation, detailed checks on the network coding will be undertaken, including the assessment of routeing within the base year assignments. WebTAG Unit M3.1 Paragraph 7.3.2 provides guidance on the number of origin-destination pairs which should be reviewed as part of the route choice validation.

8.3.3 The purpose of undertaking these network checks and route choice validation before the application of matrix estimation is to limit or eradicate matrix estimation updating the prior matrices to correct for network and / or routeing errors within the assignment.

8.3.4 The available screenlines and cordons will be categorised as calibration and validation. Those defined as calibration data will be used within the matrix estimation process to update the prior matrices, whereas those defined as validation will remain independent of the model calibration exercise.

8.3.5 In terms of the calibration screenlines and cordons themselves, these will be used within matrix estimation as ‘short screenlines’ as opposed to individual counts. This is in-line with WebTAG Unit M3.1 Paragraph 8.3.5, as the use of individual counts within matrix estimation can potentially compensate (undesirably) for errors / issues in the network coding or prior matrices.

8.3.6 Consideration of ‘freezing’ trips to / from Luton Airport within matrix estimation will be given. If there is sufficient confidence in the demand data for these movements, these trips will remain fixed within matrix estimation. If however there is considered to be a similar level of certainty for these trips compared with other trips in the matrices, these movements will be subject to change through matrix estimation.

8.3.7 Consideration will be given to including the validation counts within matrix estimation as part of the final round of model calibration. The reasoning for this approach is that if the model can be demonstrated to meet WebTAG criteria without the validation data, this becomes the basis for discussion within the Local Model Validation Report (LMVR). However, including the validation counts will (in general) further improve the model performance, and the results of this run would become the base year model, and would also be documented within the LMVR.

8.3.8 This approach of including the validation data within the calibration process is a deviation from WebTAG advice; however, the objective of this approach is to provide the highest performing model for use in the assessment of the proposed Luton Airport expansion. This approach would only be adopted if the base year model with independent validation data demonstrates a sufficient level of performance against the WebTAG criteria.

8.3.9 The pros and cons of including the validation data set within matrix estimation will be discussed towards the end of the calibration process in light of the emerging performance of the model against observed data. Within this specification we assume that the validation count data set will not be used, and this is the approach which will be followed. However the option to include some or all of the validation data set will be considered during the model calibration process.

8.3.10 For each run of matrix estimation there are a number of analysis tasks that will be undertaken. Amongst these are the comparison of the modelled flows against calibration and validation count data sets, and the comparison of modelled journey times against observed data. However, in addition to these comparisons, the following analysis will also be undertaken:

- scatterplots of matrix zonal values comparing the prior matrices against the matrix estimated matrices, along with regression statistics;

- scatterplots of zonal trip-ends comparing the prior matrices against the matrix estimated matrices, along with regression statistics;
- comparison of trip-length profiles prior and post-matrix estimation, along with mean trip lengths and standard deviations; and
- sector-to-sector matrix changes between the prior matrices and the matrix estimated matrices with both absolute and percentage changes.

8.3.11 The above analysis will be compared against the guidance set out in Table 5 of WebTAG Unit M3.1 (and reproduced in Table 8.1). However it should be noted that, as stated in WebTAG, it may be less achievable to meet these WebTAG criteria for larger models, although attention should be paid to the area of detailed modelling, and failure to meet these benchmarks does not necessarily mean that the model is not fit for purpose.

Table 8.1: Significance of Matrix Estimation Changes (WebTAG Unit M3.1, Table 5)

Measure	Significance Criteria
Matrix zonal cell values	Slope within 0.98 and 1.02 Intercept near zero R^2 in excess of 0.95
Matrix zonal trip-ends	Slope within 0.99 and 1.01 Intercept near zero R^2 in excess of 0.98
Trip-length distributions	Means within 5% Standard deviations within 5%
Sector-to-sector level matrices	Differences within 5%

8.3.12 With regards to the above point on the area of detailed modelling, it is proposed that the analysis regarding matrix cell changes, matrix trip-end changes and trip-length profiles be undertaken both for the whole matrix and for trips with an origin and / or destination within the Fully Modelled Area. Given the relatively large scale of matrix values within the external network, it is likely that WebTAG criteria will be met when considering the model as a whole, and a more informative comparison will be for trips in the Fully Modelled Area.

8.3.13 This is a stricter test than prescribed within WebTAG, but will highlight the changes to the prior matrices occurring within the area of interest for the model. Any assessment of the changes to the prior matrices due to matrix estimation should be made with reference to the underlying data sources used to develop the matrices in a given area. The larger the uncertainty regarding data sources in a given area of the matrix, the larger the likelihood of matrix estimation adjusting the matrix to match observed count data.

8.3.14 Based on the results of a given run of matrix estimation in relation to flow and journey time performance, and with regards to the changes in the prior matrices, a number of areas of investigation could be taken forward. The most likely area of investigation will be the network coding, and adjustments to the coding made to improve the flow and journey time performance, but the prior matrices and observed data (counts and journey times) could also be reviewed in areas of the model that are not meeting WebTAG criteria.

8.3.15 These investigations will not solely focus on the flow or journey time performance, as often the results of one measure influences the results of the other. For example, increasing the modelled flow on a given route is also likely to increase the modelled journey times. These investigations will be undertaken spatially considering different geographical areas in turn, firstly considering the key routes within the area and then moving onto the local roads.

8.3.16 For context, Table 8.2 provides a summary of the existing model performance for total vehicle flows against screenlines and individual count sites, and against observed journey time data.

8.3.17 In terms of screenlines, all calibration screenlines meet WebTAG criteria, with between 50% and 75% of the eight validation screenlines meeting the criteria. Overall the screenline performance is around 90% in all three time periods.

8.3.18 For individual flows the performance is below the criteria of 85% of links set out in WebTAG for both calibration counts (between 76% and 82%) and validation counts (between 48% and 63%).

8.3.19 The journey time validation meets the criteria set out within WebTAG, with 87% of journey time routes meeting the criteria in each time period.

8.3.20 Within the calibration of the existing CBLTM highway model, the validation count data has remained independent from the model calibration, and has not been used within the matrix estimation process.

Table 8.2: Existing CBLTM Highway Model Performance

		AM Peak	Interpeak	PM Peak
Screenlines	Calibration	100%	100%	100%
	Validation	75%	50%	63%
	Total	**93%**	**87%**	**90%**
Link Flows	Calibration	76%	82%	76%
	Validation	48%	61%	63%
	Total	**70%**	**78%**	**73%**
Journey Times		**87%**	**87%**	**87%**

8.3.21 The performance of the existing highway model against traffic survey data are below the criteria set out within WebTAG, particularly for validation screenlines and individual counts (both calibration and validation).

8.3.22 As with the calibration of any highway model, whilst AECOM will work towards meeting WebTAG acceptability criteria, the calibration process cannot, and does not, guarantee any particular level of calibration or validation of the highway model against these WebTAG criteria.

9 PUBLIC TRANSPORT DEMAND DEVELOPMENT

9.1 Introduction

9.1.1 Public transport travel demand in CBLTM was generated for an average weekday in a neutral week (a week without bank holidays) in Spring 2016. Demand includes both bus and rail travel. Taxi travel is not included in the CBLTM public transport model.

9.1.2 Demand represents travel on scheduled public bus services and national rail. It does not include all education travel on dedicated school buses, travel on coaches (scheduled or charter) or travel on heritage railway lines.

9.1.3 External-external bus trips (which do not enter Central Bedfordshire or Luton Borough), have not been estimated. For example, bus travel between Stevenage and Hitchin is not included. However, rail external-external trips are included.

9.2 CBLTM Public Transport Demand Development

9.2.1 Matrices have been segmented in several ways: by time period; by purpose; direction of travel; by rail / bus; and car-availability of traveller. Each valid combination of these dimensions has resulted in a separate matrix.

9.2.2 Ticket data were used primarily as the source of public transport demand: Electronic Ticket Machine data for bus; and LENNON data for rail. This information was distributed among ultimate origins and destinations (as the raw data relate to boarding and alighting stations and bus stops) using trip-ends derived from TEMPro. It was split into travel purposes similarly. For rail travel, National Travel Survey data were used to split the demand into time periods (bus data were already by time period).

9.2.3 Synthetic models were used to infill demand on bus services within Central Bedfordshire and Luton Borough for which ticket data were not available. These were primarily required for bus travel in the north of the model area, particularly travelling between Milton Keynes and Bedford.

9.2.4 No mobile network data have been used, or are proposed to be used, as part of the development of the base year rail and bus demand. It is considered that the collated ticket data is a more reliable source of demand data for public transport.

9.3 Public Transport Demand Refinements: Non-Airport Demand

9.3.1 As the updated zone system will include disaggregation of the existing CBLTM zones, it will be necessary to re-zone the public transport demand in as part of the model enhancements. This will be done using suitable proportions based on population and employment data, rather than by re-running the demand matrix development processes.

9.3.2 It will be necessary to review the model performance against validation data following this. As part of this, a more detailed review of the performance of the rail assignment regarding proportions of passengers using the two Luton stations (town centre and Airport Parkway) will be undertaken. This is in conjunction with the review of Luton Airport public transport demand outlined in Section 9.4.

9.4 Public Transport Demand Refinements: Luton Airport Demand

9.4.1 As with the base year highway demand matrices, it is assumed that 2016 public transport demand for employees and passengers will be provided to AECOM within the required timescales set out in Section 13.

9.4.2 In terms of the existing demand data for travel to / from Luton Airport, both passengers and employees are likely to have been captured in the ticket data collected as part of the development of the existing CBLTM public transport model for scheduled bus and rail travel. The ticket data for bus travel includes information regarding the time of the trip, whereas no time period information is recorded as part of the rail ticket data. The rail ticket data only include the start and end stations for the ticket purchased, and do not include information on the ultimate origin / destination of trips.

9.4.3 The existing CBLTM public transport matrices do not include trips made by coach to / from Luton Airport, as these were not captured in the ticket data provided.

9.4.4 Where possible, information from the existing public transport ticket data will be used to inform and validate the processing of the base year Luton Airport public transport demand.

10 PUBLIC TRANSPORT SUPPLY MODEL

10.1 Introduction

10.1.1 The network used by the CBLTM public transport model consists of roads, railway lines and pedestrian access routes, as well as centroid connectors used to allocate model zones to suitable loading points on the road network.

10.1.2 The assignment in the CBLTM public transport model is frequency-based; therefore it represents intervals between services, but not precise departure times. Rail and bus are modelled and assigned separately, with a public transport sub-mode choice included in the demand model. Mixed-mode public transport trips (for example, bus access to rail) trips are not explicitly modelled.

10.1.3 Public transport fares are included in the assignment and influence route choice. Variations in highway congestion do not directly affect the bus assignment, although an allowance for this effect is made within the variable demand model at a matrix level (as opposed to network level) when calculating bus travel times.

10.2 CBLTM Public Transport Network Development

10.2.1 The road network in the existing public transport model has been taken directly from the CBLTM highway model, converted from SATURN to Emme format using an automated process.

10.2.2 To this has been added rail network, which has been coded manually with reference to GIS maps of UK railway lines. All lines within Central Bedfordshire and Luton Borough have been coded in detail. With increasing distance away from the Fully Modelled Area, fewer lines have been coded.

10.2.3 Walk links connecting railway stations to the road network have been added.

10.2.4 Bus service data have been taken from the Traveline National data set (TNDS). This is updated weekly with information on all bus, tram, light rail and ferry services in Britain. It does not cover rail, coach or underground services.

10.2.5 Rail services within Central Bedfordshire and Luton Borough have been coded manually with reference to online timetables.

10.2.6 Rail services outside of Central Bedfordshire and Luton Borough were not coded in detail as this would have generated excessively detailed service coding in the external area of the model. Instead, line frequencies were manually coded in a simpler way to ensure broadly correct routes and frequencies, without including detailed representation of stopping patterns.

10.3 Public Transport Network Review and Enhancement

10.3.1 The coding of public transport access to Luton Airport will be reviewed as part of this update. All public transport services to and from the airport will be reviewed; however, particular reference will be made to the shuttle bus between Luton Airport Parkway rail station and the airport, and to the coding of coach services that call at the airport.

10.3.2 Some changes to the network coding are expected to ensure that the enhanced model is capable of representing the access / egress routes of passengers and employees to and from the airport.

10.4 Public Transport Calibration and Validation Data Sets

10.4.1 As part of the development of the existing CBLTM public transport model, a number of matrix validation checks have been undertaken, and these are detailed in Section 12 of the Local Model Validation Report (LMVR). These compare the base year matrices against independent data sources to compare trip-rates, trip-lengths and purpose splits.

10.4.2 Checks have also been undertaken on the routeing and journey times within the public transport assignment, and these are detailed within Section 14 of the LMVR.

10.4.3 Finally, comparisons of the modelled flows against the observed bus counts (detailed in Section 5.6) have been undertaken.

10.4.4 No additional bus or rail surveys are proposed to be conducted as part of this model enhancement; however, a comparison of the Luton Airport public transport demand against survey data (CAA and Luton Airport employees) will be undertaken.

10.5 Public Transport Assignment Calibration and Validation

10.5.1 As part of the validation of the enhanced public transport model, the validation tests of the matrices against observed data and the route choice validation will be repeated. In addition to this, a further comparison of the matrices against existing Luton Airport survey data will be undertaken.

10.5.2 As with the existing public transport model, it is not expected that matrix estimation will be applied. This is due to the relative confidence in the data underpinning the demand matrices and the observed passenger surveys. Considering bus demand, the matrices are based on three months of ticket data, which will capture day-to-day variation in travel patterns which will not be captured in one-day bus passenger counts (either on-board, or boarding / alighting counts).

11 VARIABLE DEMAND MODEL

11.1 Introduction

11.1.1 The variable demand model estimates the effect of changes in transport infrastructure and travel cost upon patterns of demand. The existing and proposed demand model is an incremental model, considering the changes in cost from the base year models.

11.1.2 The existing and proposed CBLTM variable demand model uses a hierarchical logit structure. The choice models are applied to all person trips and to freight demand, although different options are available within the choice structure for different demand segments. For example, rail freight is not modelled, so there is no mode choice for freight demand, and only public transport and active modes (walking and cycling) are available to no-car owning demand segments.

11.1.3 As part of the model enhancement for the assessment of the proposed Luton Airport expansion, the demand model will be used to forecast only non-airport trips. Non-airport demand forecast by the demand model will be combined with the forecast Luton Airport demand within the highway and public transport assignments.

11.1.4 Forecasts for Luton Airport passengers, employees and freight are assumed to be made externally to the model, and are assumed to be an input provided to AECOM. Forecast mode shares for surface access trips by passengers and employees are to be derived externally to the CBLTM suite, given the specific characteristics and behaviour of these trips.

11.2 Demand Choice Structure

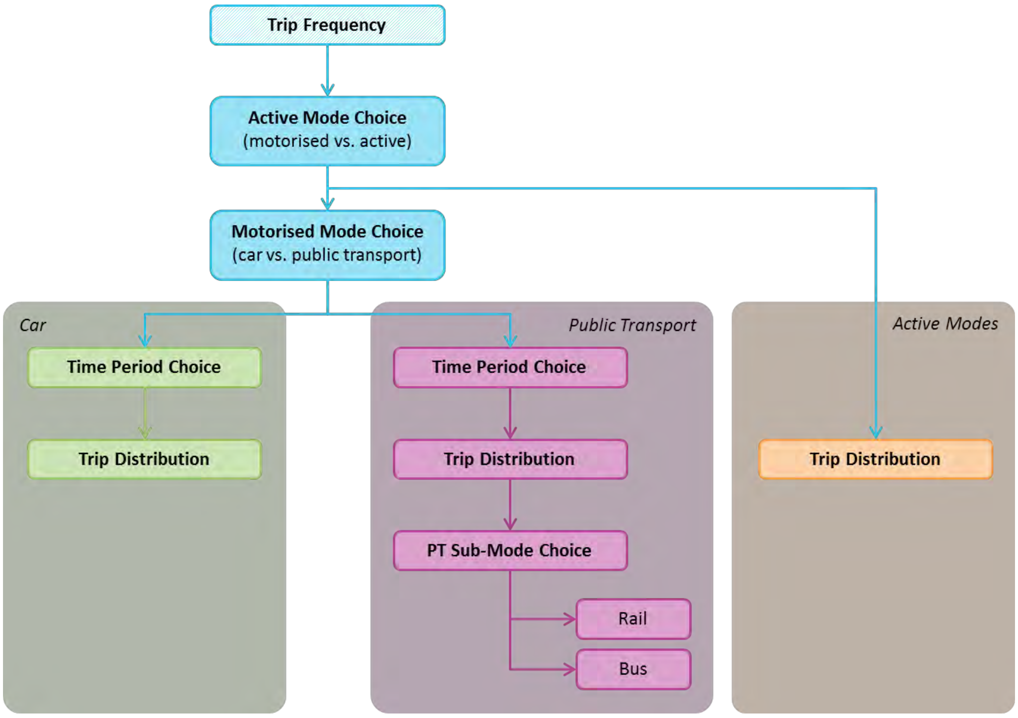
11.2.1 The existing and proposed CBLTM demand model includes the following choice models in order of increasing sensitivity:

- trip frequency;
- motorised versus active mode choice;
- motorised mode choice between car and public transport;
- time period choice;
- attraction choice (trip distribution); and
- public transport sub-mode choice between rail and bus.

This hierarchy is illustrated in Figure 11.1.

11.2.2 Trip frequency is currently only applied for 'other' trips within the existing CBLTM demand model, and this assumption will be reviewed as part of the model enhancement for this study.

Figure 11.1 Demand Model Choice Hierarchy (Non-Airport Demand)



11.2.3 The hierarchy detailed in Figure 11.1 is that applied to personal travel for car-owning households. Variations on this choice structure are applied to other segments of demand, where certain options are not available. For example, no-car-owning households do not have the option of 'car' travel, and so their mode choice is between public transport and active modes.

11.2.4 It is worth noting that the time period choice contained within the variable demand model is between the four periods set out in Table 4.1. Demand choosing to travel in the AM Peak Period (07:00 to 10:00) then has a fixed set of peak hour factors applied to generate AM Peak hour (08:00 to 09:00) assignment demand for the highway model.

11.2.5 The proposed variable demand model therefore will represent macro-level time period choice, and will not represent more detailed time period choice, such as peak spreading.

11.3 Demand Data Sources

11.3.1 The demand model will operate using 24-hour production / attraction, person trip demand. The demand model includes macro-level time period choice, and will include factors to convert the demand forecast by the demand model to assignment matrices.

11.3.2 The development of the base year highway and public transport demand matrices are discussed in Section 7 and Section 9 respectively.

11.3.3 In addition to travel by highway and public transport, the demand model will also include a representation of active mode (walking and cycling) demand.

11.3.4 The active mode demand will be synthetic, based on trip-ends and trip-length profiles. A default assumption in forecasting will be that the cost of active mode travel is unchanged over time, but the structure of the model will permit adjustments to active mode costs if necessary.

11.3.5 Given the nature of the assumptions underpinning the active mode representation within the enhanced CBLTM, the active mode forecasts themselves from the model should not be used within the appraisal of the proposal. It is considered unlikely that non-airport active mode travel will be critical to the assessment.

11.4 Generalised Cost Calculation

11.4.1 The CBLTM demand model responds to changes in generalised cost. For the highway generalised cost, the functions below are used, derived from WebTAG Unit M2. The data are expressed in minutes, pence and kilometres, except where otherwise stated.

$$FuelCost = F * D * i * \left(\frac{f_a}{v} + f_b + f_c * v + f_d * v^2\right)$$

$$NonFuelCost = D * \left(n_a + \frac{n_b}{v}\right)$$

$$GenCost_{Highway} = Time + \left(\frac{FuelCost + NonFuelCost}{ValueOfTime * VehOcc}\right)$$

where:

- F is the fuel cost in pence per litre;
- D is the assigned distance in kilometres;

- v is the average assigned speed for the matrix cell in kilometres per hour;
- i is the fuel efficiency improvement factor, which reduces fuel consumption over time;
- f_a, f_b, f_c, f_d are fuel cost parameters (defined by WebTAG); and
- n_a, n_b are non-fuel cost parameters (defined by WebTAG, and assumed to be zero for non-work trips).

11.4.2 Public transport calculations use generalised costs (expressed in minutes) that are skimmed from the public transport model.

$$GenCost_{PT} = Time_{InVehicle} + 2.5 * Time_{Walk} + 2 * Time_{Wait} + BoardingPenalty + \frac{Fare}{ValueOfTime}$$

11.5 Cost Dampening

11.5.1 In forecasting, the demand model will consider the forecast changes in travel costs from the base year. As the model covers all of Great Britain (albeit in a lower level of detail in the external areas of the model), it includes a wide range of trip-lengths, from less than 1 kilometre to over 1,000 kilometres.

11.5.2 The sensitivity of the demand response to a ten-minute change in travel time would be expected to be larger for a 30-minute journey compared with a six-hour journey; however, in the direct application of the choice functions defined in WebTAG, the response would be similar irrespective of trip-length.

11.5.3 In order to represent the variation of responses with trip-length, and to produce a model with an acceptable overall sensitivity to changes in cost (discussed in Section 11.7), the following function is proposed to be applied based on guidance contained in WebTAG Unit M2, Paragraph 3.3.11.

$$CostDampeningFactor = min\left(\frac{\sqrt{d_1}}{\sqrt{distance}}, 1\right)$$

where d_1 is a calibration parameter, with a starting value of 30kms as defined within WebTAG.

11.5.4 In addition to this, we intend to vary the value of time for non-work trips by trip-length, which is a second form of cost dampening. This methodology is described in WebTAG Unit M2, Section 3.3, with the variation in non-work value of time defined as follows:

$$VoT = max\left(VoT_c\left(\frac{D}{D_0}\right)^{n_c}, VoT_c\left(\frac{D_c}{D_0}\right)^{n_c}\right)$$

where:

- VoT_c is the central value of time as defined in the WebTAG databook;
- D is the trip-length; and
- D_0, D_c and n_c are calibrated parameters.

11.5.5 Initial values for the parameters defined above are given in WebTAG Unit M2, and these will be adjusted to ensure that the average value of time weighted by trip-distance are approximately the central values provided within the WebTAG data book.

11.5.6 It is noted that the value of time for business trips also varies by trip distance within WebTAG; however, this is not part of the application of cost dampening, but is part of the core guidance contained within WebTAG.

11.5.7 As specified within WebTAG Unit M2, we will assess the demand model sensitivity both without and with the cost dampening measures detailed above to confirm that such measures are required; however, our experience is that it is highly likely that cost dampening will be required.

11.6 Demand-Supply Iteration and Convergence

11.6.1 The highway and public transport supply (assignment) models and the demand model are run in sequence iteratively until the CBLTM demand model is deemed to have converged. The costs from the supply models and functions are fed into the demand calculations, with the resulting demand used to recalculate the costs. This process continues until convergence.

11.6.2 As defined within WebTAG Unit M2, Section 6.3, the convergence of this process is assessed by considering the change in demand estimates between two iterations of the demand model using the following equation:

$$\%Gap = 100 * \frac{\sum_a C_a^{n-1} * |D_a^n - D_a^{n-1}|}{\sum_a C_a^{n-1} D_a^{n-1}}$$

where:

- D_a^{n-1} is the demand from the previous iteration;
- C_a^{n-1} are the generalised costs from the assignment of D_a^{n-1} within the highway and public transport models;

- D_a^n is the demand forecast using the current estimate of generalised costs, C_a^{n-1}; and
- a represents every combination of production and attraction zone, demand segment, time period and mode.

11.6.3 We will seek to achieve a $\%Gap$ value of less than 0.1% for the variable demand model, although WebTAG acknowledges that values closer to 0.2% may be required in congested locations.

11.6.4 Demand smoothing is proposed to be used to improve the speed with which the model convergences. Following choice model calculations, new demand is calculated, from which the $\%Gap$ is calculated prior to the averaging process which is then applied to the demand matrices before they are reassigned in the supply models in the next iteration of the demand model.

11.6.5 The demand smoothing uses the following function, a variation of the method of successive averages (MSA) algorithm that AECOM has adopted in existing demand models:

$$\widehat{D}_{x+1} = \frac{2D_x + (x-3)D_{x+1}}{x-1}$$

where:

- x is the current demand model iteration;
- D_x is the demand estimated in for use in the current iteration of the demand model; and
- D_{x+1} is demand estimated from the costs generated by the assignment of demand D_x onto the highway network.

11.6.6 Model testing has demonstrated that this variant of the standard MSA algorithm produces better overall model convergence, as it gives more weight to the demand calculated within the more recent demand-supply iterations. The algorithm is of course only applied when x is four or greater; therefore for the first three iterations no smoothing is applied.

11.7 Realism Testing

11.7.1 The validation of the CBLTM demand model is a consideration of the realism tests and recommended acceptable values or ranges of values for model sensitivity, generally derived from WebTAG Unit M2, Section 6.4. A number of realism tests will be undertaken to demonstrate that the modelled demand responses are plausible, both in the direction and scale of change.

11.7.2 Elasticities represent a measure of how rapidly one dependent variable (trips or vehicle-kilometres in this context) changes with respect to an independent one, and are defined by the following expression:

$$Elasticity = \frac{log_e\left(\frac{d_t}{d_b}\right)}{log_e\left(\frac{i_t}{i_b}\right)}$$

where:

- d_t and d_b are the test and base value for the dependent variable respectively; and
- i_t and i_b are the test and base value for the independent variable respectively.

11.7.3 In calculating elasticities, we propose not to use the entire demand in the model, as most of this is external to the area of interest, with the majority of external demand being intra-zonal movements. This demand is modelled approximately, and is not representative of the internal area of interest. Accordingly, matrix calculations will be performed on only demand produced within the internal area of the model, and highway network calculations only traffic on the highway network within the same area.

11.7.4 This approach of excluding external demand from the elasticity calculation required for the realism testing is consistent with the approach set out in WebTAG Unit M2, Paragraph 6.4.13.

11.7.5 WebTAG advises that four main realism tests should be carried out:

- 10% increase in car fuel costs: expected elasticity of car vehicle-kms to be between -0.25 and -0.35
- 10% increase in car travel times: expected elasticity of car demand between 0 and -2 (single iteration; no convergence to equilibrium).
- 10% increase in public transport fares: expected elasticity of public transport demand between -0.2 and -0.9
- As above, but with the 10% increase in fares applied to bus fares only.

12 FORECASTING

12.1 Introduction

12.1.1 The preceding sections within this Model Specification Report detail the development of the base year models for the highway, public transport and variable demand model components of the enhanced CBLTM to be developed for the purposes of assessing proposed expansion at Luton Airport.

12.1.2 This section details the process by which the forecast year scenarios will be produced based on these 2016 base year models.

12.2 Collation of Forecasting Assumptions and Uncertainty Log

12.2.1 In order to produce a set of model forecast, assumptions are required on the changes in land-use and transport infrastructure over time. The outcome of this review is an Uncertainty Log, where the certainty of each potential change is assessed against the criteria detailed in WebTAG Unit M4, Table A2, and reproduced in Table 12.1.

12.2.2 We assume that the development of the Uncertainty Log will build on the existing forecasting assumptions collated for the CBLTM. These existing assumptions will be reviewed against the latest available information on land-use changes and infrastructure changes. Particular attention will be given to the land-use and network changes assumed in the vicinity of Luton Airport.

12.2.3 We assume that the 'central' forecasts for this application will adopt the WebTAG advice of including only those schemes (both land-use and infrastructure) which are 'near certain' or 'more than likely' as defined within Table 12.1.

12.2.4 It is however recognised that sensitivity testing may be required to understand the impact of alternative growth assumptions and other infrastructure schemes, which may be classed as 'reasonably foreseeable' or 'hypothetical'. The model structures will be defined to allow for sensitivity testing on the land-use and network infrastructure assumptions.

Table 12.1: Classification of Future Inputs (WebTAG Unit M4, Table A2)

Probability of the Input	Status	Core Scenario Assumption
Near certain: the outcome will happen or there is a high probability that it will happen.	Intent announced by the proponent to regulatory agencies. Approved development proposals. Projects under construction.	This should form part of the Core Scenario.
More than likely: the outcome is likely to happen, but there is some uncertainty.	Submission of planning or consent application imminent. Development application within consent process.	This could for part of the Core Scenario.
Reasonably foreseeable: the outcome may happen, but there is significant uncertainty.	Identified within a development plan. Not directly associated with the transport strategy / scheme, but may occur if the strategy / scheme is implemented. Development conditional upon the transport strategy / scheme proceeding. Or, a committed policy goal, subject to tests whose outcomes are subject to significant uncertainty.	These should be excluded from the Core Scenario, but may form part of the alternative scenarios.
Hypothetical: there is considerable uncertainty where 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. Or, a policy aspiration.	These should be excluded from the Core Scenario, but may form part of the alternative scenarios.

12.3 Non-Airport Travel Forecasting

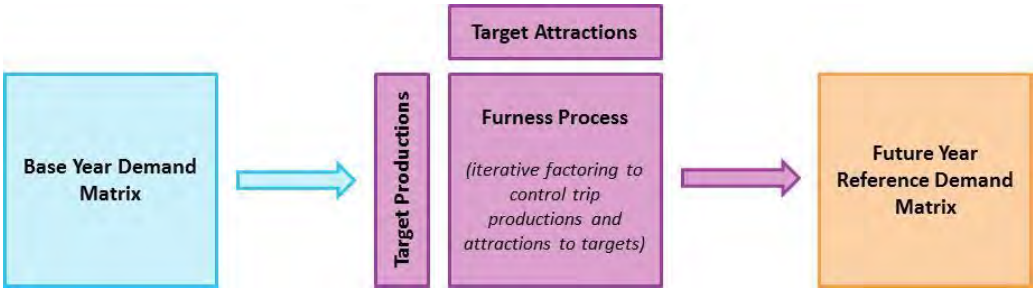
12.3.1 As part of the model development, a trip-end model will be produced. This will be a variant of the DfT's CTripEnd software which underpins the TEMPro v7.2 forecasts, with the zone system adopted within CTripEnd updated to reflect the model zoning. This is the approach adopted within the existing CBLTM suite.

12.3.2 This trip-end model will be used throughout the development of the base year models to provide an estimate of base year trip-ends, and this process will be adopted within forecasting using the agreed planning forecasts for a given scenario.

12.3.3 Using the trip-end forecasts from the trip-end model, the base year demand by mode and trip purpose will be uplifted to the given forecast year using the growth rate implied by the forecast trip-ends compared with the base year trip-ends. This process creates forecast 'reference demand' matrices.

12.3.4 This uplift process will apply a Furness procedure on the base year matrix to the base year trip-ends with growth applied. This approach retains, as much as possible, the trip patterns observed within the base year matrices, whilst also adjusting these matrices to reflect the changes in land-use. This process is illustrated within Figure 12.1.

Figure 12.1 Reference Demand Process



12.3.5 Trip-end forecasts will not provide estimates for freight demand, as CTripEnd produces forecasts for personal travel only. Using TRICS trip-rates applied to the forecast employment, forecast freight growth will be developed and applied to the base year freight demand using the same approach as adopted for personal travel.

12.3.6 The forecast freight growth will be constrained to the growth contained in the latest available Road Traffic Forecasts (RTF), derived from the National Transport Model (NTM). This ensures consistency with national forecasts.

12.3.7 This 'reference demand' forms the starting point for the variable demand model, which then adjusts this reference demand in response to changes in travel costs, including changes to economic parameters such as values of time and fuel costs.

12.3.8 It is important to note that the forecast trip generation for key developments within the vicinity of Luton Airport will be based on TEMPro trip-rates and the time period, vehicle occupancy and peak hour factors produced as part of the matrix development. Application of similar models elsewhere suggests that these forecasts may not agree with the trip generation estimates produced as part of the Transport Assessment of these developments.

12.3.9 As part of the review of the initial forecasts (discussed in Section 13), where possible we will review the forecast trip generation for key development sites (such as Century Park, Bartlett Square and Napier Gateway) against available data from Transport Assessments. Where significant differences are found between the model forecasts and the Transport Assessments, changes to the model forecasting assumptions will be made to closer represent the assumed trip generation for these key developments.

12.3.10 As discussed, the CBLTM demand model is a pivot-point incremental model that estimates changes in trip patterns relative to a reference matrix derived from detailed observation of travellers. The predicted relative changes are applied to the reference matrix, so that the characteristics of the reference matrix are reflected. This is in-line with the recommendation contained within WebTAG Unit M2, Paragraph 4.3.12.

12.3.11 In the preparation of a model forecast, the model pivots from the base year model, calculating the difference in generalised cost of travel between the given forecast year and the base year. Within this, freight demand is fixed as that forecast based on the base year matrix with growth (based on TRICS trip-rates, controlled to RTF). This is in-line with WebTAG Unit M2, Paragraph 1.15 which states that *“it is often sufficient to assume that total freight traffic is fixed, but susceptible to rerouteing”*.

12.4 Airport Travel Forecasting

12.4.1 The forecasting processes detailed above will be used to forecast all travel demand with the exception of demand to / from Luton Airport. This includes passengers, employees and freight to / from the airport.

12.4.2 The specification of the enhanced CBLTM assumes that these forecasts for airport passengers, employees and freight will be provided to AECOM. They will not be included within the variable demand model, but will be added to the highway and public transport assignment matrices to include their trips on the network and their impact on travel costs.

12.4.3 It is assumed that forecast airport demand data will be provided by modelled time period (AM Peak hour, average interpeak hour, PM Peak hour, average off-peak hour[5]) and by model zone (including the ultimate origin / destination and the detailed trip-end within the airport).

12.4.4 We will make best use of the data provided for forecast Luton Airport travel demand; however it is outside of the scope of this model specification to undertaken significant processing of the forecasts provided. For example, we are not proposing to

[5] If off-peak airport demand data is not available, an estimate will be made based on the average interpeak hour forecasts.

develop a trip distribution or parking model for Luton Airport passengers, employees or freight.

13 INDICATIVE PROGRAMME

13.1 Indicative Programme

13.1.1 A programme of work for the proposed update to the CBLTM suite will be finalised once this Model Specification Report is signed-off; however, this section provides an overview of the likely programme from model development through to the production of model forecasts based on the scope of work detailed in this Model Specification Report.

13.1.2 Within the programme, an initial phase of forecast modelling has been defined. Within this task the 'central' without and with Luton Airport expansion forecasts will be produced and subsequently reviewed. This initial phase of model forecasts therefore includes:

- 2021 representing 18 million passengers per annum (mppa)
- 2023 representing both without expansion (18 mppa) and with expansion (21 mppa)
- 2035 representing both without expansion (18 mppa) and with expansion (30 mppa)
- 2042 representing both without expansion (18 mppa) and with expansion (38 mppa)

13.1.3 These forecasts will be reviewed to assess the travel demand forecasts for significant developments in the vicinity of Luton Airport and the performance of the highway networks with forecast year demand. Where required, adjustments will be made to the forecasting modelling assumptions in response to this review.

13.1.4 Should any adjustments to the forecasting assumptions be required, the second phase of model forecasts will include a re-run of these 'central' forecasts incorporating any changes. In addition to this, the second round of forecasting will also include a number of sensitivity tests to understand the variation in the model forecasts with alternative assumptions.

13.1.5 The exact specification of the sensitivity testing to be undertaken is uncertain at the time of writing; however, it is assumed that the sensitivity testing will consider alternative land-use scenarios for growth in housing and / or employment and alternative mode share assumptions for trips to / from Luton Airport. Forecast model runs beyond 2042 may also be required by Highways England.

13.1.6 Table 13.1 provides a summary of the assumed 19 forecast year scenarios to be produced as part of this assessment.

Table 13.1: Summary of Forecast Model Scenarios

Scenario	2021	2023	2035	2042	Post-2042
Central "Without Expansion" Forecasts	✓	✓	✓	✓	✓
Central "With Expansion" Forecasts		✓	✓	✓	✓
Alternative Mode Share "With Expansion" Forecasts			✓	✓	
Alternative Land-Use v1 "Without Expansion" Forecasts			✓	✓	
Alternative Land-Use v1 "With Expansion" Forecasts			✓	✓	
Alternative Land-Use v2 "Without Expansion" Forecasts			✓	✓	
Alternative Land-Use v2 "With Expansion" Forecasts			✓	✓	

13.1.7 Table 13.2 and Figure 13.1 provide an overview of the assumed indicative programme, with Figure 13.1 highlighting the critical path activities.

Figure 13.1 Summary of Indicative Programme

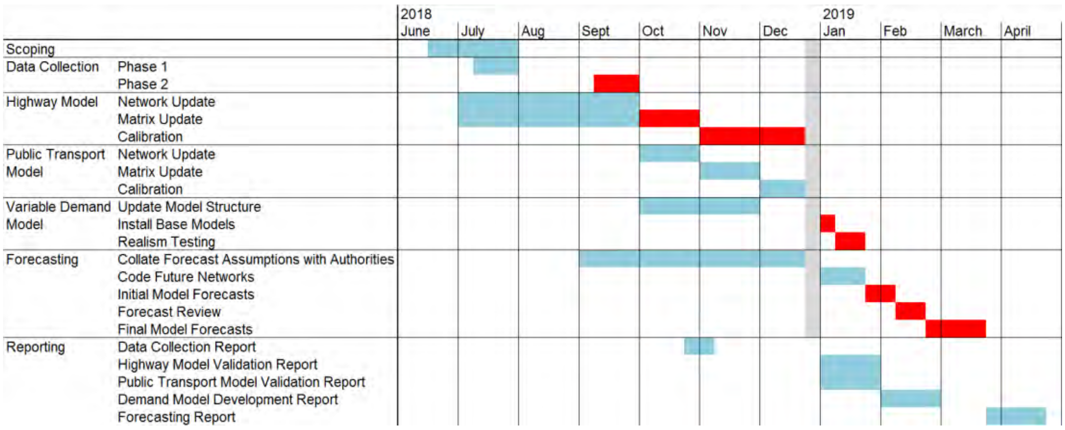


Table 13.2: Summary of Indicative Programme

Task		Timescale
Scoping		Mid-June through July 2018
Data Collection	Phase 1	July 2018
	Phase 2	September 2018
Highway Model	Network Update	July through September 2018
	Matrix Update	July through October 2018
	Calibration	November through December 2018
Public Transport Model	Network Update	By November 2018
	Matrix Update	By December 2018
	Calibration	December 2018
Variable Demand Model	Update Model Structure	By January 2019
	Install Base Models	Early January 2019
	Realism Testing	Mid-January 2019
Forecasting	Collate Forecast Assumptions	By January 2019
	Code Future Networks	Mid-January 2019
	Initial Model Forecasts	Late January / Early February 2019
	Forecast Review	Mid- February 2019
	Final Model Forecasts	Late February to mid- March 2019

13.1.8 Within this programme of work a number of Project Reports detailing the work undertaken during the development of the updated CBLTM suite and the model forecasts will be produced. It is expected that these will be:

- Data Collection Report (late-October / early-November 2018): detailing the surveys undertaken as part of this model update.
- Highway Model Validation Report (January 2019): detailing the development and performance of the updated highway assignment model.
- Public Transport Model Validation Report (January 2019): detailing the development and performance of the updated public transport assignment model.
- Demand Model Development Report (February 2019): detailing the development and performance of the updated variable demand model.
- Forecasting Report (April 2019): detailing the forecasting assumptions and key model forecasts for the scenarios

produced as part of the assessment of the proposed airport expansion.

13.1.9 Figure 13.1 shows that a key item within the programme is the second phase of data collection, expected to be undertaken in September 2018. The count data collected during September (expected during the middle two weeks of the month) will be processed by the survey company, and will then require checking and processing by ourselves prior to use in the model. On this basis we do not expect to be able to use the full count dataset until mid-October.

13.1.10 Finalising the traffic survey data then allows work to review the performance of the highway prior matrices to commence, and then subsequently allow work on the calibration of the highway model to begin.

13.1.11 The date of this second phase of data collection cannot be brought forward (due to the school summer holidays), and is critical in determining the overall strategic modelling programme.

13.1.12 This data collection in September 2018 also provides an opportunity during August and September 2018 to review and enhance the highway network coding and prior matrices. Reducing the scope of these review and update tasks from those detailed in this Model Specification Report would not reduce the overall strategic modelling programme.

13.1.13 It is also worth noting that forecast models will be available for use by other workstreams of work prior to mid-March. As each model run is undertaken and reviewed, the results of these forecasts will be made available to other workstreams. It is therefore expected that the first set of model forecasts will be made available in late-February.

13.1.14 The following are other comments on the indicative programme:

- Work to update the public transport model can be undertaken at any time between an agreement of scope and the end of December 2018, and would most likely be undertaken during late summer / autumn 2018.
- Similarly, work to update the variable demand model structures can be undertaken at any time before the end of December 2018.
- We have assumed two rounds of model forecasts. An initial set of forecasts will be followed by a period of review, with any adjustments / corrections to the model forecasts incorporated into the second round of forecasting.

14 KEY ASSUMPTIONS

14.1 Summary of Key Assumptions

14.1.1 Throughout this Model Specification Report, a number of key assumptions have been highlighted. Further detail on these items can be found within the text; however, Table 14.1 provides a summary of these key assumptions.

Table 14.1: Summary of Key Assumptions

Paragraph	Assumption
Paragraph 2.1.4	As part of the specification of the updated CBLTM suite, it has been assumed that charging policies (such as offsite road tolls) are not required to be assessed within the strategic modelling. As such, income segmentation within the model suite has been considered, but will not be represented.
Paragraph 2.2.2 and Paragraph 11.1.4	We assume that travel demand for the 2016 base year and forecast years for employee, passenger and freight to / from Luton Airport will be provided to AECOM for use within the strategic assessment of the proposed development. (See Section 12.4 for further discussion on airport travel demand forecasts.)
Paragraph 2.2.10	Retaining a 2016 base year for the strategic modelling will introduce an inconsistency between the strategic and microsimulation modelling, and between the strategic modelling and the noise / air quality assessment, which will need to be considered as part of the use of data from the strategic modelling.
Paragraph 4.6.6	It is not proposed to include a specific taxi user class for trips to / from Luton Airport, with travel to / from Luton Airport via taxi considered in the same way as other highway airport passenger trips.
Paragraph 8.3.22	As with the calibration of any highway model, whilst AECOM will work towards meeting WebTAG acceptability criteria, the calibration process cannot, and does not, guarantee any particular level of calibration or validation of the highway model against these WebTAG criteria.
Paragraph 11.2.5	The proposed variable demand model therefore will represent macro-level time period choice, and will not represent more detailed time period choice, such as peak spreading.

Appendix C: Strategic Modelling Data Collection Report

London Luton Airport Expansion Development Consent Order

Strategic Modelling: Data Collection Report

23 September 2019

Report ref: LLADCO-3B-AEC-00-00-RP-CH-0004

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1 INTRODUCTION

1.1 Context

1.1.1 London Luton Airport Limited is preparing to secure the necessary consents to allow London Luton Airport to grow beyond the current permitted capacity of 18 million passengers per annum (mppa).

1.1.2 The strategic modelling tool identified to assess the proposed Luton Airport expansion has been developed based on the existing Central Bedfordshire and Luton Transport Model (CBLTM). This model has been enhanced and updated for the purposes of assessing the proposed expansion creating an updated version of CBLTM, hereafter referred to as CBLTM-LTN. The specification of the update to the CBLTM is detailed in *'Luton Airport Surface Access - Strategic Modelling - Model Specification Report'*.

1.1.3 In addition to the strategic model, a Vissim microsimulation model is being developed to assess the operation of the road network in the vicinity of Luton Airport. The CBLTM-LTN will be used to work with this microsimulation model to provide an assessment of the transport networks with the proposed expansion.

1.1.4 As part of the update to the CBLTM, best use of existing data and data collected as part of the development of the microsimulation model has been made; however, some additional traffic count surveys were required for the purposes of the strategic modelling.

1.1.5 This report details the traffic count surveys commissioned by AECOM for the purposes of developing the CBLTM-LTN, and also provides an overview of the existing data sources used as part of the development of the 2016 base year highway and public transport assignment models.

1.2 Structure of Data Collection Report

1.2.1 In addition to this introduction, this Data Collection Report includes the following sections:

- Section 2: Highway Traffic Count Survey Data – discussing the collation of the traffic count survey data used as part of the calibration and validation of the highway model.

- Section 3: Highway Journey Time Survey Data – this section details the journey time data used as part of the validation of the highway model.
- Section 4: Highway Demand Data – this section summarises the observed highway demand used within the development of the model.
- Section 5: Public Transport Data – this section provides a summary of the data used in the development of the public transport model contained within the CBLTM-LTN.

2 HIGHWAY TRAFFIC COUNT SURVEY DATA

2.1 Introduction

2.1.1 A review of available traffic count survey data was undertaken for the expansion and update of the CBLTM-LTN model. This considered data available from the existing CBLTM, Hertfordshire’s county-wide model (COMET) and Highways England’s WebTRIS database. In addition to this, traffic count survey data collected as part of the development of the microsimulation model for the assessment of the proposed Luton Airport expansion were reviewed.

2.1.2 In addition to the existing screenlines and cordons defined as part of the development of the existing CBLTM, new screenlines and cordons were defined for the CBLTM-LTN making use of existing traffic survey data where possible. These have focussed on traffic flows in the vicinity of Luton Airport and on routes within Hertfordshire to the east and south of the airport.

2.1.3 Where additional traffic count survey data were required to define these screenlines and cordons, new survey data have been collected. This data collection has been undertaken in two phases: early July 2018; and mid-September 2018.

2.1.4 Figure 2.1 provides an overview of the collated traffic count survey data for the development of the CBLTM-LTN, along with the defined screenlines and cordons. Figure 2.2 provides the same information, focusing on Luton Borough.

2.1.5 It should be noted that not all counts shown are necessarily part of a screenline or cordon. Some of these counts will be used as individual count locations within the calibration and validation of the base year highway model. For example, a number of traffic count surveys have been collated covering the Strategic Road Network, namely the M1, M25 and A1(M), and these count data will be used as part of the model development.

2.1.6 The following sections provide further details on the traffic data collection undertaken for the model enhancement, and the data cleaning and processing undertaken prior to use of the data within the highway assignment model development.

Figure 2.1 Collated Traffic Count Survey Data – Overview

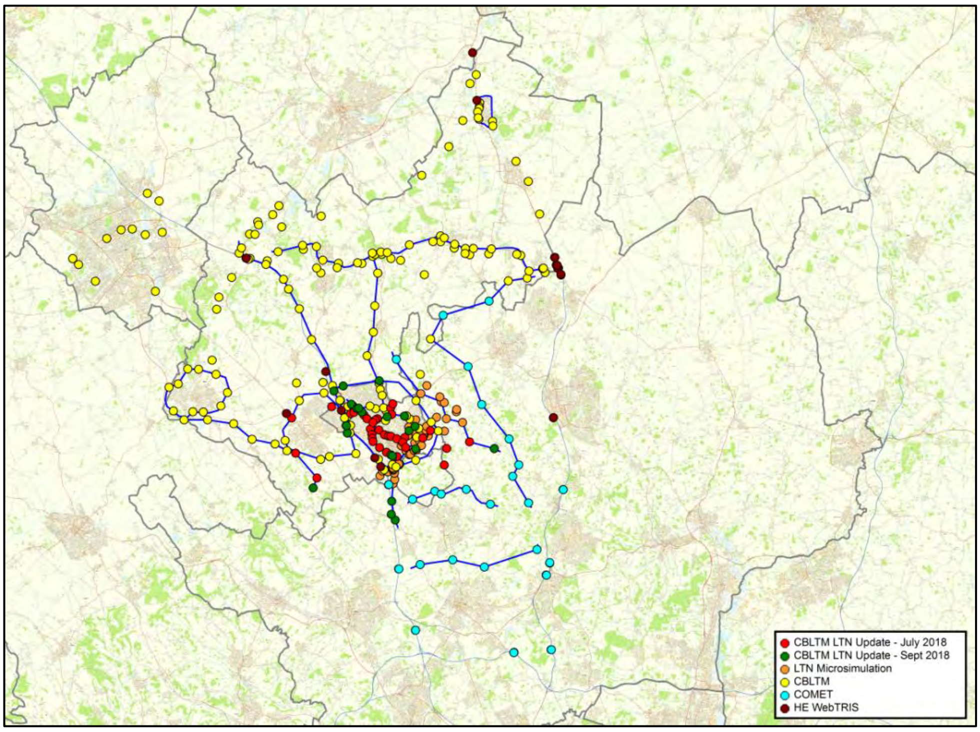

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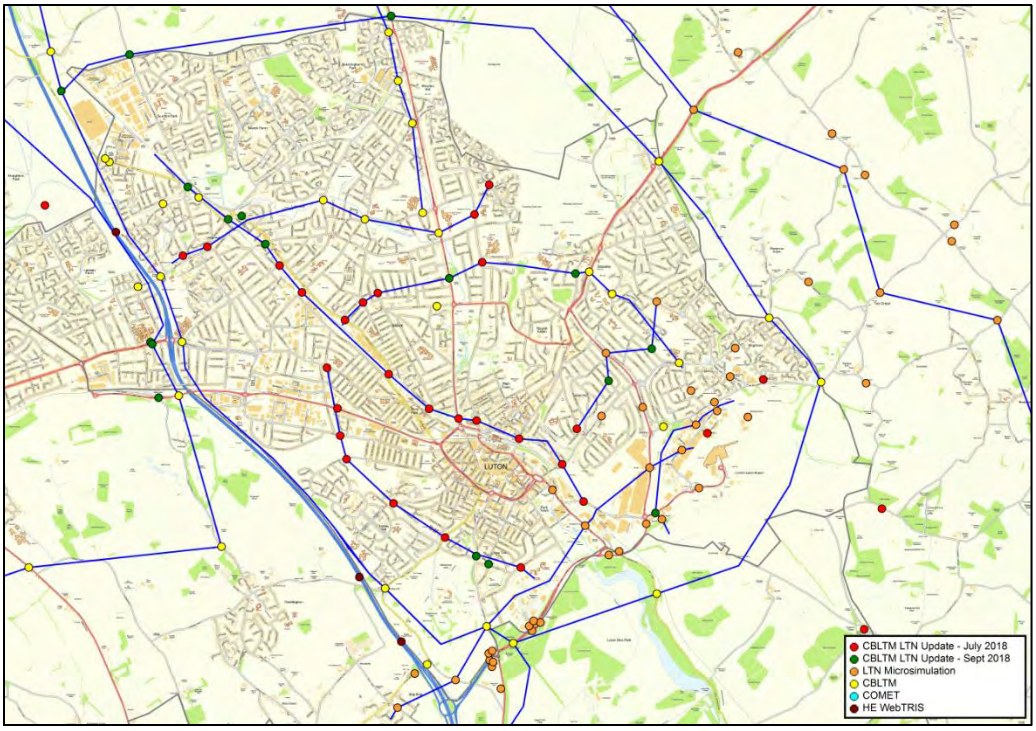
Figure 2.2 Collated Traffic Count Survey Data – Luton Borough



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2.1.7 Figure 2.3 and Figure 2.4 provides further details on the screenlines defined for the calibration and validation of the base year highway model, providing the naming of these screenlines used within the highway Local Model Validation Report (LMVR). Screenlines and cordons shown in blue are those identified for use in calibration of the highway model, with those shown in red identified for validation. Further detail on the calibration and validation of the base year highway model is included in the highway LMVR.

Figure 2.3 Screenline Definitions – Overview

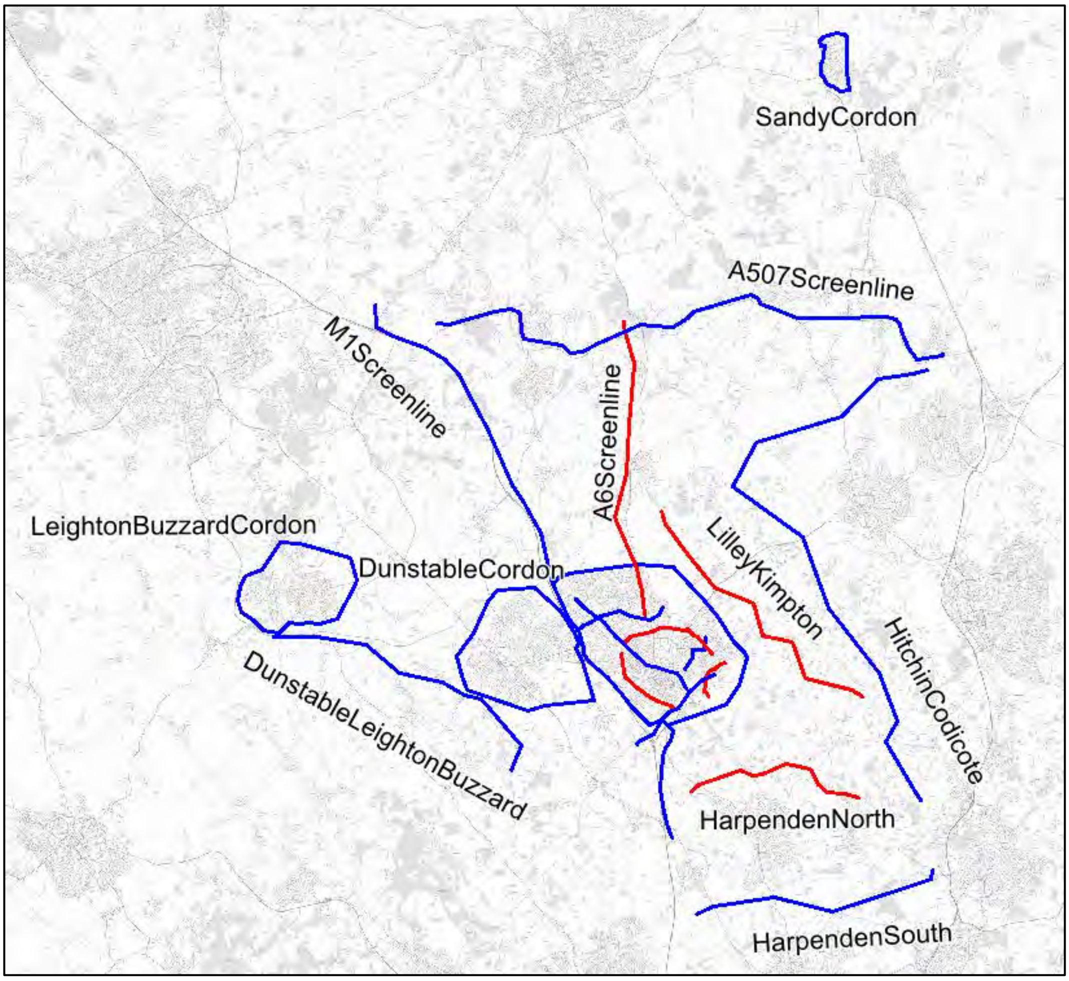

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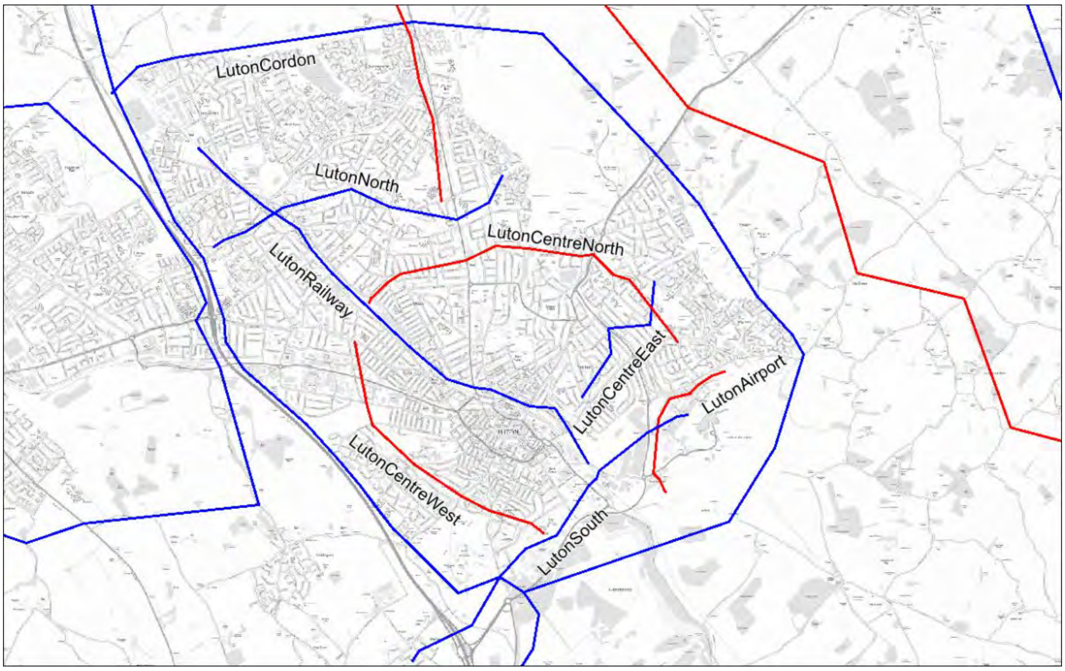
Figure 2.4 Screenline Definitions – Luton



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2.2 Traffic Count Data Collection

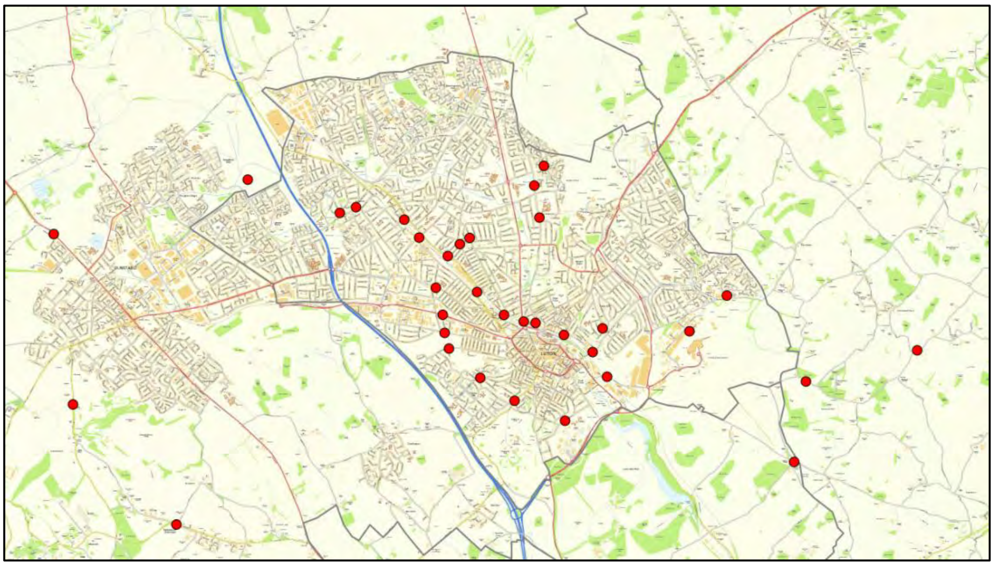
2.2.1 Two phases of traffic count survey data collection have been undertaken as part of the development of the CBLTM-LTN. These were undertaken during July 2018 (Phase 1) and September 2018 (Phase 2), and constitute the only new data collection undertaken specifically for the strategic modelling.

2.2.2 It is noted that the 2016 base year of the highway model represents conditions before the opening of the A5-M1 link and Woodside Link to the north of Dunstable. This change in the highway infrastructure since 2016 will have impacted on the flows in this area, and undertaking new count data collection in the vicinity of the scheme has been avoided wherever possible.

2.2.3 In terms of the Phase 1 July 2018 traffic count surveys, Nationwide Data Collection was commissioned to undertake 38 automated traffic count surveys (ATCs) across Luton, Central Bedfordshire and Hertfordshire.

2.2.4 Traffic count surveys were conducted continuously for two full weeks in July. The survey were undertaken on neutral dates prior to the school summer holidays (Monday 9th July to Friday 20th July) over a full 24-hour day. The locations of these traffic surveys are shown in Figure 2.5.

Figure 2.5 Phase 1: July 2018 Traffic Count Surveys



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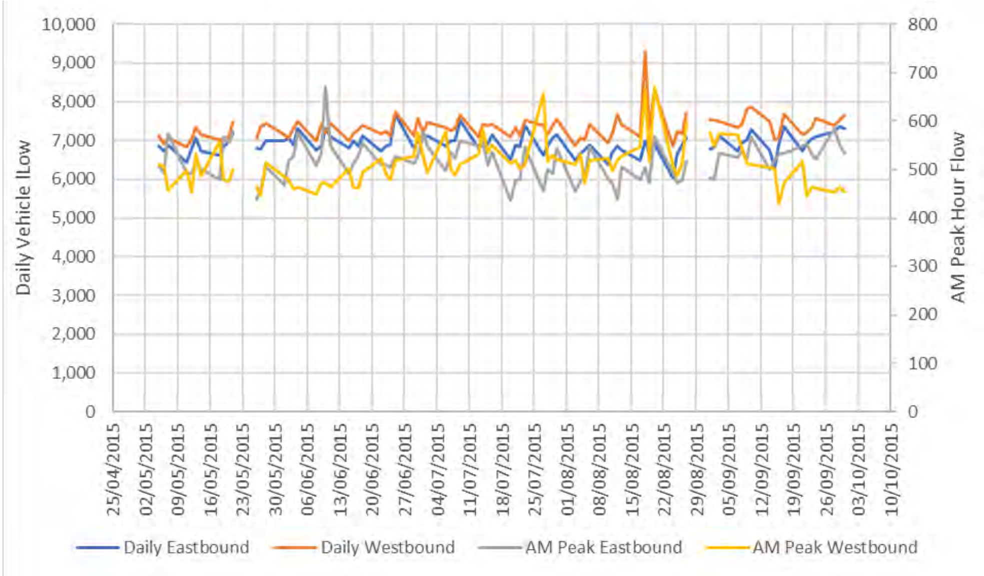
2.2.5 Whilst July is not a neutral month as defined by WebTAG, effort has been made to undertake the Phase 1 surveys as early as possible within July to avoid the school summer holidays. Figure 2.6 shows the pattern of daily and AM Peak hour traffic for May to September for the available long-term traffic count data.

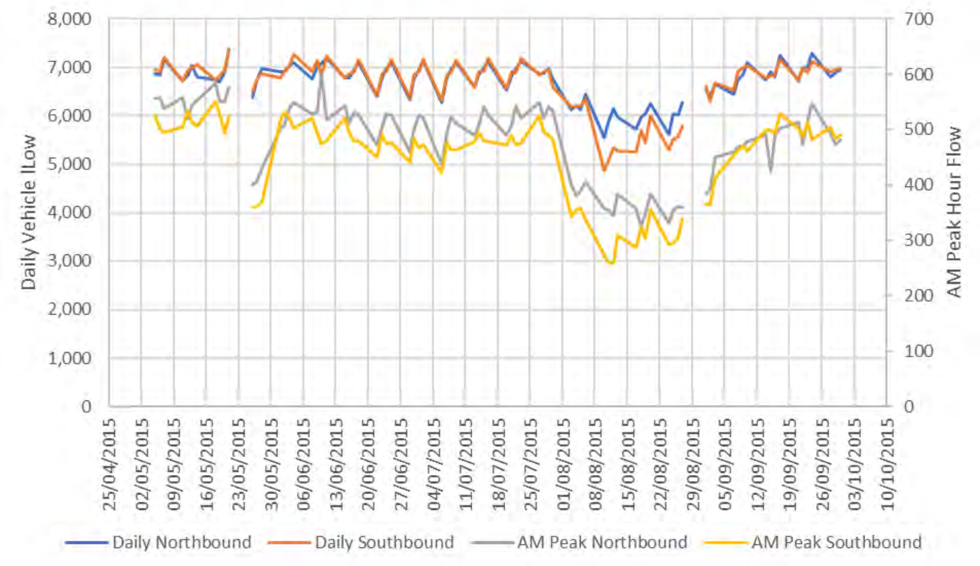
2.2.6 This limited sample suggests that traffic flow levels are not affected by the school summer holidays until the second half of July, suggesting that the use of traffic survey data from the first half of July is representative of a neutral month. Monitoring sites 6 and 90 do not show a significant change in traffic flow levels over the summer period; however, sites 7 and 49 show a reduction in traffic flow level during late-July and August.

Figure 2.6 Observed Traffic Flow Levels over Summer Period

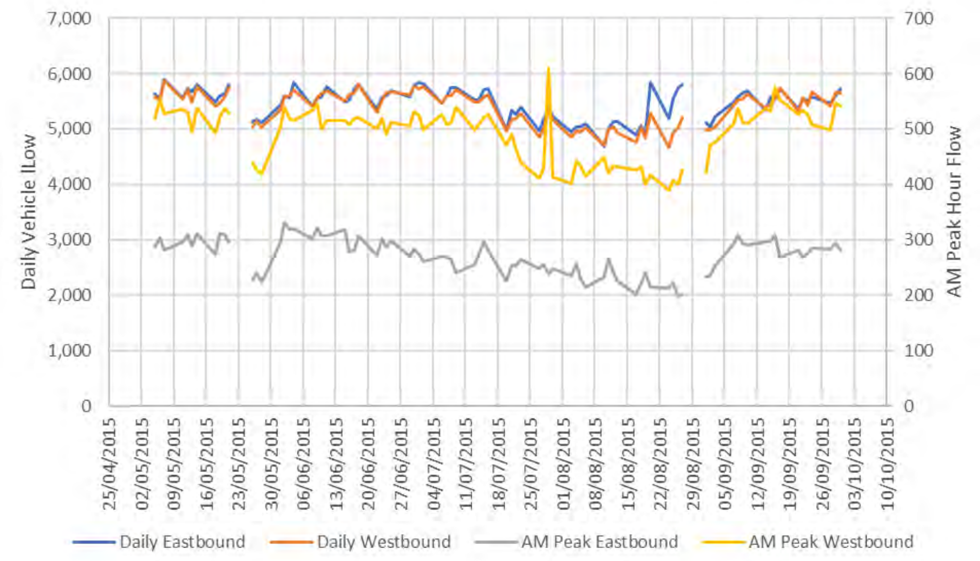
CBC Monitoring Site 6



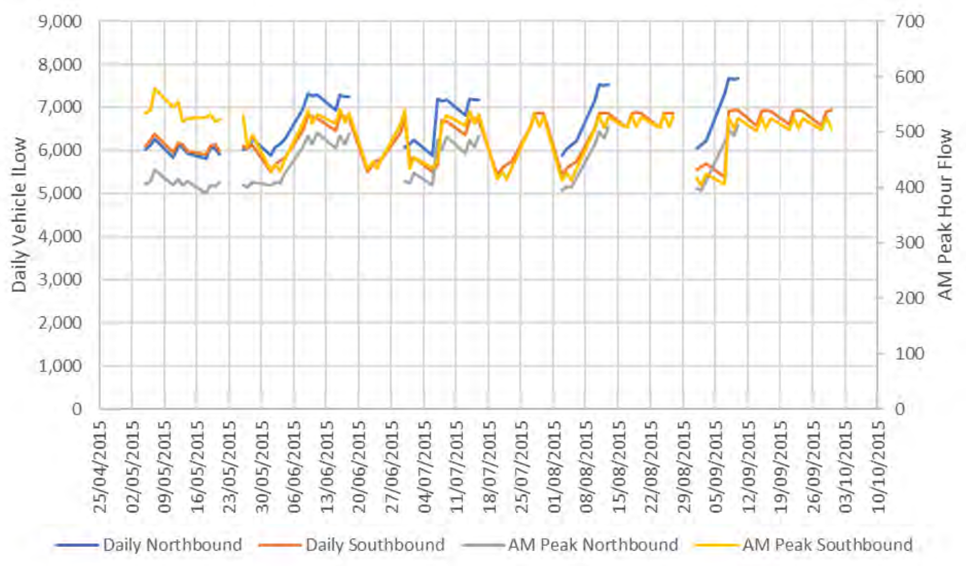
CBC Monitoring Site 7



CBC Monitoring Site 49



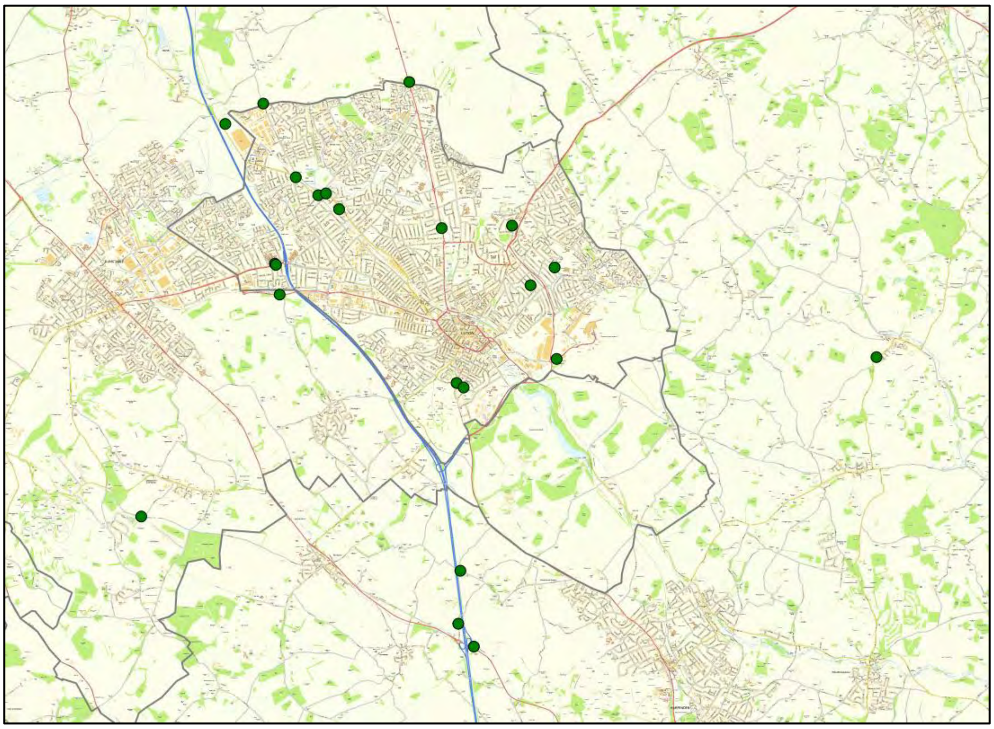
CBC Monitoring Site 90



2.2.7 After the school summer holidays Intelligent Data Collection Ltd was commissioned to undertake an additional 22 automated traffic count surveys across a similar geographical area for Phase 2 data collection.

2.2.8 These surveys were conducted continuously for two full weeks in September. The surveys were undertaken on neutral dates after the school summer holidays (Monday 10th September to Friday 21st September) over a full 24-hour day. The locations of Phase 2 traffic surveys are shown in Figure 2.7.

Figure 2.7 Phase 2: September 2018 Traffic Count Surveys



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2.3 Data Collection Issues

Phase 1 (July 2018)

2.3.1 During the first phase of the traffic count data collection there were nine sites where a loss of data occurred over the two week survey period. Loss of data typically occurred for one or two days out of the 14 days surveyed with no site experiencing more than 3 days of missing data. Loss of data typically occurred due to damage to the count equipment (typically broken tubes) or vehicles being parked on the tubes for a period of time. Any days which experienced a loss of data were subsequently removed from the data set. These sites were:

- Woodside Link east of Pastures Way;
- Beech Rd between Lowther Road and Hollick's Lane;
- Leagrave High Street east of M1;
- A505 Dunstable Rd between M1 Junction 11 and Stoneygate Road;
- Dallow Road between Kingsway and Marlow Avenue;

- Waller Avenue between Leagrave Road and Selbourne Road;
- B579 Leagrave Road between Althorp Road and Selbourne Road;
- Waldeck Road between Biscot Road and Bury Park Road; and
- Airport Approach Road between Prince Way and Percival Way.

2.3.2 One site was re-surveyed due to equipment failure (damaged laptop) after the count data had been checked. This site (Hatters Way between Kingsway and Marlow Avenue) was re-surveyed between the 12th and 18th of October.

2.3.3 An independent inspection of the count locations and equipment was carried out on the 13th July 2018 by AECOM staff. From this inspection, it was identified that count data equipment were installed in the correct location and one site where count data equipment was damaged. This was reported to the survey company, who had been made aware of the damage, and repaired the equipment at the next available opportunity.

Phase 2 (September 2018)

2.3.4 For the second phase of data collection there were four count site locations where ATCs couldn't be installed for safety reasons. Manual Classified Counts (MCCs) using video equipment was deemed a safe method of collecting traffic data at these locations. MCCs were surveyed for a one week period. These count site locations were:

- Hatters Road between Skimpot Road and Chaul End Road;
- A5183 Dunstable Road, east of M1;
- Sundon Park Road, east of Toddington Road under railway Bridge; and
- B579 Luton Road between Coverdale and Sundon Road.

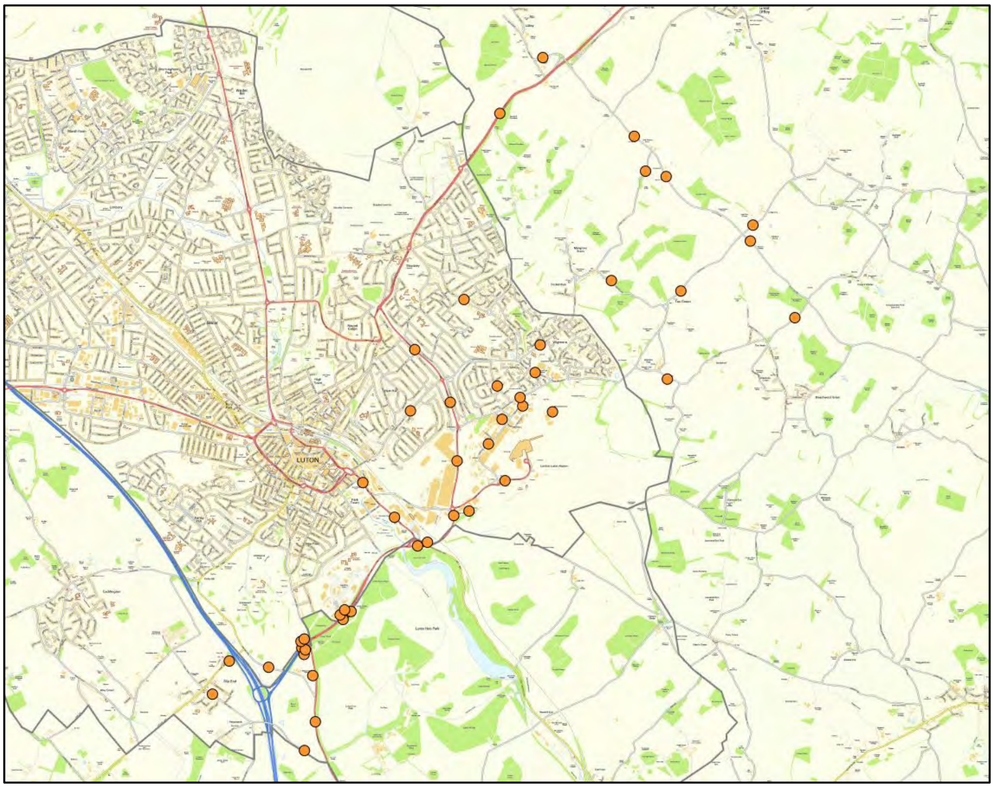
2.3.5 As with the Phase 1 data collection, some ATC sites experienced damage to equipment or parking on the equipment. The survey period for these sites was extended to capture a full two weeks' worth of weekday data.

2.4 Data Collated from Luton Airport Microsimulation Model

2.4.1 As part of the development of the microsimulation model for the assessment of the proposed Luton Airport expansion, Arup undertook a number of automated traffic count and video surveys in Autumn 2017. Further information on these surveys can be found in the Local Model Validation Report for the microsimulation model.

2.4.2 The locations of these traffic count surveys are shown in Figure 2.8.

Figure 2.8 Microsimulation Traffic Count Surveys



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2.5 Data Collated from the Existing CBLTM

2.5.1 Traffic count survey data were collected as part of the development of the existing 2016 base year CBLTM highway model. Three sources of count data were used, which are:

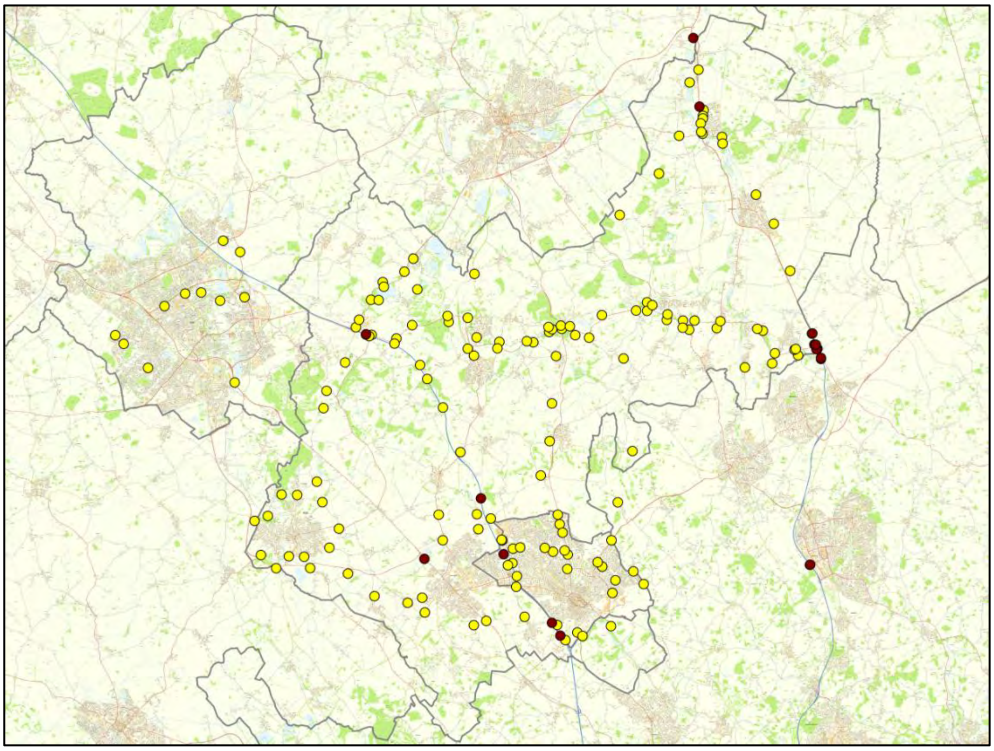
- existing count data obtained from Central Bedfordshire Council and Luton Borough Council;

- data available from Highways England's WebTRIS database; and
- bespoke data collected for the CBLTM development.

2.5.2 The data collected as part of the development of the existing CBLTM highway model is detailed in the *'Central Bedfordshire & Luton Transport Model Development – Traffic Data Collection Report'* (dated February 2017).

2.5.3 Figure 2.9 shows the location of the traffic count survey data collated as part of the development of the existing CBLTM highway model, with the locations sourced from WebTRIS shown in dark red.

Figure 2.9 Existing CBLTM Traffic Count Surveys



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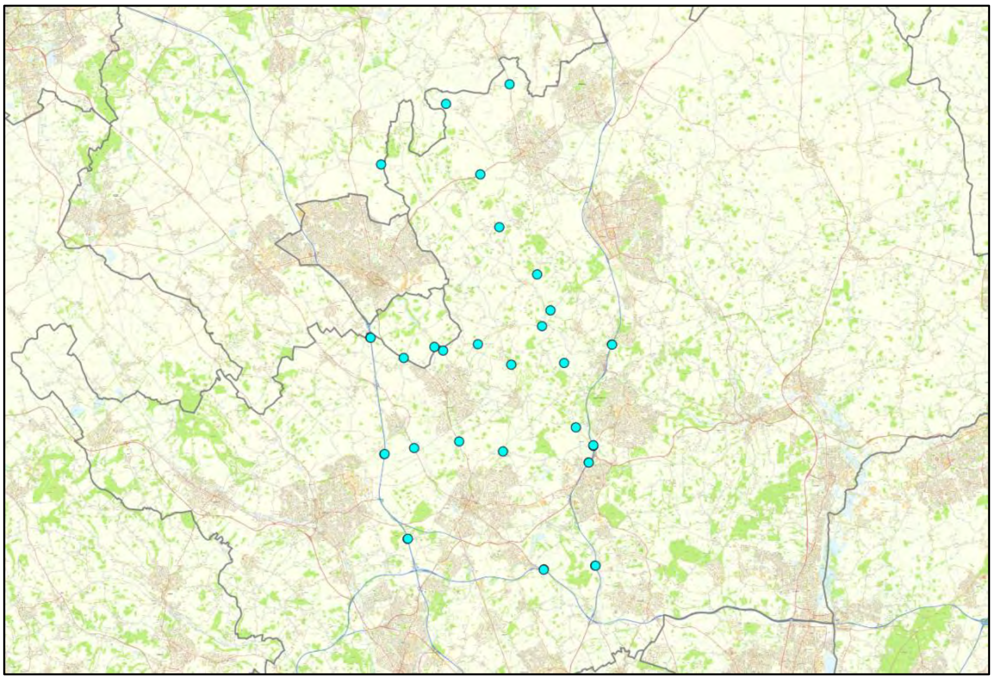
2.6 Data Collated from COMET

2.6.1 Processed traffic count survey data from the COMET highway model have also been used for locations within Hertfordshire. These counts have been produced as part of an update to the COMET model which is being undertaken in parallel to the development of the CBLTM-LTN. A Data Collection Report for the updated COMET model will detail the collection and processing of these count data.

2.6.2 Figure 2.10 shows the location of the processed traffic survey data used within the CBLTM-LTN highway model from Hertfordshire's COMET model.

Figure 2.10 COMET Traffic Count Surveys



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2.7 Temporal Adjustments

2.7.1 The traffic count survey data collated for use in the calibration and validation of the CBLTM-LTN highway model have been collected over the course of a number of years, and at different times within these years. The base year highway model represents June 2016, and therefore the collated count data require adjustment to estimate the traffic flows in June 2016.

2.7.2 Separate factors have been developed to consider the year-on-year growth in traffic, and the variation in traffic between months within a year. Long-term traffic survey data have been used to derive the variation in traffic levels by month within a year, relative to June, by time period.

2.7.3 Figure 2.11 shows the adjustment factors adopted to convert observed traffic flows to June estimates. A factor of greater than one suggests that flows within this month are below that observed in June, which can be seen in January and December. Conversely, a factor of less than one is where traffic flows are above those observed in June, such as during July and August in the interpeak period. These adjustment factors are also detailed in Table 2.1.

2.7.4 Limited count data covering a 12-month period was available in order to calculate adjustment factors relative to June. Count data by direction and time period on the A5 (south of Little Brickhill), M1 (between Junction 11 and 12) and A1 (near Biggleswade) have been used to calculate these adjustment factors for the existing CBLTM, and these factors have been retained within the CBLTM-LTN.

Figure 2.11 Monthly Adjustment Factors (relative to June)

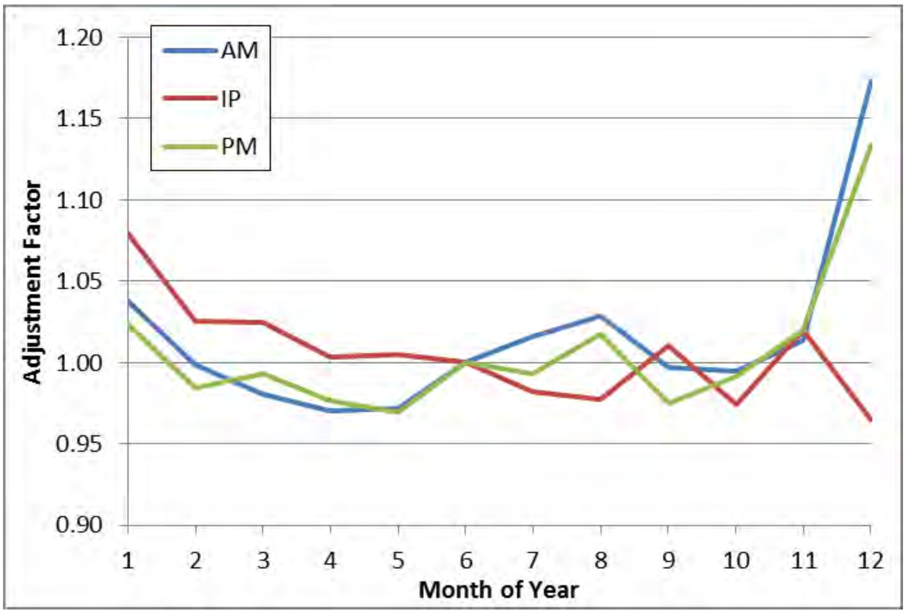


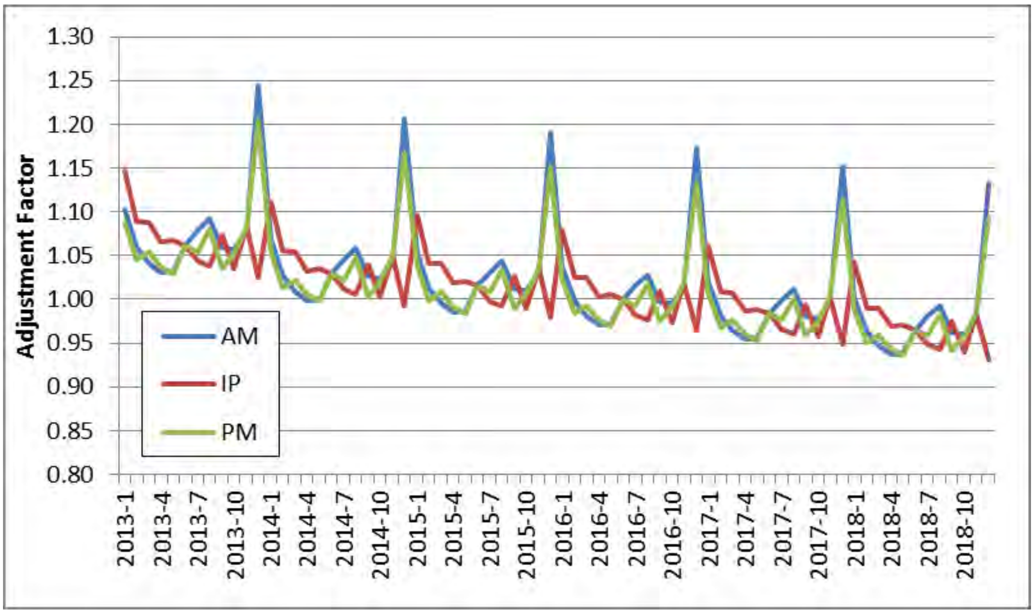
Table 2.1: Monthly Adjustment Factors (relative to June)

Month	AM Peak	Interpeak	PM Peak
January	1.04	1.08	1.02
February	1.00	1.03	0.98
March	0.98	1.02	0.99
April	0.97	1.00	0.98
May	0.97	1.01	0.97
June	1.00	1.00	1.00
July	1.02	0.98	0.99
August	1.03	0.98	1.02
September	1.00	1.01	0.97
October	0.99	0.97	0.99
November	1.01	1.02	1.02
December	1.17	0.96	1.13

2.7.5 Long-term traffic count survey data are not available showing the year-on-year change in traffic levels within the study area. Therefore, information from the Department for Transport's Road Traffic Statistics for the South-East has been used to estimate the year-on-year change.

2.7.6 Combining both the monthly and yearly adjustment factors provides the factors applied to the count data to estimate the June 2016 equivalent traffic flow. These factors are shown in Figure 2.12, which shows a general reduction in the adjustment factor over time, representing the increase in traffic levels year-on-year.

Figure 2.12 Adjustment Factors (relative to June 2016)



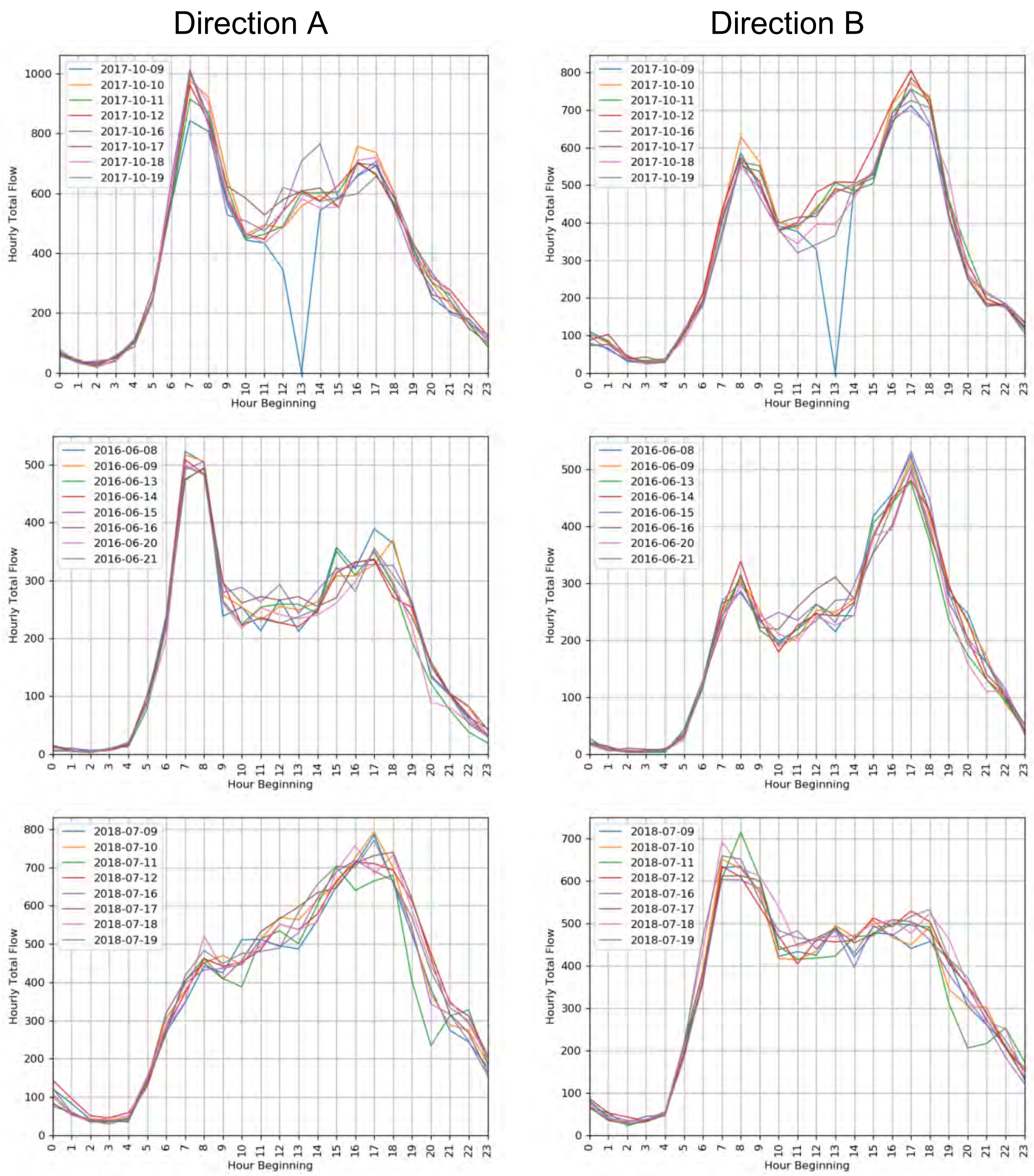
2.8 Data Checking and Cleaning

2.8.1 With the exception of the data sourced from the COMET highway model, which has undergone its own data checking and cleaning process, all traffic survey data collated for the CBLTM-LTN highway model have been checked and cleaned.

2.8.2 In terms of checking, the day-to-day variation of the traffic survey data at individual locations has been assessed to identify any issues in the data collection. The traffic count data have also been assessed by direction at a given location to identify the peak direction of travel in the morning and evening, and considered in the context of the local network and land-use characteristics.

2.8.3 Figure 2.13 provides some examples of this analysis comparing the day-to-day variation at individual sites, and also comparing the pattern of traffic levels across the day by direction at a given location.

Figure 2.13 Examples of Traffic Count Survey Data Checking



2.8.4 After data checking, a series of data cleaning tasks were undertaken. These included the removal of data for Fridays, Saturdays and Sundays, and data collected during weeks where Bank Holidays occurred, to obtain average weekday flows.

2.8.5 Records for sites with zero observed traffic flows across a time period or peak hour were also removed, as these are likely to be where there is an error in the survey data collection.

2.8.6 Using non-zero average weekday flows, potential outliers were identified and removed. Given the sample size of the traffic count data for a given time period, generally eight observations (Monday to Thursday for two weeks), the data cannot be assumed to be normally distributed and therefore application of a cleaning approach based on standard deviations from the mean has not been applied.

2.8.7 An alternative approach based on the median has been applied, which is considered to be suitable for data sets with small sample sizes. This approach removes records with a Z-score above 3.5 where:

$$Z = abs\left(0.675 * \frac{Flow - Median_{Flow}}{MedianDeviation}\right)$$

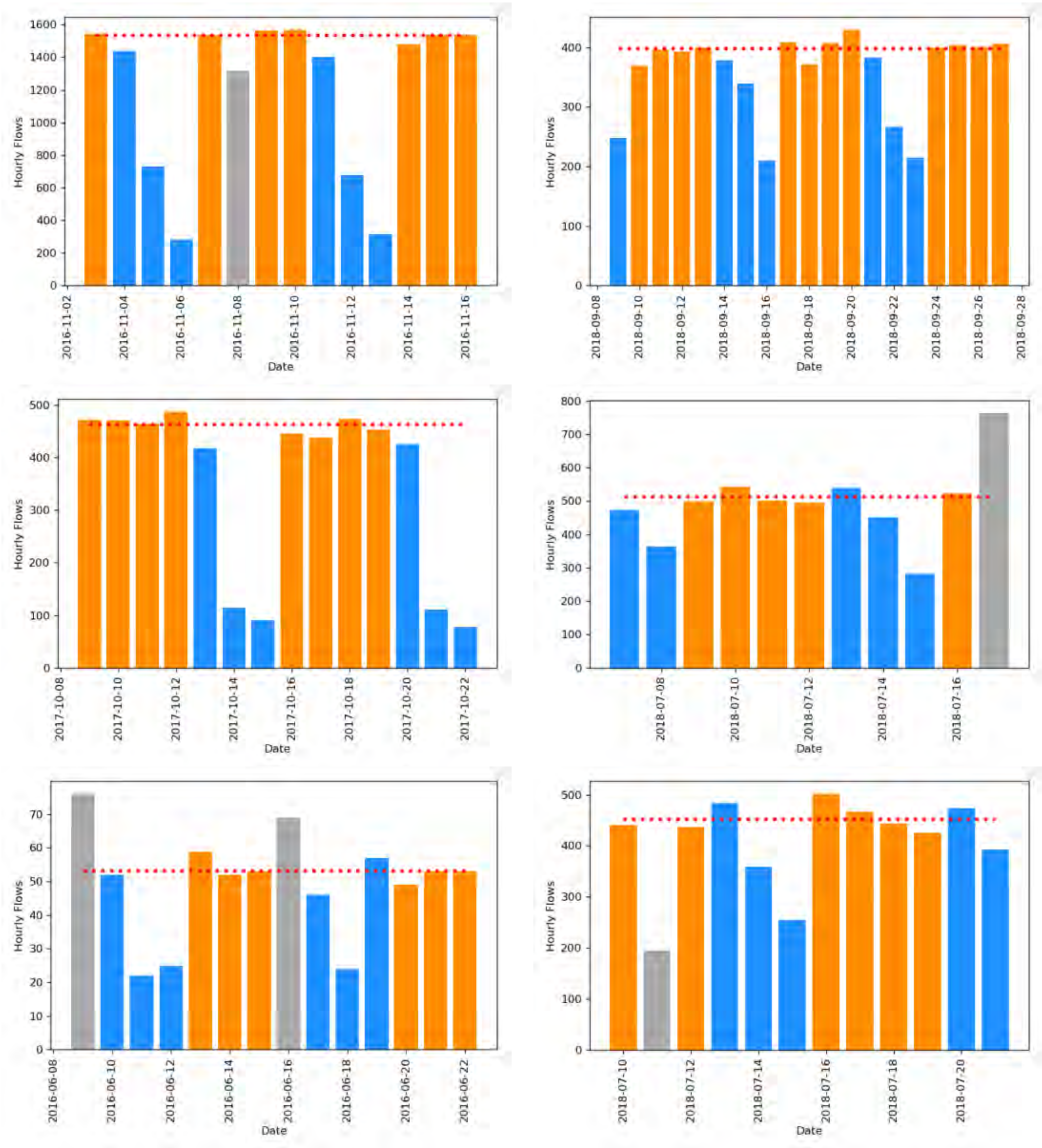
and the $MedianDeviation$ is the median of the difference between the observed flow and the median for a given site, direction and time period.

2.8.8 Figure 2.14 shows some examples of this data cleaning. For each figure, the survey days not on an average Monday to Thursday are shown in blue, with those records which have failed the Z-score test shown in grey. This leaves the records shown in orange, with the dotted red line showing the average flow for these records.

2.8.9 Average total vehicle flows by site and direction have been calculated based on the cleaned data records for the three modelled hours:

- AM Peak Hour: 08:00 to 09:00;
- Average Interpeak Hour: between 10:00 and 16:00; and
- PM Peak Hour: 17:00 to 18:00.

Figure 2.14 Examples of Traffic Count Survey Data Cleaning



2.8.10 Table 2.2 provides a summary of the data cleaning applied to the input count data. For each time period there are around 55,000 input observations, of which around 47% were removed as they were collected on non-average weekdays (i.e. Fridays to Sundays, and weeks including Bank Holidays).

2.8.11 Of the remaining records, up to 0.9% was removed due to the observed count being zero for the modelled time period, giving around 29,000 records within each time period. The Z-score test was then applied to these records, and at this stage between 3.8% and 4.9% of records was removed as potential outliers.

2.8.12 Following the data cleaning, across all counts there were 27,688 records in the AM Peak hour, 27,897 for the average interpeak hour, and 28,255 in the PM Peak hour.

Table 2.2: Summary of Data Cleaning

Measure	AM Peak	Interpeak	PM Peak
Total observations	**55,302**	**55,230**	**55,473**
Non-average weekdays	25,948 (46.9%)	25,887 (46.9%)	25,965 (46.8%)
…remaining records	*29,354*	*29,343*	*29,508*
Zero observed flow	254 (0.9%)	65 (0.2%)	124 (0.4%)
…remaining records	*29,100*	*29,278*	*29,384*
Removed through Z-test	1,412 (4.9%)	1,381 (4.7%)	1,129 (3.8%)
Cleaned records	**27,688**	**27,897**	**28,255**

2.9 Application of Vehicle Splits

2.9.1 The analysis detailed above provides total vehicle flows by site, direction and time period for an average Monday to Thursday during June 2016. In order to use these data within the calibration and validation of the highway model, these total flows are required to be split by vehicle type.

2.9.2 In order to provide vehicle splits, manual classified count data available across the study area have been collated. These count locations have been grouped by geographical area and by road type to increase the sample size, and therefore statistical confidence, in the outturn proportions of different vehicle types. These vehicle type proportions have been calculated by time period for each geographical area and road type combination.

2.9.3 Figure 2.15 shows the location of the manual classified count data used for this purpose, and the groups into which each count has been assigned. The outturn vehicle split proportions by time period for these road type groupings are detailed in Table 2.3.

Figure 2.15 Manual Classified Count Data Locations

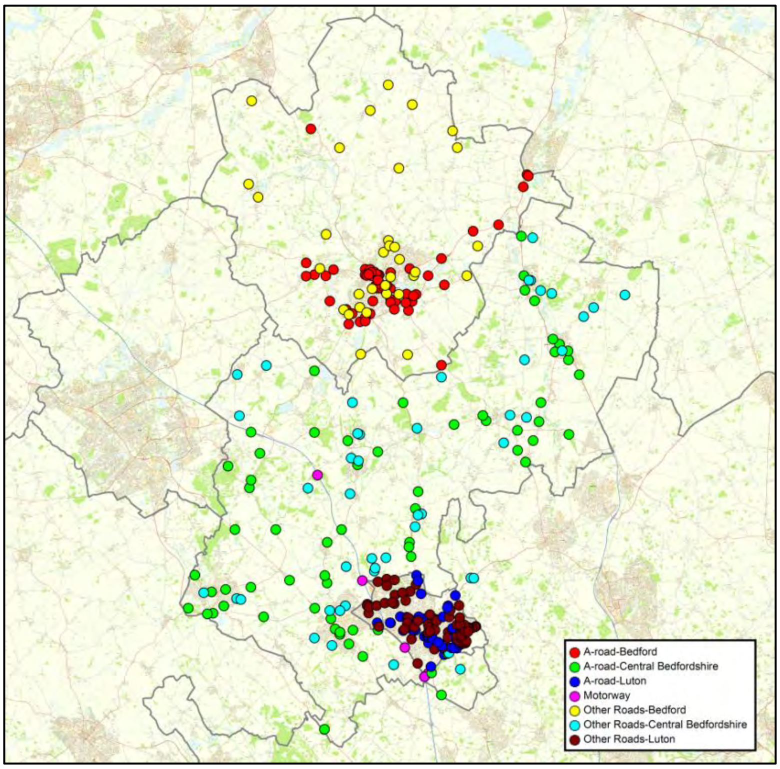


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Table 2.3: Adopted Vehicle Splits by Road Type and Time Period

Road Type	Time Period	%Car	%LGV	%HGV
Motorway	AM	76.7%	9.4%	12.9%
Motorway	IP	65.3%	13.3%	20.3%
Motorway	PM	79.5%	9.5%	9.9%
A-road-Luton	AM	85.7%	9.2%	3.2%
A-road-Luton	IP	81.1%	12.0%	4.8%
A-road-Luton	PM	88.5%	8.3%	1.4%
Other Roads-Luton	AM	87.7%	8.0%	2.0%
Other Roads-Luton	IP	82.7%	11.7%	3.3%
Other Roads-Luton	PM	88.9%	8.2%	0.9%
A-road-Central Bedfordshire	AM	79.6%	11.8%	7.1%
A-road-Central Bedfordshire	IP	70.9%	15.6%	12.1%
A-road-Central Bedfordshire	PM	83.6%	10.8%	4.1%
Other Roads-Central Bedfordshire	AM	84.7%	10.7%	3.0%
Other Roads-Central Bedfordshire	IP	77.6%	15.0%	5.7%
Other Roads-Central Bedfordshire	PM	86.5%	10.2%	1.7%
A-road-Bedford	AM	81.6%	10.3%	6.2%
A-road-Bedford	IP	73.7%	14.2%	10.1%
A-road-Bedford	PM	85.6%	9.3%	3.4%
Other Roads-Bedford	AM	86.7%	8.9%	2.1%
Other Roads-Bedford	IP	81.0%	13.2%	3.3%
Other Roads-Bedford	PM	88.4%	8.9%	0.7%

Percentages may not sum to 100% due to rounding

2.9.4 Each traffic count survey has been allocated to one of these seven classifications, and based on this allocation the corresponding observed vehicle type proportions have been applied to the data.

2.9.5 For counts outside Luton Borough and Central Bedfordshire sourced from the COMET model, these were provided including assumptions regarding vehicle classifications. These classifications by vehicle type were retained within the CBLTM-LTN.

3 HIGHWAY JOURNEY TIME SURVEY DATA

3.1 Introduction

3.1.1 As with the highway traffic count survey data, a review of the available journey time data has been undertaken. This has considered the journey time routes defined as part of the development of the existing CBLTM highway model, those available from the COMET model, and those collected as part of the development of the microsimulation model for the assessment of the proposed Luton Airport expansion.

3.1.2 Following this review, no additional journey time surveys have been undertaken. The journey time routes defined as part of the validation of the highway model have been based on available data from the existing CBLTM, COMET and the microsimulation modelling.

3.2 Existing CBLTM Journey Time Routes

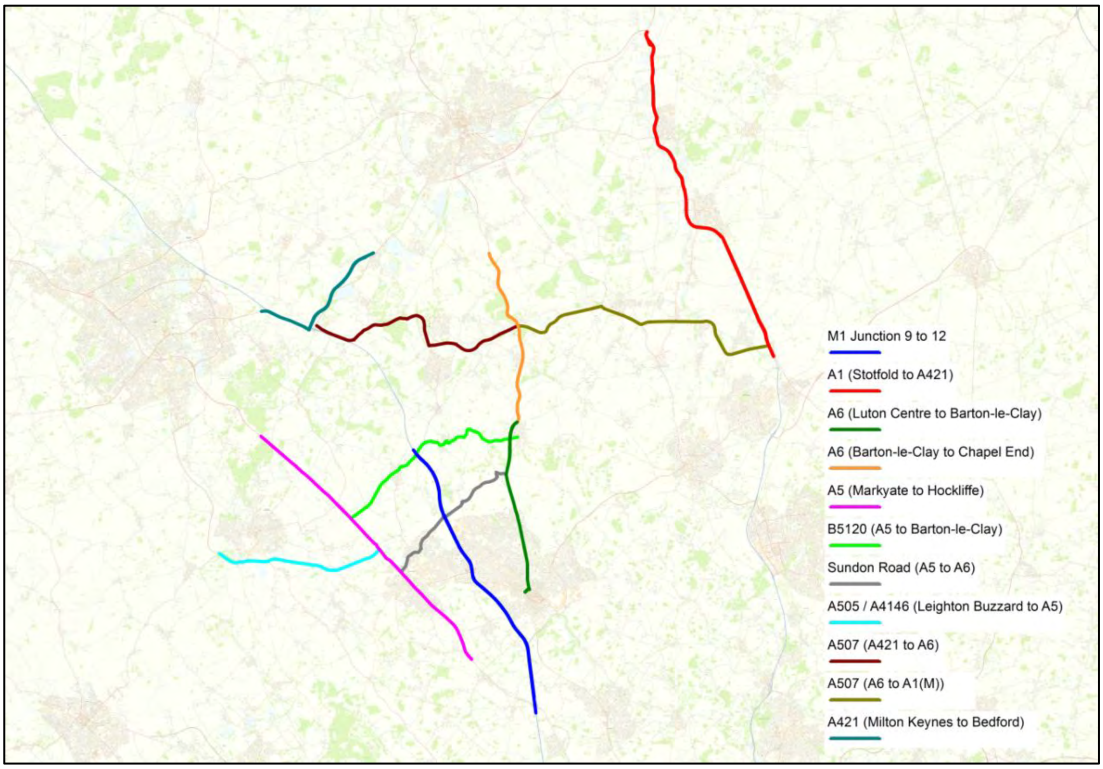
3.2.1 The majority of the journey time data collected for the development of the existing CBLTM highway model have been derived from Trafficmaster data. The exception to this is the journey time data on the M1 between Junctions 10 and 12, which are based on moving car observed surveys due to roadworks being in place on the M1 within the Trafficmaster data.

3.2.2 The routes defined in the existing journey time validation have been largely retained within the CBLTM-LTN. There are two exceptions to this:

- firstly where data from the COMET model has been used to extend the M1 journey time route to cover the section between Junctions 9 and 10;
- and secondly a redefinition of journey time routes on the A4146 and A505 to the south of Leighton Buzzard, to create a single journey time route between Leighton Buzzard and the A5.

3.2.3 The journey time routes primarily sourced from the existing CBLTM are shown in Figure 3.1.

Figure 3.1 Journey Time Routes Based on Existing CBLTM Data



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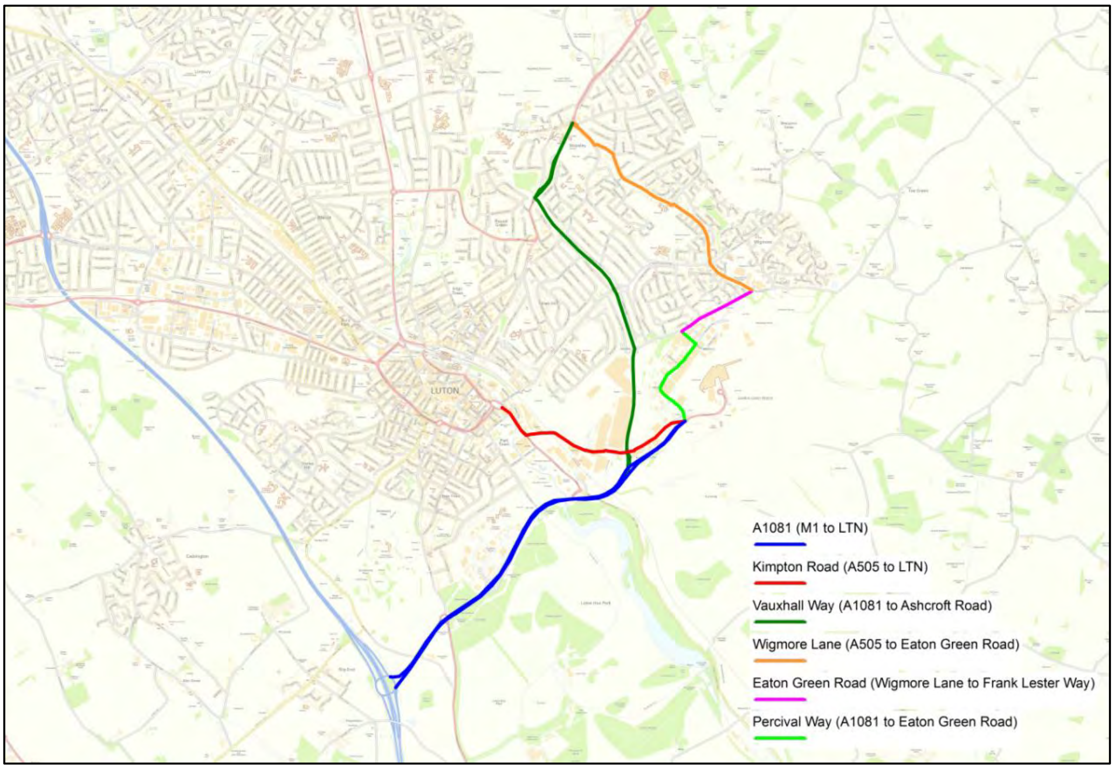
3.3 Data Collated from Luton Airport Microsimulation Model

3.3.1 As part of the development of the microsimulation model assessing the operation of the local road network around Luton Airport, a number of moving car observer surveys were undertaken in October 2017. These defined a number of routes in south and east Luton, which are shown in Figure 3.2.

3.3.2 This survey data have been reviewed and cleaned using the same methodology as adopted for the traffic count survey data (see Section 2.8).

3.3.3 These additional six journey time routes have been added to the validation process for the CBLTM-LTN highway model.

Figure 3.2 Journey Time Routes Based on Microsimulation Model Data



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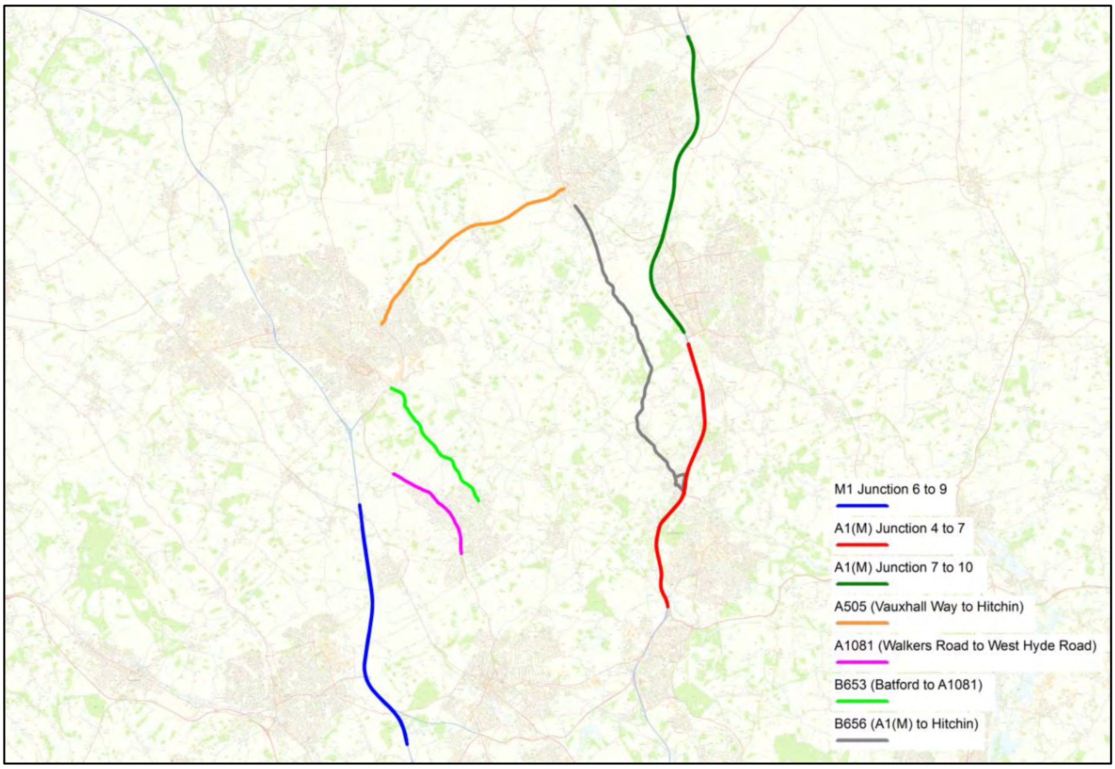
3.4 Data Collated from COMET

3.4.1 The data collected for the journey time validation of the COMET highway model have been based on Trafficmaster data. The processed data as provided from the COMET model have been used directly within the journey time validation of the CBLTM-LTN highway model.

3.4.2 The COMET highway model includes a number of journey time routes across Hertfordshire, and a subset of these has been used within the CBLTM-LTN highway model. These are shown in Figure 3.3, and include:

- journey time data on routes to / from Luton within Hertfordshire, such as the A505 between Hitchin and Luton, and the A1081 and B653 to the south of Luton; and
- additional journey time data on the Strategic Road Network covering the M1 between Junction 6 and 9, and the A1(M) between Junction 4 and 10.

Figure 3.3 Journey Time Routes Based on COMET Data



Map contains Ordnance Survey data © Crown copyright and database right 2019

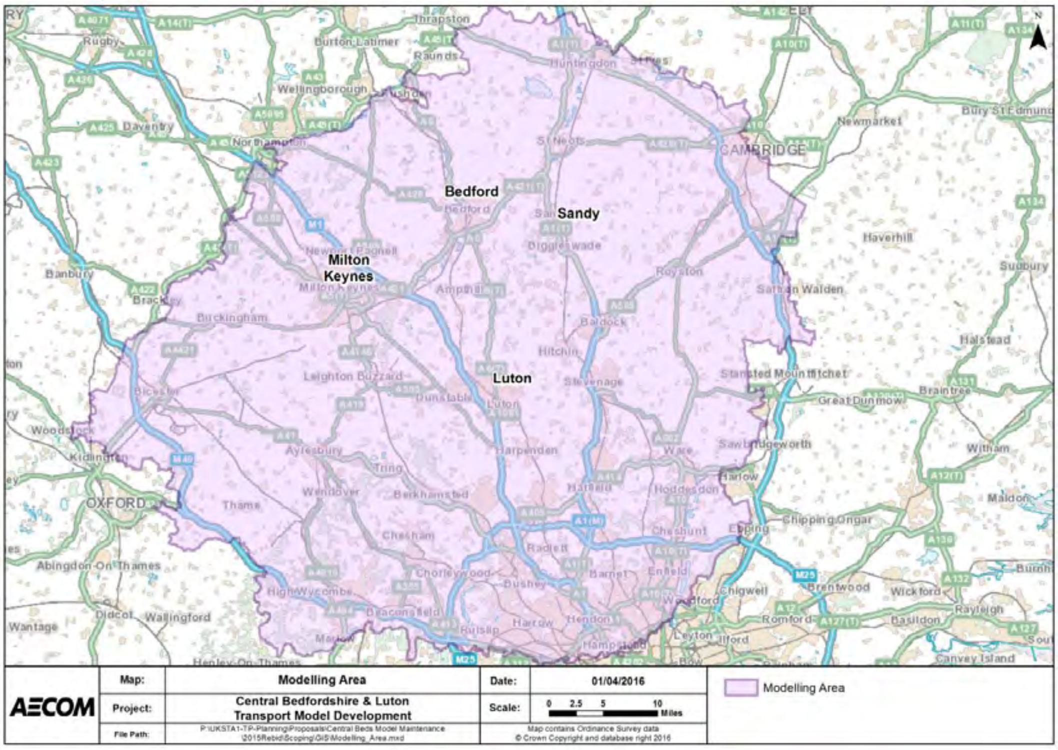
4 HIGHWAY DEMAND DATA

4.1 Demand Data Sources

4.1.1 No additional data collection to capture highway demand data has been undertaken as part of this development of the CBLTM-LTN. Therefore, the base year highway demand data are primarily based on mobile network data provided by Telefonica (O2 in the UK) covering the period from mid-April to mid-June 2016.

4.1.2 Figure 4.1 shows the cordon area for which mobile network data were collected for the development of the CBLTM, and further information on this data set can be found in the existing CBLTM Local Model Validation Report (dated August 2017).

Figure 4.1 CBLTM Mobile Network Cordon



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4.1.3 In addition to the demand data available from mobile network data, a number of complementary data sources have been used within the development of the 2016 base year highway demand matrices. These include:

- data from Highways England's South East Regional Traffic Model (SERTM);

- data from the Continuing Survey of Road Goods Transport (CSRGT) collected by the Department for Transport; and
- National Travel Survey (NTS) data.

4.1.4 The processing of this highway demand data and how these complimentary data sources were used is detailed in the CBLTM-LTN Highway Model Local Model Validation Report.

5 PUBLIC TRANSPORT DATA

5.1 Introduction

5.1.1 As with the highway demand data, no new data collection with regards to public transport has been undertaken for CBLTM-LTN. The data used for the development of the public transport model are discussed in detail in Section 9 and Section 10 of the existing CBLTM Local Model Validation Report (dated August 2017).

5.1.2 The remainder of this section provides an overview of these data sources.

5.2 Public Transport Demand Data

5.2.1 Both the rail and bus base year travel demand have been developed using ticket sales data. For rail travel this has been based on LENNON ticket data obtained from the Association of Train Operating Companies (ATOC) for the whole country for March 2016.

5.2.2 The LENNON data provide a complete representation of all rail tickets sold, and forms the basis of the 2016 public transport rail matrices. The data include information on the type of ticket sold, the origin station and the destination station.

5.2.3 For travel by bus, Electronic Ticket Machine (ETM) data have been collected from two operators in Central Bedfordshire and Luton, namely Arriva and Centrebus. Combined, these two operators cover around 73% of bus services operated within the two districts. These ticket data cover the three-month period between March and May 2016.

5.2.4 As with the LENNON data, the bus ETM data provide a record for each ticket sold, including information on the ticket type, the boarding stage location, potentially the alighting stage location (depending on the ticket type), and the time the ticket was purchased.

5.3 Public Transport Validation Data

5.3.1 Limited data have been collected to calibrate and validate the public transport assignment model. In total four on-board bus passenger counts have been undertaken in September 2016 at the following locations:

- Ampthill Road, Flitwick;
- Stanbridge Road, Leighton Buzzard;
- Biscot Road, Luton; and
- Barton Road, Luton.

5.3.2 WebTAG Unit M1.2 outlines some of the key challenges in collecting reliable bus count data. These include challenges in undertaking on-board passenger count surveys on crowded services with frequent stops, and the limitations of undertaking roadside counts of passengers on a given service. These counts are often labour-intensive and generally undertaken on a single day, therefore not capturing day-to-day variation.

5.3.3 Given the use of ETM data over a three month period to derive the bus travel demand, and the validation of these trip matrices against independent data sources such as the National Travel Survey and the National Trip-End Model (as detailed in the Public Transport LMVR), it was determined that the collection of additional bus passenger count data was not required for this assessment.

5.3.4 In addition to the bus count data, data from the Office of Rail and Road (ORR) has been used to validate the rail travel demand and assignment. The ORR data provides estimates of annual passenger usage at all stations within Great Britain. Of interest for this model development are the station usage estimates for stations within the modelled area, including stations on:

- the Midland Main Line (such as Luton, Luton Airport Parkway, Bedford and St Albans);
- the East Coast Main Line (such as Biggleswade and Sandy);
- the West Coast Main Line (such as Milton Keynes and Leighton Buzzard); and
- stations along the Bedford-Bletchley Line.

5.3.5 As with the validation of the bus travel demand, data from the National Travel Survey and the National Trip-End Model have been used to validate the processing of the rail observed ticket data.

Appendix D: VISSIM Model LMVR

London Luton Airport Expansion Development Consent Order

VISSIM Model LMVR

16 April 2019

Final

Contents

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Appendix A

Junction Turning Movement Validation Results

Appendix B

AM and PM Vissim Results with 10 Seeds

Appendix C

Highways England - Initial Comments

1 Introduction

1.1 Purpose of the Report

The purpose of this report is to outline the model calibration and validation exercise for the London Luton Airport (LLA) local area network Vissim micro-simulation model. The report summarises the model development methodology, data sources and output results, demonstrating the model suitability for use in the assessment of future year scenarios and appraisal of the proposed London Luton Airport Expansion. The Vissim micro-simulation models were developed for the morning (AM) and evening (PM) peak hours based on a comprehensive traffic survey conducted in October 2017.

This report is an update of the Local Model Validation Report (LMVR) and associated modelling files submitted in August 2018 to Highways England (HE) and Jacobs who were instructed to review the material on behalf of HE. This updated LMVR addresses all the comments received from HE on 3rd October 2018, and subsequent response from 14th March 2019. The main HE comments affecting the modelling approach and results, as well as the Reponses are presented in **Appendix C**.

1.2 Study Area

The study area, modelled in Vissim, focuses on the strategic and local road network in the vicinity of LLA as illustrated in **Figure 1.1**. The study area comprises:

- Junction 10 of the M1
- Stretches of the M1 on both side of Junction 10
- The A1081 linking Luton to the M1
- Various roads and junctions (roundabouts, signalised junctions, and priority junctions) located within the boundary of the study area
- Circulation routes and car parking associated with Luton Airport

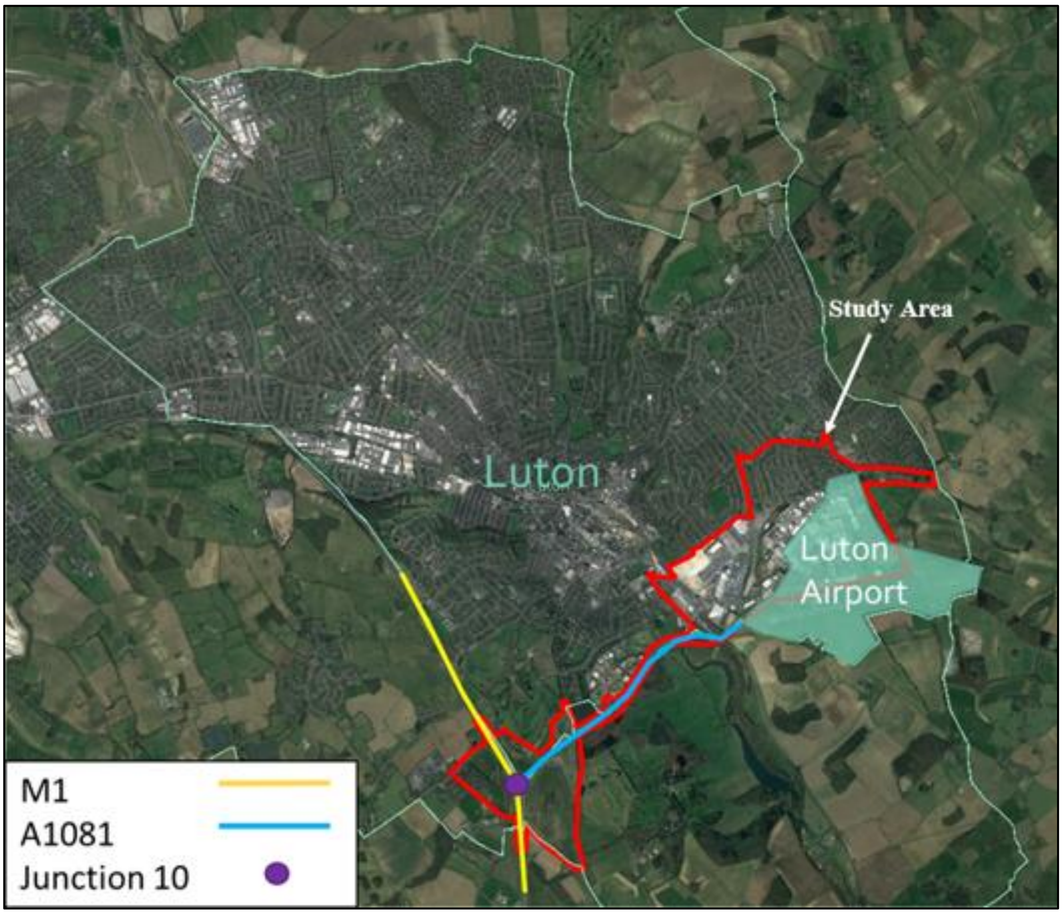

Figure 1.1 London Luton Airport Vissim Model Study Area

1.3 Report Structure

In addition to this introductory chapter, the report comprises the following:

- Chapter 2 presents the 2017 traffic survey analysis and the identification of the peak hours.
- Chapter 3 sets out the 2017 Base Model development.
- Chapter 4 highlights the 2017 Base Model calibration and validation process.
- Chapter 5 provides the summary and conclusions.

2 2017 Peak Hour Analysis

2.1 Introduction

Traffic counts were conducted in the south-east region of Luton in order to evaluate the existing traffic conditions and identify the peak hours in the surrounding area of LLA. **Figure 2.1** illustrates the defined study area, which also depicts the extents of the developed Vissim models.

Figure 2.1 London Luton Airport Vissim Study Area

2.2 Traffic Counts

Automatic Traffic Counts (ATC) were conducted for two weeks during October 2017 from 9th October through to 22nd October. Turning Movement Counts (TMC) were conducted for one day on 11th October 2017. The average of ATC counts for a normal weekday was used to identify the morning (AM) and evening (PM) traffic peak hours within the study Area. The locations of the ATC and TMC counts are illustrated in **Figure 2.2** and **Figure 2.3** respectively.

Figure 2.2 ATC Locations

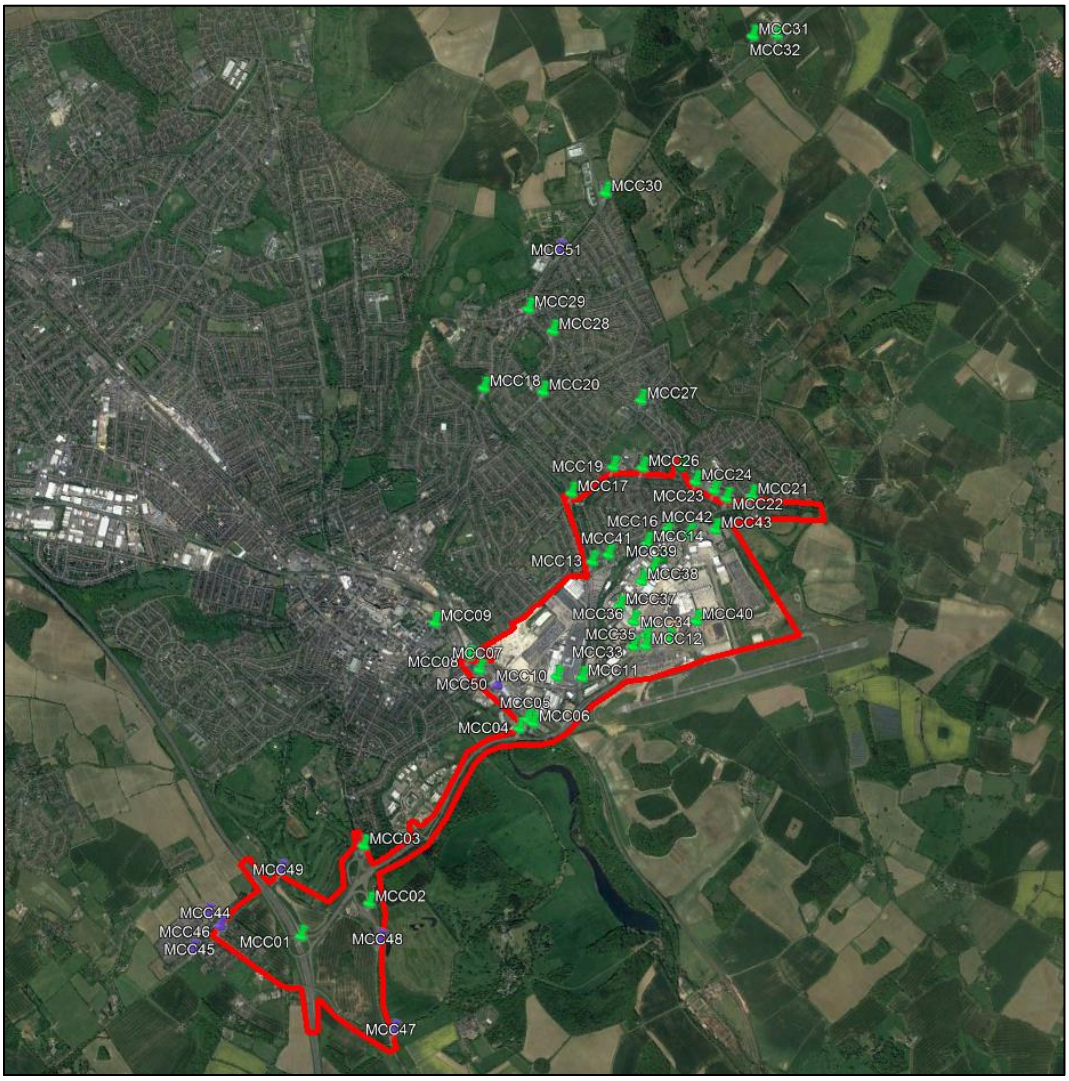

Figure 2.3 MCC Locations

For the peak hour analysis, only the ATCs falling within the study area (red polygon) were considered in identifying the AM and PM peak hours. **Figure 2.4** shows all the ATCs used for the peak hour analysis. The traffic volume along the M1 motorway (in its both directions) was not accounted for in the analysis. The traffic volume from/to Luton using the M1 motorway was captured at the ATCs east of Junction 10.

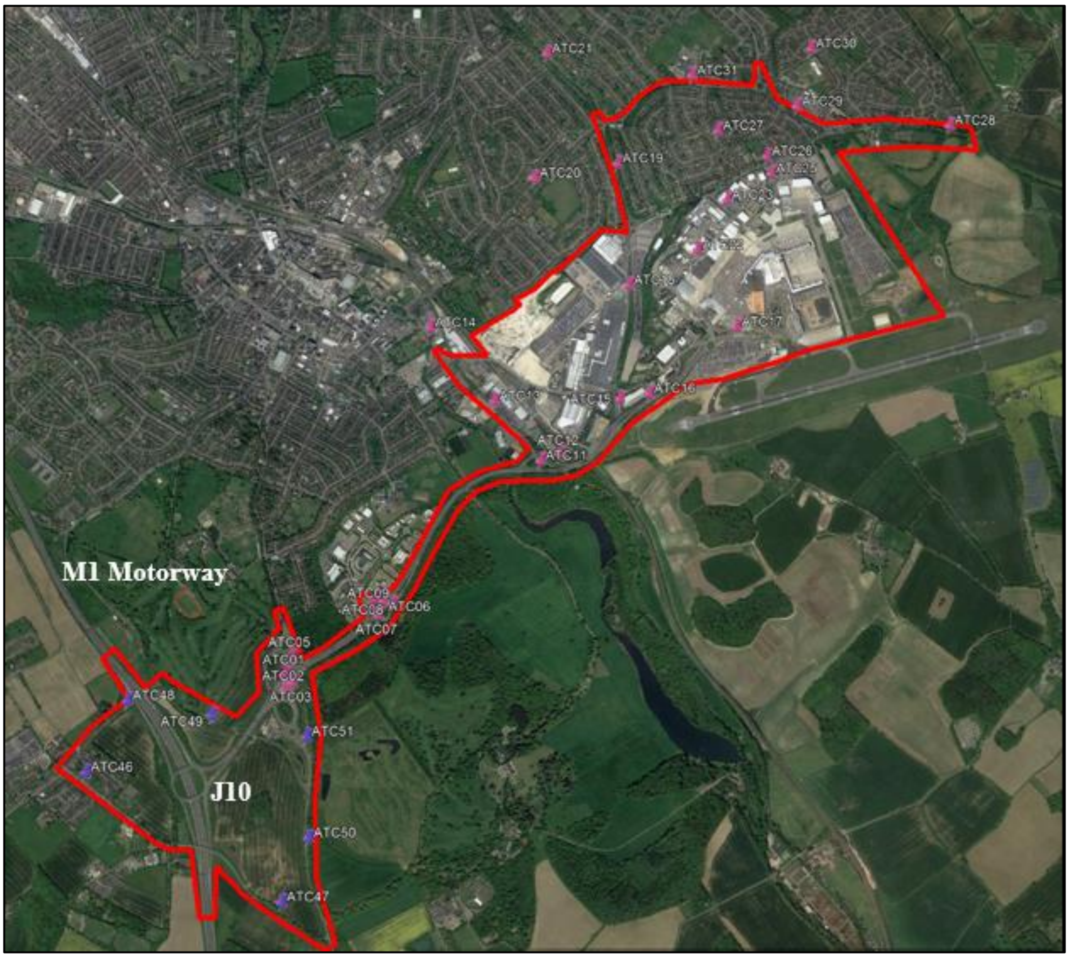

Figure 2.4 ATC Locations Used to Identify Peak Hour Analysis

2.3 ATC Analysis

A total of 36 ATCs within the study area (**Table 2.1**) were used for the peak hour analysis. The counts were recorded for two weeks in October 2017 at every location per direction. The hourly average volumes for weekdays of the survey period were computed to identify the traffic flow pattern.

Table 2.1 ATC Locations

Survey ID	Easting	Northing	Road Name
ATC01	509213	219033	A1081 New Airport Way
ATC02	509179	218910	A1081 New Airport Way WB on slip from London Rd
ATC03	509217	218942	A1081 New Airport Way WB off slip to London Rd
ATC04	509136	218994	A1081 New Airport Way EB off slip to London Rd
ATC05	509204	219093	A1081 New Airport Way EB on slip from London Rd
ATC06	509698	219401	A1081 New Airport Way
ATC07	509645	219318	A1081 New Airport Way WB on slip from Capability Green Estate
ATC08	509787	219462	A1081 New Airport Way WB off slip to Capability Green Estate
ATC09	509632	219366	A1081 New Airport Way EB off slip to Capability Green Estate
ATC10	509706	219454	A1081 New Airport Way EB on slip from Capability Green Estate
ATC11	510581	220228	A1081 New Airport Way
ATC12	510678	220281	Bus lane
ATC13	510318	220560	Gipsy Ln
ATC14	509917	220992	Windmill Rd
ATC15	511021	220561	A505 Airport Way
ATC16	511195	220644	A1081 New Airport Way
ATC17	511673	221027	A1081 Airport Way
ATC18	511061	221271	A505 Vauxhall Way
ATC19	510967	222003	A505 Vauxhall Way
ATC20	510535	221915	Crawley Green Rd
ATC21	510555	222608	A505 Vauxhall Way
ATC22	511397	221424	Percival Way
ATC23	511590	221778	Frank Lester Way
ATC24	512248	221871	President Way
ATC25	511846	221924	President Way
ATC26	511834	222037	Eaton Green Rd
ATC27	511548	222175	Lalleford Rd
ATC28	512673	222271	Eaton Green Rd
ATC29	512006	222339	Wigmore Ln
ATC30	512068	222669	Crawley Green Rd
ATC31	511539	222484	Crawley Green Rd
ATC32	511097	223243	Wigmore Ln
ATC33	510303	223468	A505 Stopsley Way
ATC34	511347	225111	A505 Beech Hill
ATC35	513655	222240	Darley Rd
ATC36	515186	223013	Church Rd
ATC37	514727	223805	Lilley Bottom
ATC38	514763	224210	The Road near Lodge Farm
ATC39	513885	223468	Stony Ln
ATC40	513070	223313	Brik Kiln Ln
ATC41	512489	223117	Luton Rd
ATC42	513364	224801	Challk Hill
ATC43	513552	224824	Lilley Bottom
ATC44	513106	225304	Lilley Bottom
ATC45	512115	226168	Lilley Bottom
ATC46	508104	218407	Front St

ATC47	509182	217766	Front St
ATC48	508281	218821	B4540 Church Rd
ATC49	508776	218744	Newlands Rd
ATC50	509326	218184	A1081 London Rd
ATC51	509317	218622	A1081 London Rd

Figure 2.5 shows the average weekday traffic flow pattern for the study area. The flow pattern was noted as similar for both directions at the survey locations. The highest traffic volume in both directions was 46,548 vehicles between 17:00 and 18:00. It should be noted that this traffic volume may include the same vehicles counted at different locations and does not reflect the generated trips of the study area.

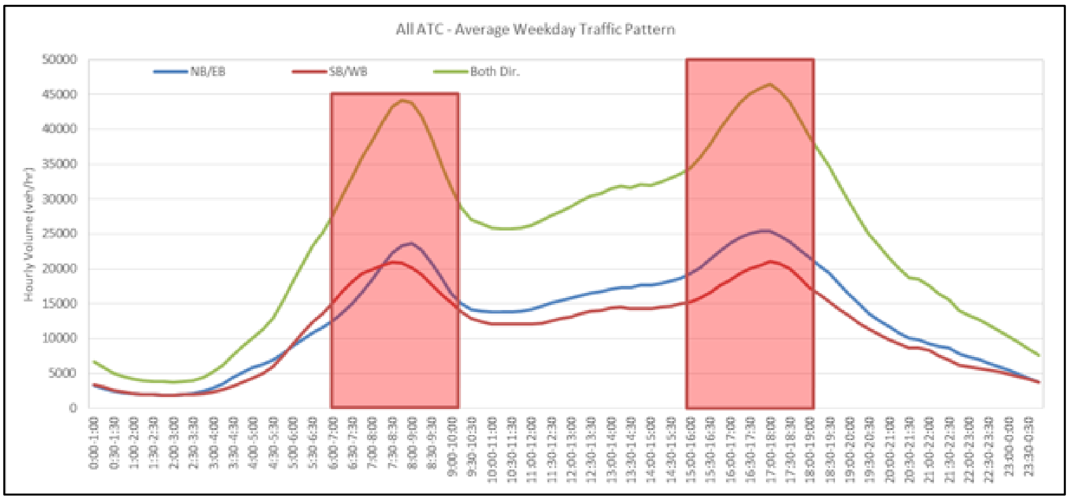

Figure 2.5 Average Weekday Luton Traffic Flow Pattern

2.4 Peak Hour Identification

The traffic pattern shown in **Figure 2.5** indicates two major peak periods:

1. AM peak period extending from 06:00 till 10:00
2. PM peak period extending from 15:00 till 19:00

The average traffic counts on a typical weekday identified the AM and PM peak hours within the study area as 07:45-08:45 and 17:00-18:00, respectively (**Table 2.2**). The critical peak was the PM peak hour with 46,548 vehicles (2,390 vehicles more than the AM peak).

Table 2.2 Weekday Peak Hours

Peak Hr/Both Directions	Average Weekday	
	Peak Hour	Volume
AM	07:45-08:45	44,158
PM	17:00-18:00	46,548

2.5 WebTRIS Data

The traffic survey counts did not cover traffic volumes on the M1 motorway, hence an external source was used to identify the traffic flow along the M1. WebTRIS data for the M1 was obtained for this task, however the traffic volume was provided hourly in a whole hour pattern (01:00-02:00, 02:00-03:00, etc…). As a result, and in order to combine the ATC data of the study area with the WebTRIS data, it was assumed that the AM peak hour is at 08:00-09:00 for the study area of **Figure 2.1** (closest interval to 07:45-08:45) while keeping the PM peak (17:00 – 18:00). In addition, the Central Bedfordshire Local Traffic Model (CBLTM) strategic traffic model identified the AM and PM peak hours to be 08:00-09:00 and 17:00-18:00, respectively.

The assumed AM peak hour (08:00-09:00) decreased the number of vehicles within the study area from 44,158 vehicles to 43,819 vehicles (339 vehicles difference at 36 locations); representing a less than 1% decrease. **Table 2.3** provides the revised peak hours with the corresponding volumes.

Table 2.3 New Weekday Peak Hours

Peak Hr/Both Directions	Average Weekday	
	Peak Hour	Volume
AM	08:00-09:00	43,819
PM	17:00-18:00	46,548

Table 2.4 provides the breakdown of traffic volumes per direction at each ATC for the identified AM and PM peak hours of **Table 2.3**

Table 2.4 AM and PM Peak Hour Volumes

Peak Hour	AM Peak Hour		PM Peak Hour	
Direction	NB/EB	SB/WB	NB/EB	SB/WB
ATC	Volume	Volume	Volume	Volume
ATC 1	2344	1503	1698	2503
ATC 2	553	-	784	-
ATC 3	480	-	782	-
ATC 4	702	-	921	-
ATC 5	766	-	382	-
ATC 6	2148	1928	1927	2377
ATC 7	80	-	836	-
ATC 8	574	-	83	-
ATC 9	977	-	116	-
ATC 10	117	-	452	-
ATC 11	1793	1951	2004	1903
ATC 12	29	-	27	-
ATC 13	867	581	719	763
ATC 14	761	952	990	768
ATC 15	833	974	965	980
ATC 16	990	962	1071	939
ATC 17	753	713	783	817
ATC 18	911	1327	1399	1195
ATC 19	561	992	928	725
ATC 20	473	583	563	519
ATC 21	637	781	980	892
ATC 22	592	728	686	483
ATC 23	292	894	887	267
ATC 25	466	168	153	414
ATC 26	446	629	952	600
ATC 27	99	520	299	97
ATC 28	198	208	239	203
ATC 29	760	315	580	1020
ATC 30	265	387	394	271
ATC 31	498	354	561	574
ATC 46	112	383	241	101
ATC 47	262	141	102	202
ATC 48	280	242	234	319
ATC 49	692	290	361	675
ATC 50	469	826	611	553
ATC 51	880	827	705	973
M1 Motorway	4317	4442	5009	4848

2.6 Manual Classified Count (MCC) Survey

The MCC survey was conducted on Wednesday 11th October 2017 (weekday). MCCs represent more accurate data than ATCs for vehicle distribution and assignment (for calibration tasks). Hence, the peak hours identified from ATCs were used and applied to the MCCs to extract further data.

2.7 Vehicle Classification

Ten vehicle classifications were considered during the MCC survey:

1. PC – Pedal Cycle
2. MC – Motorcycle
3. Car
4. Taxi (Hackney)
5. Private Hire Taxi
6. LGV
7. OGV1
8. OGV2
9. Public Bus
10. Private Coach

The counted vehicle classes were summarized in 3 categories:

1. **Car**: Car, Taxi (Hackney), Private Hire Taxi
2. **LGV**: LGV
3. **HGV**: OGV1, OGV2, Public Bus, Private Coach

The pedal and motorcycles were excluded from the vehicle classifications as their volumes were very low compared to the other modes of transport.
The vehicle classifications presented in **Figure 2.6** and **Figure 2.7** for the AM and PM peak hour showed that the percentage of cars was approximately 90%. The vehicle classification was for the study area excluding the M1.

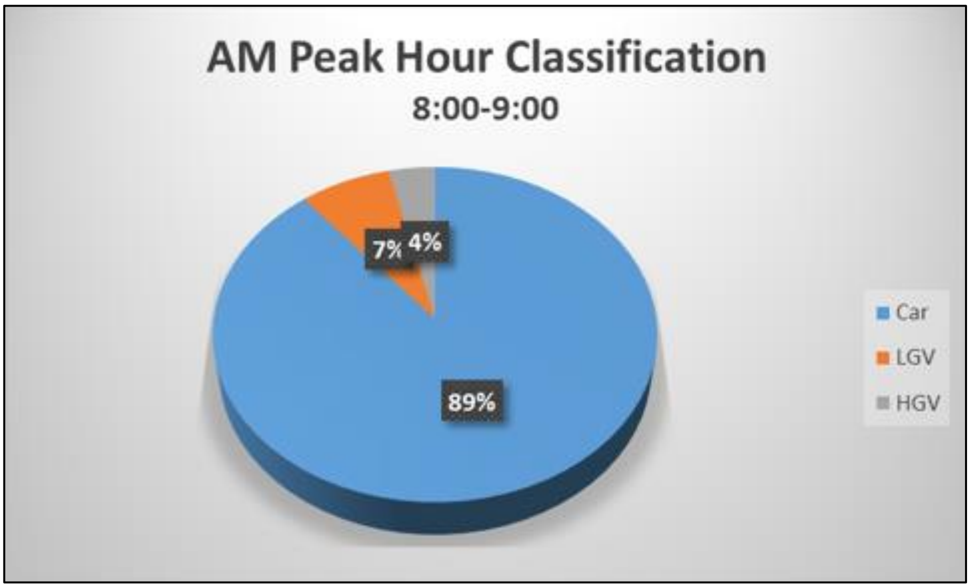

Figure 2.6 AM Peak Hour Vehicle Classification

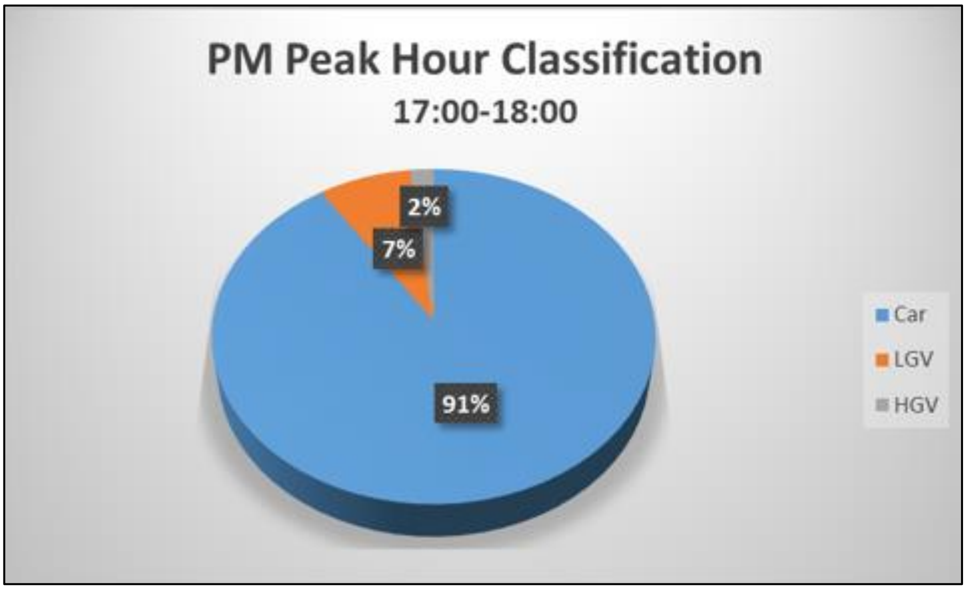

Figure 2.7 PM Peak Hour Vehicle Classification

3 2017 Base Model Development

3.1 Introduction

The purpose of this chapter is to summarise the process which was used to build and develop the 2017 Base Model. This includes a description of the data sources, the network coding process, public transport coding, calibration and validation criteria, and the initial modelling results.

3.2 Data Sources for Model Development

A variety of data sources were used for the development of the model and coding of the local road network. These include:

- OS Mapping – used to define the strategic and local network layout
- Site visits for road inventories and speed limits
- Traffic Survey Data – extensive survey programme carried out in 2017 including automatic traffic counts, turning movement counts and journey time surveys
- Bus Timetables – to define the routes, bus stops and frequency of local services
- Traffic Signal Data – details gathered during surveys and on-site signal settings provided by Luton Borough Council (LBC)

3.3 Vissim Network Coding

3.3.1 Vissim Micro-simulation Modelling

The Vissim model was coded based on the data sources highlighted in **Section 3.2**. The model extent and proposed study area are illustrated in **Figure 3.1**.

Figure 3.1 Extents and detail of the Vissim Network

The operation of the traffic signal-controlled junctions simulated within the Vissim model was based on the information supplied by Luton Borough Council (via the IMTRAC online database) as well as on-site observations gathered during site walkovers. All signalised junctions within the study area have variable cycle lengths and green times, and operate on a demand basis per approach using vehicle detection technique. This was reflected in Vissim, using the add-on VisVap module to program the controller settings, simulating signal operation in line with the provided operational information.

Similar to the traffic signals, the accurate coding of priority junctions and their operation is also important when developing micro-simulation models. In this context, site observations have assisted to ensure that all the modelled junction priorities accurately reflect those found across the modelled network.

The coding of roundabouts is particularly important, where gap acceptance is judged based on circulatory speeds and a clear path onto the roundabout. Within Vissim there is a choice of ‘Conflict Areas’ or ‘Priority Markers’ to define give-way behaviour. Conflict areas are useful for simple priority junctions, however for more complex approaches the use of priority markers provides more flexibility to represent on-site behaviour. Both of these methods were applied, where appropriate within the LLA Vissim model.

Public transport routes falling within the study area were implemented in the Vissim model. The timetable of each route was obtained from the corresponding public transport website.

3.3.2 Driving Behaviour

Vissim has default driving parameters that define driving behaviour such as the lane change conditions for vehicles. Two main driving behaviour settings are present in Vissim. These are defined as ‘Motorised’ based on Wiedemann 99 for use on the motorway and, ‘Urban’ based on Wiedemann 74 for the use on the urban roads. Changes to the default driving behaviours were introduced in the Vissim model based on a number of site visits, traffic surveillance cameras showing the driving behaviour, and the nature of the study area itself (high number of mini roundabouts and junctions, various local roads).

Driving behaviour was set to ‘cooperative’ for all vehicles to facilitate the necessary lane change behaviour. A subcategory of driving behaviour was defined for both the Motorised and Urban link categories based on a more cooperative lane change. This driving behaviour was mainly used at ‘bottleneck’ locations, for examples a drop in the number of lanes, and on motorways where vehicles merge from the on-ramp to the main line. **Figure 3.2** illustrates the driving behaviour parameters adopted in the Vissim modelling.

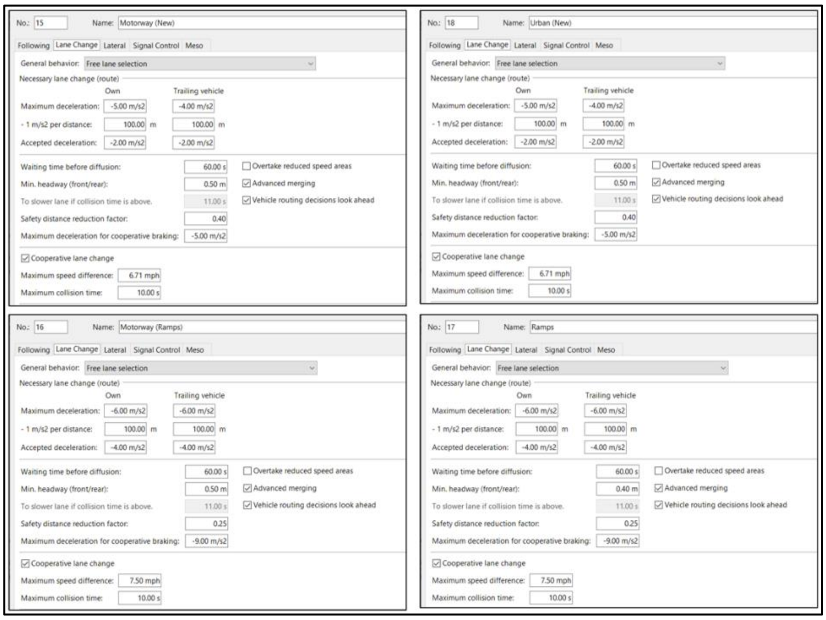

Figure 3.2 Driving Behaviour Parameters adopted in the Vissim Models

3.4 Convergence, Calibration and Validation Criteria

3.4.1 Convergence

Iterative simulation runs were conducted for each model to reach a state of convergence, where travel times and volume changes between model runs is considered to be stable and between successive model runs using a constant random seed. Three convergence criteria are available in Vissim

- Travel time on paths
- Travel time on edges
- Volume on edges

For the LLA models the 'Travel time on paths' criteria was selected

The long paths and the high number of edge forming each path make the 'travel time on edge' an unpractical choice for convergence in the defined study area

The study area is characterised by a high number of vap-controlled signals. Therefore, the green time per phase is not constant and vary depending on traffic demand. This results in some challenges when setting constrained convergence criteria. In the case of the LLA model the following convergence criteria was adopted:

- No more than 10% variation in 'Travel time on paths' on no less than 90% of the paths
- If point 1 is not achieved due to the above highlighted reasons, a more relaxed convergence parameters of no more than 10% variation in 'Travel time on paths' on no less than 85% of the paths was considered

To demonstrate the level of convergence, each Vissim file was run for a 100 iteration and each iteration was carefully checked to confirm whether the convergence criteria were met. One converged the model was run for another 10 iterations with random seed variation. The outcomes of these 10 iterations were averaged to obtain the modelling results. These modelling results were in return compared with the survey data.

The convergence process will conduct as many iterative runs as needed to reach, if possible, the criteria set for convergence. As a result, vehicles will be distributed on the road network in a way that does not necessary reflect the actual traffic distribution (from the traffic counts). Therefore, a model can converge without necessary being calibrated against survey data. To overcome this problem, an alternative approach was developed consisting of:

- Conduct 100 different run
- For each run, compare the modelling results with those from the survey data
- Select the best run that matched the survey data

- Re-run the selected model 10 time with variable seed number. The modelling results will be the average outcomes of the 10 runs

  This approach was adopted for the PM peak hour

Appendix B highlights the results of the 10 model runs for the AM and PM peaks.

3.4.2 Calibration and Validation Criteria

The goodness of fit between the modelling results and observed data is determined using the GEH statistical formula as recommended within Volume 12 of the Design Manual for Roads and Bridges (DMRB). In general, the GEH statistic is applied to individual links and screenline flows; however it is an acceptable practice to apply the GEH measurement to turning movements.

For an acceptable fit between modelling and observed results, DMRB suggested criteria and targets are summarised within **Table 3.6.1**.

Table 3.6.1 Calibration and Validation Criteria

Flows	Criteria	Target
Link Flows	Individual flows GEH < 5	More than 85% of the cases
Turning Counts	Individual flows GEH <5	More than 85% of the cases
Screenline Counts	Individual Flows GEH <4	All or nearly all screenlines

For validation purposes, DMRB recommends to evaluate, as additional validation criteria, the percent difference for link flows, turning counts, and screenline flows and compare the results against the criteria and targets set in **Table 3.6.2**.

Table 3.6.2 Additional Validation Criteria

<table>
<tr><th>Data Type</th><th>Criteria</th><th>Target</th></tr>
<tr><td rowspan="3">Turning counts and link flows</td><td>For flows 700 - 2,700vph: to be within 15%</td><td rowspan="3">More than 85% of cases</td></tr>
<tr><td>For flows <700vph: to be within 100vph</td></tr>
<tr><td>For flows >2,700vph: to be within 400vph</td></tr>
<tr><td>Total screenline flows</td><td>To be within 5%</td><td>All (or nearly all) screenlines</td></tr>
</table>

Travel time is an additional criteria that can be used to demonstrate model validation. Again, with reference to DMRB criteria, the validation criteria for travel time is provided in **Table 3.6.3**.

Table 3.6.3 Travel Time Validation Criteria

Criteria	Target
Total journey time to be within 15%	All (or nearly all) journey times

3.5 Available Traffic Data

The available traffic data for the Vissim micro-simulation model consisted of:

- Origin/Destination (OD) matrices for a cordoned area from the Saturn model of CBLTM corresponding to the base 2016 morning (AM) and evening (PM) peak hours
- Traffic survey data conducted in October 2017 covering automatic traffic counts (ATC), classified turning movement counts (CTMC), and journey time surveys (JTS)

Figure 3.3 highlights the cordoned area of the CBLTM model which matches with the study area of **Figure 1.1**. OD matrices corresponding to 35 traffic analysis zones (TAZ) were provided for each of the AM and PM peak hours.

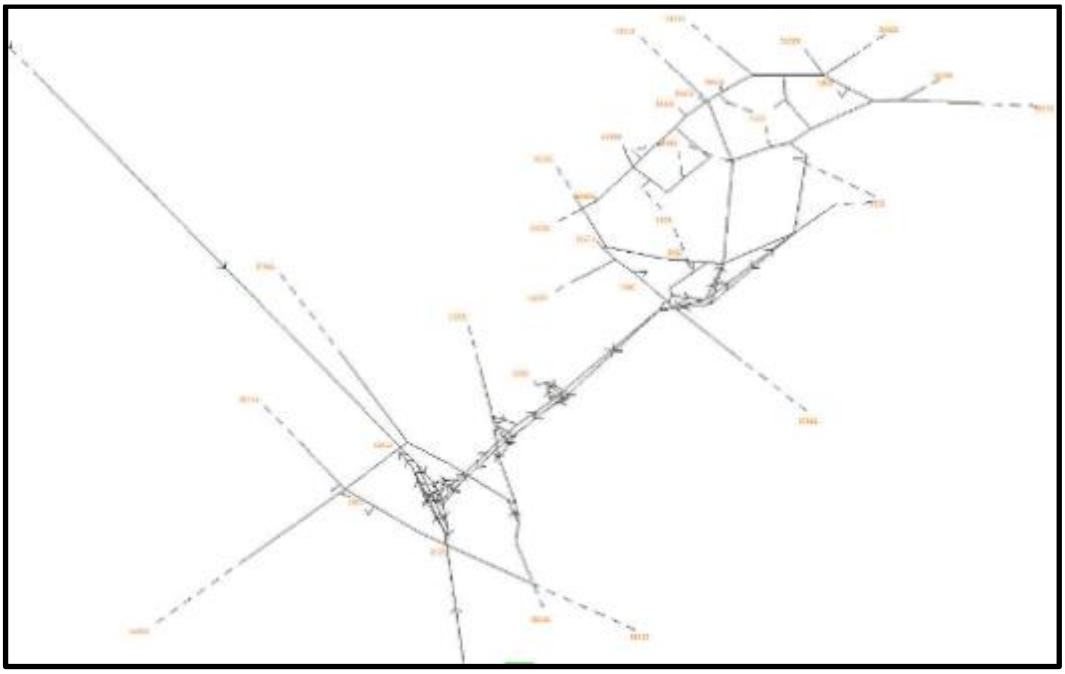

Figure 3.3 Cordoned Area of the CBLTM Model

The OD matrices from the CBLTM model correspond to Car Commuting, Car Business, Car Others, Light Good Vehicles (LGV), and Heavy Good Vehicles (HGV). **Figure 3.4** and **Figure 3.5** highlights the traffic composition of the CBLTM cordoned model for the AM and PM peak hours, respectively. Private car forms the majority of vehicles followed by LGV, and HGV. It should be noted that for the AM peak hour, 35% of LGV and 43% of HGV are through traffic in both directions of the M1. These numbers change to 33% and 47% during the PM peak hour.

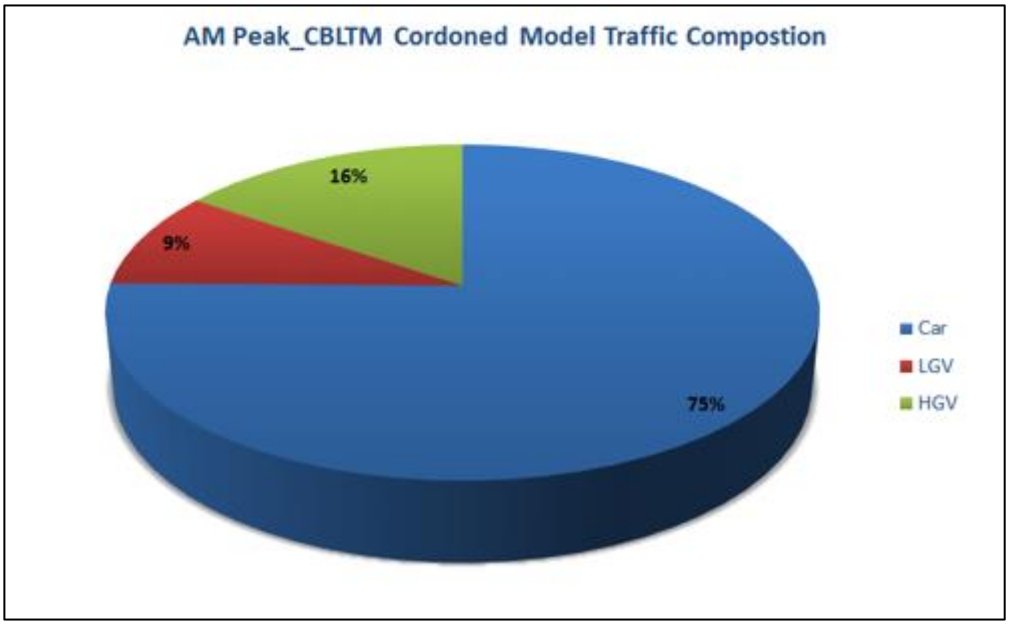

Figure 3.4 CBLTM Cordoned Model Vehicle Composition – AM Peak Hour

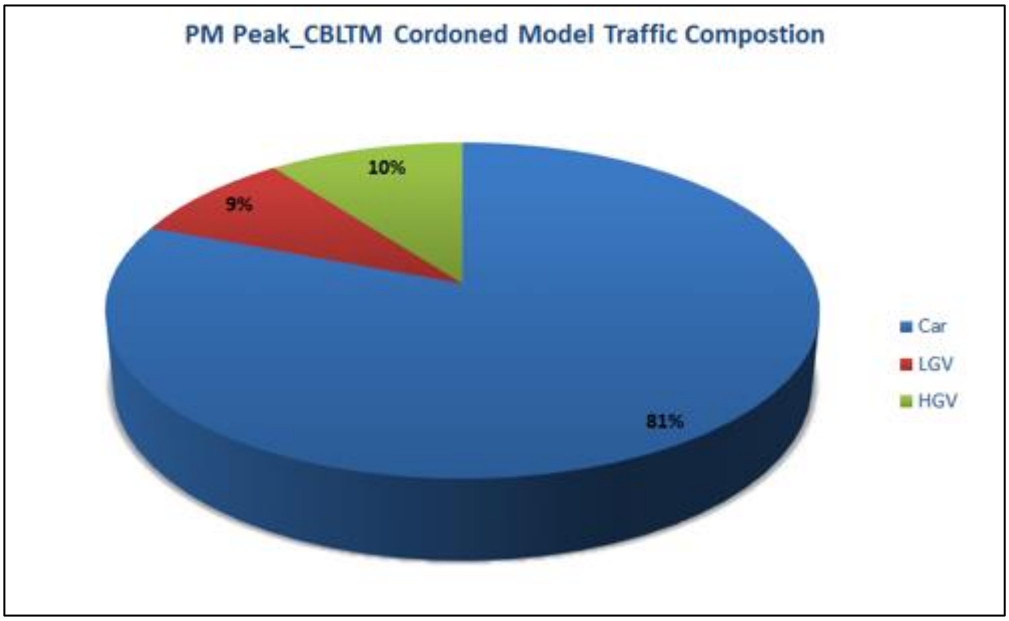

Figure 3.5 CBLTM Cordoned Model Vehicle Composition – PM Peak Hour

3.6 Dynamic Assignment

Vissim software offers two types of traffic assignments: static and dynamic. For static assignments, vehicles follow a user defined route between zones regardless of traffic congestions and delays. In turn, dynamic assignment provides the potential of several route choice options for vehicles travelling between zones (OD pairs). This assignment requires iterative model runs where vehicles between OD pairs choose the desired route to reach their destination with a more balanced road assignment within the network. With the availability of the OD matrices, the use of dynamic assignment within the Vissim software was considered appropriate. For the defined study area, drivers will have several route options when travelling between OD pairs. Traffic should be realistically distributed between the available route choices, based on the theory of generalised travel costs and network equilibrium. Therefore, dynamic assignment was chosen for the LLA model. The 35 zones provided from the CBLTM model are illustrated in **Figure 3.6,** and the corresponding attraction and production trips for each zone are summarised in **Table 3.7** for the AM and PM peak hours.

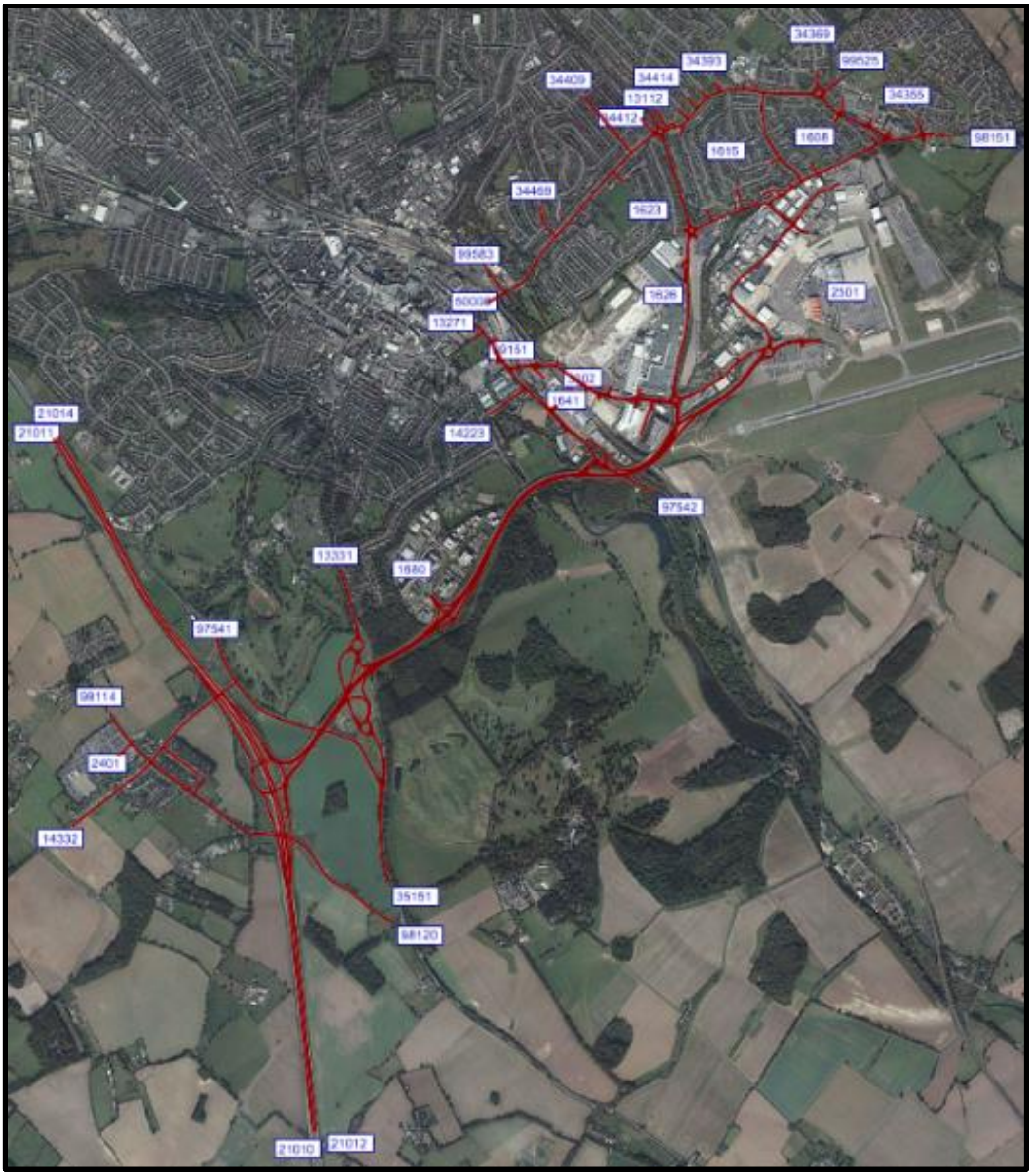

Figure 3.6 Traffic Analysis Zones

Table 3.7 Provided Trip End for the AM and PM Peak Hours

Zone Number	Zone Name	AM Peak Hour		PM Peak Hour	
		Production	Attraction	Production	Attraction
1608	Raynham Way	280	457	471	346
1615	Vauxhall Park	352	62	142	374
1623	Residential Area North to Vauxhall Way	282	311	316	387
1626	Vauxhall Factory	190	327	309	267
1641	B&Q	76	150	166	138
1680	Capability Green	105	418	360	155
2401	Luton Airparks	192	81	126	190
2501	Luton Airport	759	1,954	2,062	971
3002	Car Dealerships	0	0	0	0
13112	Vaxhall Way	799	451	636	855
13271	Windmill Rd	703	846	1138	518
13331	London Rd	693	1,367	1029	855
14223	Osborne Rd	316	585	299	530
14332	Markyate Rd	605	360	453	672
21010	M1 South	6508	0	7,559	0
21011	M1 North	0	5,543	0	6,659
21012	M1 South	0	7,064	0	6,840
21014	M1 North	6,073	0	5,816	0
34355	Colwell Rise	198	56	85	239
34369	Wingmore Ln	740	204	271	676
34393	Ashcroft Rd	483	195	245	405
34409	Somerset Ave	778	193	454	521
34412	Saywell Rd	38	10	23	64
34414	Dovehouse Hill	26	8	19	26
34469	Hart Ln	278	190	347	328
35151	London Rd	1,019	349	657	849
50008	Crawley Green Rd	175	355	395	400
97541	Newlands Rd	256	201	203	274
97542	Lower Harpenden Rd	655	613	601	548
98114	Grove Rd	35	28	45	40
98120	Front St	209	400	318	198
98151	Eaton Green Rd	211	276	240	297
99151	Luton Dunstable Busway	0	0	0	0
99525	Crawley Green Rd	314	80	129	241
99583	Hart Hill Dr	27	241	110	161

3.7 General Modelling Approach

The OD matrices generated from the CBLTM model represent the 2016 conditions, while the traffic survey was conducted in 2017. In addition, the OD data was obtained from a strategic traffic model which is less detailed in terms of network representation than micro-simulation models. Moreover, the junction turning movements within the study area may not be fully calibrated within the strategic model. In addition, the Specification Note: CBLTM Cordon for East Luton Microsimulation Model prepared in October 2017 by AECOM stated that in the strategic model, from which the cordoned data used in this study was obtained, the turning movement flows were not validated against observed data within the cordoned area.

Therefore, the OD matrices would be assigned to the Vissim network, followed by an iterative correction process to ensure that the resulting model is suitably calibrated and validated to observed data, and fit for purpose.

3.8 Modelled Period

A Vissim micro-simulation model was developed for each of the AM and PM peak periods. Each model consists of three hours comprising:

- Warm-up hour – The hour preceding the peak hour. This ensures that the road network is not empty when the volumes corresponding to the peak hour are deployed in the model
- Peak hour period – This corresponds to either the AM or PM peak hour
- Cool-down period – This is the hour succeeding the peak. It ensures that the model is a realistic one in order to maintain the interaction of the peak hour vehicles with the cool-down period before reaching their destinations

The OD matrices for the warm-up and cool-down hours were derived as a percentage of those of the peak hour (extracted from the 2017 survey data). The corresponding factors were calculated from the traffic survey data and are summarised in **Table 3.8**.

Table 3.8 Warm-up and Cool-down Hours Conversion Factors

Hour	AM Model	PM Model
Warm-up	0.8773	0.9027
Cool-down	0.7179	0.8380

3.9 Initial Modelling Results

Table 3.9 and **Table 3.10** provide a comparison between the traffic volumes obtained from the cordoned CBLTM model and those from the traffic survey. The discrepancies between these two datasets indicates that the difference is not due to growth between 2016 and 2017, and hence matrix estimation should be utilised to minimise the gap between the OD matrices and the traffic survey results.

The initial review of the link GEH values for the AM and PM peak hours identified compliance levels of 42% and 36% respectively.

Table 3.9. Comparison between CBLTM and Survey Data – AM Peak Hour

Zone	Production		Attraction		Difference (V1-V2)/V1	
	Matrix	Counts	Matrix	Counts	Production	Attraction
1608	280	126	457	85	-122.2%	-437.5%
1641	76	62	150	84	-22.0%	-78.3%
1680	105	197	418	1558	46.7%	73.2%
2401	192	48	81	45	-300.6%	-80.8%
2501	759	879	1954	1373	13.6%	-42.3%
13112	799	808	451	687	1.1%	34.4%
13271	703	839	846	810	16.3%	-4.4%
13331	693	789	1367	672	12.1%	-103.5%
14223	316	378	585	215	16.5%	-172.1%
14332	605	370	360	257	-63.6%	-39.9%
34355	198	289	56	130	31.6%	57.1%
34369	740	954	204	473	22.5%	56.9%
34393	483	273	195	176	-76.8%	-10.9%
35151	1019	501	349	876	-103.3%	60.2%
97541	256	585	201	238	56.2%	15.5%
97542	655	628	613	746	-4.4%	17.9%
98114	35	179	28	74	80.6%	61.5%
98120	209	126	400	340	-65.7%	-17.7%
98151	211	193	276	202	-9.2%	-36.8%
99525	314	497	80	361	36.9%	78.0%

Table 3.10. Comparison between CBLTM and Survey Data – PM Peak Hour

Zone	Production		Attraction		Difference (V1-V2)/V1	
	Matrix	Counts	Matrix	Counts	Production	Attraction
1608	471	140	346	133	-236.6%	-160.1%
1641	166	233	138	218	28.7%	36.5%
1680	360	1334	155	188	73.0%	17.3%
2401	126	45	190	58	-179.8%	-227.3%
2501	2062	1309	971	897	-57.6%	-8.2%
13112	636	899	855	1027	29.2%	16.7%
13271	1138	745	518	965	-52.7%	46.3%
13331	1029	734	855	1063	-40.2%	19.6%
14223	299	372	530	207	19.6%	-155.8%
14332	453	266	672	328	-70.3%	-104.9%
34355	85	185	239	360	54.3%	33.7%
34369	271	581	676	977	53.3%	30.9%
34393	245	224	405	289	-9.2%	-40.1%
35151	657	622	849	548	-5.7%	-54.9%
97541	203	293	274	514	30.8%	46.7%
97542	601	794	548	517	24.3%	-6.0%
98114	45	48	40	112	7.0%	64.3%
98120	318	209	198	116	-52.3%	-71.1%
98151	240	200	297	224	-20.1%	-32.6%
99525	129	258	241	317	50.1%	23.9%

4 2017 Base Model Calibration and Validation

4.1 Airport Distribution

The airport traffic routes were fixed based on the CAA passenger survey data (**Figure 4.1**). The CAA survey relied on passenger postcodes that were input into GIS and the most obvious routes between the airport and passenger postcodes plotted. As such, any rerouting to avoid congestion will not be captured. The CAA passenger data does not disaggregate into peak periods, and simply shows where passengers travel to/from at all times of the day. Therefore, some variation in the distribution can occur through the day particularly during the peak hour. The CAA data did not take into account passengers who parked in the Long Stay car park and subsequently connected to the airport via shuttle bus. The peak period traffic, particularly AM peak, will include employee trips, staff, and taxi traffic which may have a different distribution than that provided in the CAA data.

In addition to the CAA defined routes, a new route was introduced from Wigmore Lane. The attraction and production traffic distribution corresponding to the Airport that was derived from the survey was used for the AM and PM peak hour micro-simulation models. The distribution for the OD pairs in the AM and PM matrices were derived from the calibration process. **Tables 4.1** and **4.2** show the Airport traffic distributions during the AM and PM peaks

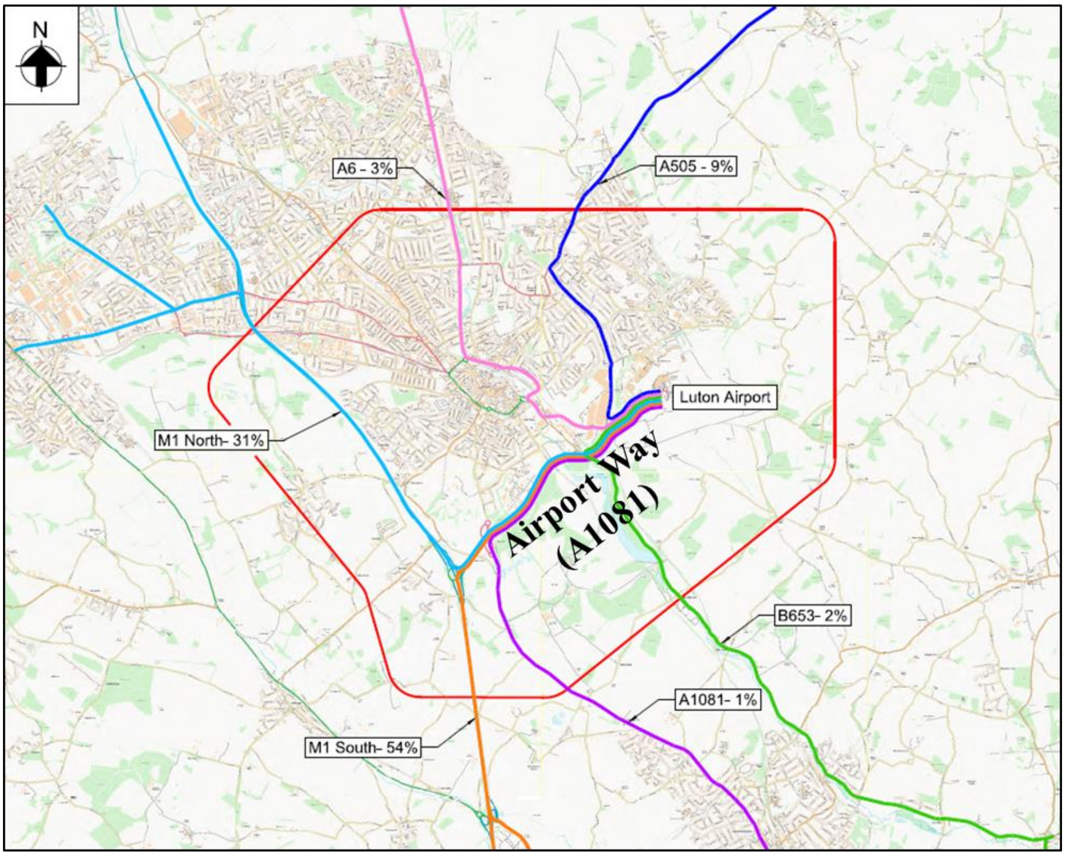

Figure 4.1 Luton London Airport Traffic Distribution

The revised split accounts for the non-passenger trips, the trips associated with staff, the peak hour variation, and the movements of taxis.

Table 4.1 AM Peak Hour Airport Traffic Distribution

Zone	CAA Derived Split (To/From Airport)	Revised Split (To Airport)	Revised Split (From Airport)
M1 South	54%	36%	46%
M1 North	31%	20%	23%
A1081	1%	1%	1%
B653	2%	1%	9%
A6	3%	7%	6%
Wigmore Lane	0%	18%	6%
A505	9%	17%	10%

Table 4.2 PM Peak Hour Airport Traffic Distribution

Zone	CAA Derived Split (To/From Airport)	Revised Split (To Airport)	Revised Split (From Airport)
M1 South	54%	41%	38%
M1 North	31%	23%	19%
A1081	1%	1%	0.5%
B653	2%	1%	7.5%
A6	3%	13%	5%
Wigmore Lane	0%	11%	13%
A505	9%	12%	17%

4.2 Matrix Estimation

The calibration process started with a correction of the OD matrices extracted from the cordoned CBLTM model. As discussed in **Section 3.9**, the modelling results varied from the 2017 observed traffic survey data. Therefore, matrix estimation was conducted to amend the original OD matrices based on the 2017 traffic counts. Traffic volumes from ATC data as well as total volumes on approach arms of the junctions from the CTMC were considered. The turning volumes per approach were not used for the calibration process since the majority of the modelled junctions in the study area are roundabouts, where it is difficult to isolate each turning movement on the circulatory. In addition, the turning volumes were retained for the validation process.

To refine the detail of the Vissim model, additional zone disaggregation was necessary, increasing from 35 (**Figure 3.9**) to 68 zones by either adding new zones or splitting existing zones where this includes a large area of different land use types. The new zones were added to represent areas included in the traffic survey but did not feature in the CBLTM cordoned model, mainly due to the variation in zone disaggregation in strategic and microsimulation models. In addition, for the purpose of calibration and validation, some zones of the CBLTM model were split to improve the accuracy of the model since an area represented by a zone might have more access and egress points than those represented in a strategic model. **Figure 4.2** depicts the locations of the 68 zones.

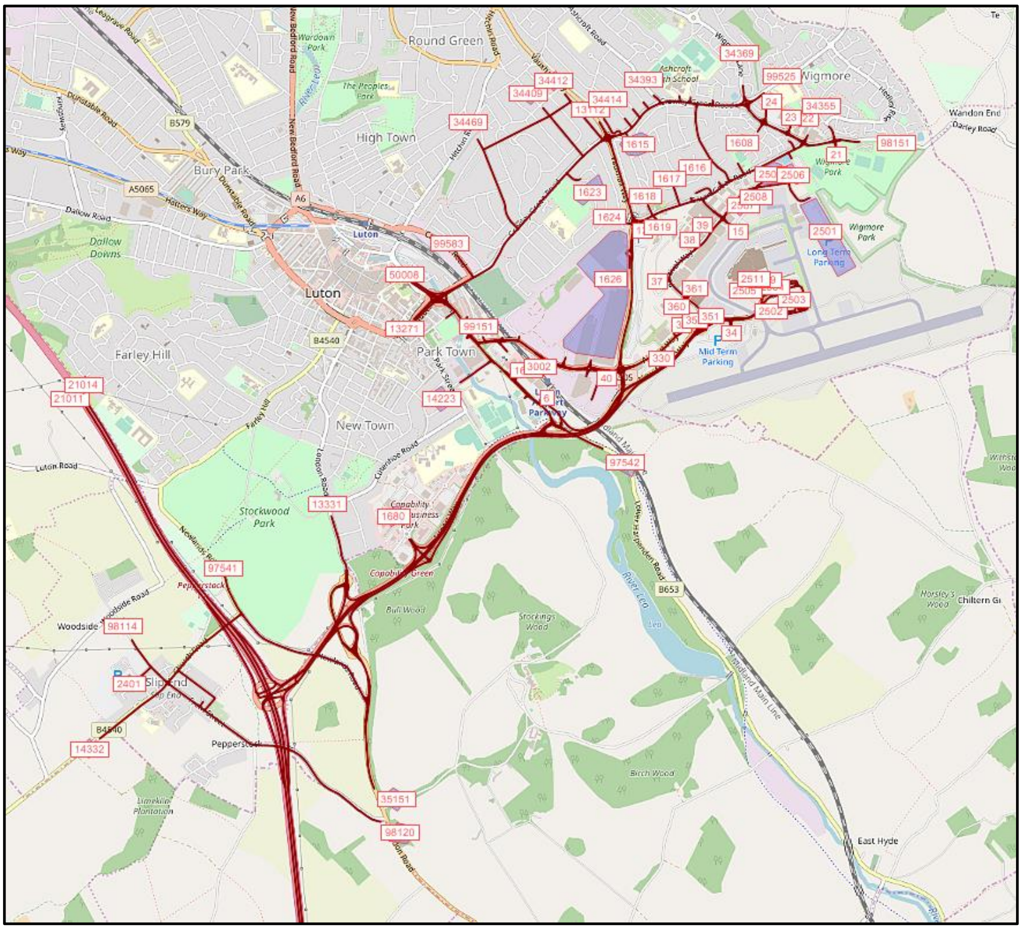

Figure 4.2 Revised Traffic Analysis Zones

The methodology adopted for the matrix estimation of the AM and PM peak hours consisted of:

1- Build the Vissim model for the study area accounting for the 35 traffic analysis zones of the CBLTM model as well as the 33 additional zones identified from the 2017 traffic survey. The resulting Vissim model has 68 traffic analysis zones
2- Combine the OD matrices of the CBLTM model into three categories, namely: cars, LGV, and HGV. The car category comprised car commuting, car business and car others. Each one of the three OD matrices has the attraction and production of each of the 35 traffic analysis zones
3- Combine the various vehicle categories of the 2017 survey into cars, LGV, and HGV. The car category comprised car and taxis, while the HGV one included OGV1, OGV2, buses/coaches
4- The attraction and production of the 33 added traffic analysis zones were set equal to the survey data per vehicle type (car, LGV, and HGV). The three OD matrices (cars, LGV, and HGV) for each of these new zones were assumed to have the same distribution as similar zones in the original CBLTM model
5- Fix the traffic distribution for Airport zones according to the diagram in **Figure 4.1** and paragraph discussed in Section 4.1

6- Calibrate each OD matrix on its own resulting in calibrated car, LGV, and HGV matrices

The adopted matrix estimation process is summarised in **Figure 4.3**.

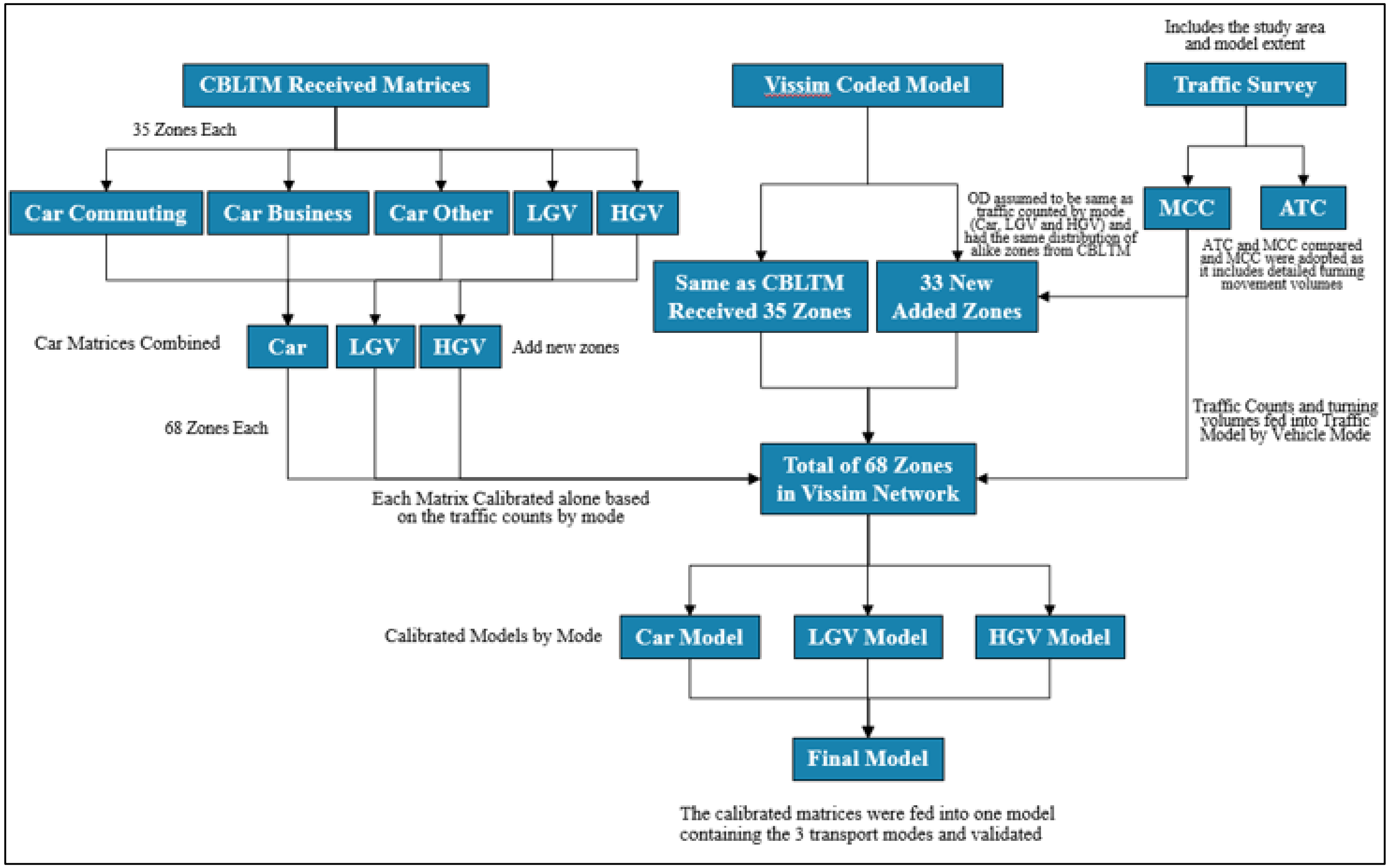

Figure 4.3 Matrix Estimation Procedure

Table 4.3 and **Table 4.4** provide a comparison of the trip ends between the original OD matrix from the CBLTM model and the resulting movements following the matrix estimation process.

Table 4.3 Trip End Resulting from Matrix Estimation – AM Peak Hour (Veh/hr)

<table>
<tr><th rowspan="2">Zone</th><th colspan="2">Production</th><th colspan="2">Attraction</th></tr>
<tr><th>CBLTM</th><th>Calibrated</th><th>CBLTM</th><th>Calibrated</th></tr>
<tr><td>6</td><td>NA</td><td>95</td><td>NA</td><td>247</td></tr>
<tr><td>13</td><td>NA</td><td>6</td><td>NA</td><td>21</td></tr>
<tr><td>15</td><td>NA</td><td>28</td><td>NA</td><td>62</td></tr>
<tr><td>21</td><td>NA</td><td>14</td><td>NA</td><td>60</td></tr>
<tr><td>22</td><td>NA</td><td>55</td><td>NA</td><td>246</td></tr>
<tr><td>23</td><td>NA</td><td>261</td><td>NA</td><td>433</td></tr>
<tr><td>24</td><td>NA</td><td>110</td><td>NA</td><td>136</td></tr>
<tr><td>33</td><td>NA</td><td>112</td><td>NA</td><td>55</td></tr>
<tr><td>34</td><td>NA</td><td>50</td><td>NA</td><td>55</td></tr>
<tr><td>37</td><td>NA</td><td>45</td><td>NA</td><td>169</td></tr>
<tr><td>38</td><td>NA</td><td>27</td><td>NA</td><td>38</td></tr>
<tr><td>39</td><td>NA</td><td>251</td><td>NA</td><td>27</td></tr>
<tr><td>40</td><td>NA</td><td>0</td><td>NA</td><td>48</td></tr>
<tr><td>330</td><td>NA</td><td>14</td><td>NA</td><td>58</td></tr>
<tr><td>350</td><td>NA</td><td>0</td><td>NA</td><td>70</td></tr>
<tr><td>351</td><td>NA</td><td>48</td><td>NA</td><td>43</td></tr>
<tr><td>360</td><td>NA</td><td>31</td><td>NA</td><td>39</td></tr>
<tr><td>361</td><td>NA</td><td>27</td><td>NA</td><td>16</td></tr>
<tr><td>1608</td><td>280</td><td>125</td><td>457</td><td>88</td></tr>
<tr><td>1615</td><td rowspan="4">352</td><td>338</td><td rowspan="4">62</td><td>152</td></tr>
<tr><td>1616</td><td>638</td><td>588</td></tr>
<tr><td>1617</td><td>155</td><td>62</td></tr>
<tr><td>1618</td><td>78</td><td>16</td></tr>
<tr><td>1619</td><td>NA</td><td>19</td><td>NA</td><td>312</td></tr>
<tr><td>1623</td><td rowspan="2">282</td><td>258</td><td rowspan="2">311</td><td>91</td></tr>
<tr><td>1624</td><td>105</td><td>24</td></tr>
<tr><td>1626</td><td>190</td><td>322</td><td>327</td><td>404</td></tr>
<tr><td>1641</td><td>76</td><td>61</td><td>150</td><td>85</td></tr>
<tr><td>1680</td><td>105</td><td>189</td><td>418</td><td>1565</td></tr>
<tr><td>2401</td><td>192</td><td>49</td><td>81</td><td>44</td></tr>
<tr><td>2500</td><td rowspan="2">759</td><td>121</td><td rowspan="2">1954</td><td>86</td></tr>
<tr><td>2501</td><td>30</td><td>26</td></tr>
</table>

2502		18		25
2503		133		153
2504		375		363
2505		36		74
2506		2		361
2507		40		157
2508		25		51
2509		21		31
2511		45		41
3002	0	0	0	0
13112	799	800	451	699
13271	703	735	846	1042
13331	693	762	1367	673
14223	316	381	585	219
14332	605	386	360	275
21010	6508	6130	0	0
21011	0	0	5543	5107
21012	0	0	7064	5547
21014	6073	5671	0	0
34355	198	354	56	136
34369	740	957	204	477
34393	483	272	195	176
34409	778	535	193	61
34412	38	67	10	109
34414	26	8	8	31
34469	278	427	190	156
35151	1019	481	349	948
50008	175	326	355	508
97541	256	573	201	242
97542	655	597	613	734
98114	35	180	28	70
98120	209	111	400	305
98151	211	166	276	209
99151	0	0	0	0
99525	314	381	80	249
99583	27	52	241	117

Table 4.4 Trip End Resulting from Matrix Estimation – PM Peak Hour (Veh/hr)

<table>
<tr><th rowspan="2">Zone</th><th colspan="2">Production</th><th colspan="2">Attraction</th></tr>
<tr><th>CBLTM</th><th>Calibrated</th><th>CBLTM</th><th>Calibrated</th></tr>
<tr><td>6</td><td>NA</td><td>213</td><td>NA</td><td>137</td></tr>
<tr><td>13</td><td>NA</td><td>20</td><td>NA</td><td>16</td></tr>
<tr><td>15</td><td>NA</td><td>55</td><td>NA</td><td>14</td></tr>
<tr><td>21</td><td>NA</td><td>50</td><td>NA</td><td>22</td></tr>
<tr><td>22</td><td>NA</td><td>194</td><td>NA</td><td>63</td></tr>
<tr><td>23</td><td>NA</td><td>658</td><td>NA</td><td>686</td></tr>
<tr><td>24</td><td>NA</td><td>77</td><td>NA</td><td>89</td></tr>
<tr><td>33</td><td>NA</td><td>97</td><td>NA</td><td>40</td></tr>
<tr><td>34</td><td>NA</td><td>82</td><td>NA</td><td>60</td></tr>
<tr><td>37</td><td>NA</td><td>171</td><td>NA</td><td>147</td></tr>
<tr><td>38</td><td>NA</td><td>85</td><td>NA</td><td>18</td></tr>
<tr><td>39</td><td>NA</td><td>32</td><td>NA</td><td>245</td></tr>
<tr><td>40</td><td>NA</td><td>22</td><td>NA</td><td>26</td></tr>
<tr><td>330</td><td>NA</td><td>148</td><td>NA</td><td>79</td></tr>
<tr><td>350</td><td>NA</td><td>0</td><td>NA</td><td>73</td></tr>
<tr><td>351</td><td>NA</td><td>29</td><td>NA</td><td>23</td></tr>
<tr><td>360</td><td>NA</td><td>48</td><td>NA</td><td>25</td></tr>
<tr><td>361</td><td>NA</td><td>38</td><td>NA</td><td>20</td></tr>
<tr><td>1608</td><td>471</td><td>142</td><td>346</td><td>132</td></tr>
<tr><td>1615</td><td rowspan="4">142</td><td>125</td><td rowspan="4">374</td><td>117</td></tr>
<tr><td>1616</td><td>426</td><td>481</td></tr>
<tr><td>1617</td><td>83</td><td>65</td></tr>
<tr><td>1618</td><td>33</td><td>102</td></tr>
<tr><td>1619</td><td>NA</td><td>240</td><td>NA</td><td>31</td></tr>
<tr><td>1623</td><td rowspan="2">316</td><td>135</td><td rowspan="2">387</td><td>143</td></tr>
<tr><td>1624</td><td>25</td><td>192</td></tr>
<tr><td>1626</td><td>309</td><td>335</td><td>267</td><td>162</td></tr>
<tr><td>1641</td><td>166</td><td>228</td><td>138</td><td>238</td></tr>
<tr><td>1680</td><td>360</td><td>1282</td><td>155</td><td>210</td></tr>
<tr><td>2401</td><td>126</td><td>45</td><td>190</td><td>60</td></tr>
<tr><td>2500</td><td rowspan="5">2062</td><td>120</td><td rowspan="5">971</td><td>98</td></tr>
<tr><td>2501</td><td>35</td><td>38</td></tr>
<tr><td>2502</td><td>24</td><td>29</td></tr>
<tr><td>2503</td><td>152</td><td>120</td></tr>
<tr><td>2504</td><td>433</td><td>425</td></tr>
</table>

2505		60		35
2506		244		1
2507		152		36
2508		34		29
2509		36		34
2511		37		35
3002	0	0	0	0
13112	636	903	855	1032
13271	1138	976	518	962
13331	1029	720	855	1074
14223	299	391	530	206
14332	453	271	672	339
21010	7559	6643	0	0
21011	0	0	6659	6572
21012	0	0	6840	6592
21014	5816	5855	0	0
34355	85	256	239	368
34369	271	579	676	1000
34393	245	220	405	290
34409	454	111	521	88
34412	23	28	64	54
34414	19	24	26	41
34469	347	297	328	365
35151	657	615	849	552
50008	395	450	400	443
97541	203	291	274	514
97542	601	753	548	502
98114	45	47	40	111
98120	318	191	198	105
98151	240	190	297	227
99151	0	0	0	0
99525	129	255	241	322
99583	110	88	161	246

4.3 Boundary Condition

Following initial dialogue with HE, a additional journey time survey was conducted along the M1 during the peak hours of three successive days (Tuesday, Wednesday, Thursday) the routes are illustrated in **Figure 4.4**. The point of interest in this survey is the stretch between markers C-D in the southbound direction in the vicinity of Junction 10.

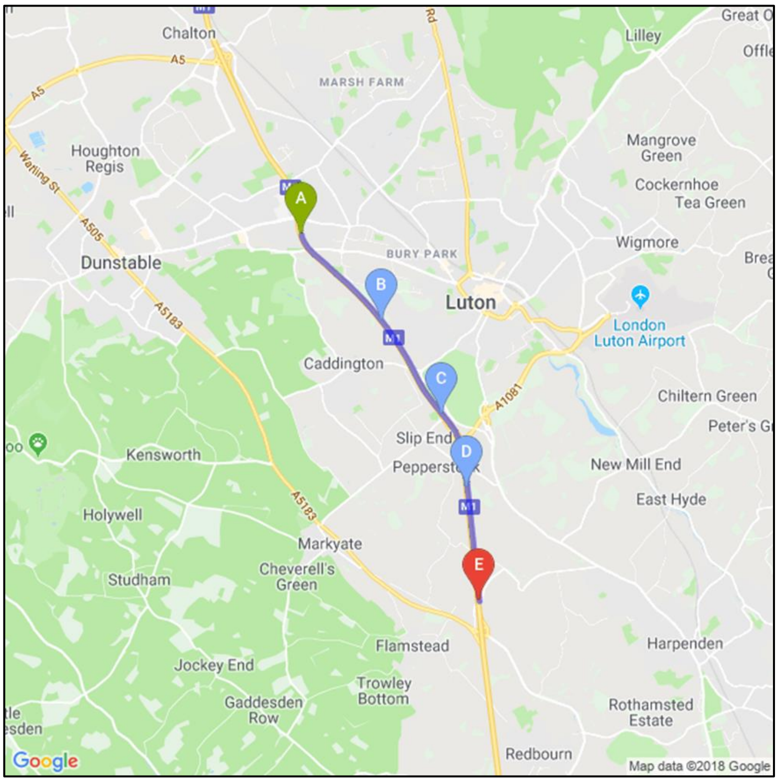

Figure 4.4 Travel Time Survey along M1

The AM peak hour is of particular interest due to the presence of slow-moving traffic along the M1 southbound, which is known to cause traffic to back-up and impede the on-ramp from Junction 10, reaching the A1081. **Figure 4.5** and **Table 4.5** presents the surveyed speed analysis relating to segment C-D southbound during the AM peak hour.

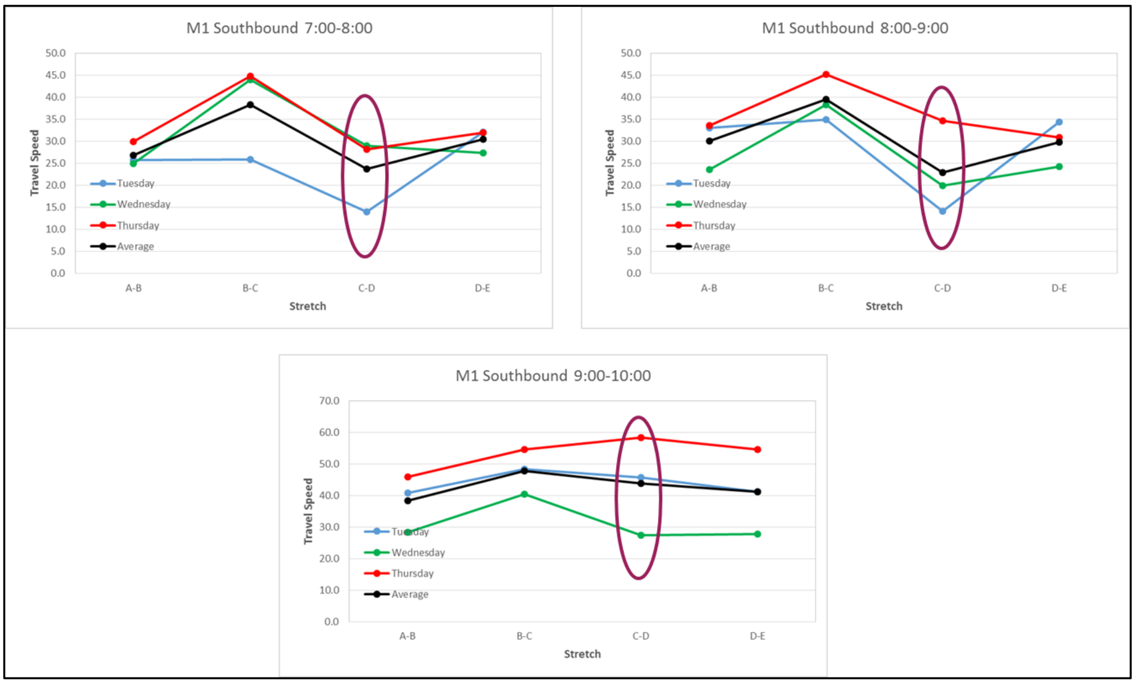

Figure 4.5 AM Travel Speed along M1

Table 4.5 AM Travel Speed along M1 Stretch C-D Southbound

C-D (Speed) Southbound	Tuesday (mph)	Wednesday (mph)	Thursday (mph)	Average (mph)
07:00-08:00	14.1	29.0	28.2	23.8
08:00-09:00	14.1	19.9	34.7	22.9
09:00-10:00	45.7	27.5	58.4	43.8

The survey speeds between C-D varied between the three surveyed days. This variation adds difficulties for the calibration process. For the Vissim modelling purpose, an average speed of 23mph was adopted. The traffic surveillance video taken during the survey on Wednesday 11th October 2017 showed traffic interruption along M1 southbound, resulting in stationary traffic at times. Such an interruption will not be picked up in the model using an average speed. Therefore, speed variation per lane on this stretch was applied based on the traffic surveillance camera in such a way to maintain the overall average speed on the stretch.

4.4 Calibration Results

The GEH statistic is used to avoid undue weighting being given to large percentage differences between small numbers and is calculated as:

$$GEH = \sqrt{\frac{(V_2 - V_1)^2}{(V_1 + V_2)/2}}$$

Where V1 is the observed value and V2 is the modelled value.

The calibration criteria defined in **Table 3.6.1 and Table 3.6.2** was adopted to provide an indication of model calibration following the matrix estimation process. The calibration phase focused on the comparison of link flows between the modelled and surveyed flows. The results are summarised in **Table 4.6**.

Table 4.6 Calibration Results

Criteria	Target	AM Peak Hour	PM Peak Hour
Individual flows GEH < 5	More than 85% of cases	97.1%	91.8%
For flows <700vph: to be within 100vph	More than 85% of cases	98.1%	93.7%
For flows 700vph-2,700vph: to be within 15%	More than 85% of cases	96.7%	85.7%
For flows >2,700vph: to be within 400vph	More than 85% of cases	100%	100%

Table 4.6 shows that the required link flow calibration criteria as specified by DMRB, where the model is shown to comply across individual flows. Taking into consideration the model extents, network characteristics, and based on the link flow GEH results, the developed model is considered calibrated and fit for purpose.

4.5 Validation Results

4.5.1 Turning Counts

The turning counts were extracted from the model and compared with those obtained from the survey. The validation results are provided in **Table 4.7**.

Table 4.7 Validation Results based on the Turning Counts*

Criteria	Target	AM Peak Hour	PM Peak Hour
Turning counts GEH < 5	More than 85% of cases	94.6%	91.6%
For flows <700vph: to be within 100vph	More than 85% of cases	99.0%	96.3%
For flows 700vph-2,700vph: to be within 15%	More than 85% of cases	92.3%	88.9%

* No turning counts more than 2,700veh/hr were recorded during the survey and hence the associated criteria was not considered

According to the results shown in **Table 4.5**, all the validation criteria for the turning counts were met during both the AM and PM peak hours.

Further analysis was carried out on a junction by junction basis to identify areas of weakness. This analysis covered both the AM and PM peak hours. The study area comprises 28 junctions. The calibration and validation criteria were applied to each one of these junctions and the number of turns falling within the acceptable range was determined. Three levels were defined for this analysis, GEH values greater than 85%, GEH values between 75% and 85%, and GEH values less than 75%. For the AM peak hour, the results are illustrated in **Figure 4.5**, which shows that 27 junctions have GEH values better than 85% and one junction has GEH values between 85% and 75%. The results of the PM peak hour are illustrated in **Figure 4.6**, where 25 junctions have GEH values better than 85%, two junctions have GEH values between 85% and 75% and only one junction with GEH values less than 75%. The junction where GEH results fail to meet the criteria may be influenced rat-running using the local roads will not be captured in the model.

Appendix A provides a comparison of each turning movement count at all surveyed junctions. A number of movements which were identified as non-compliant related to the representation of U-turn movements which are difficult to replicate when applying dynamic assignment within Vissim.

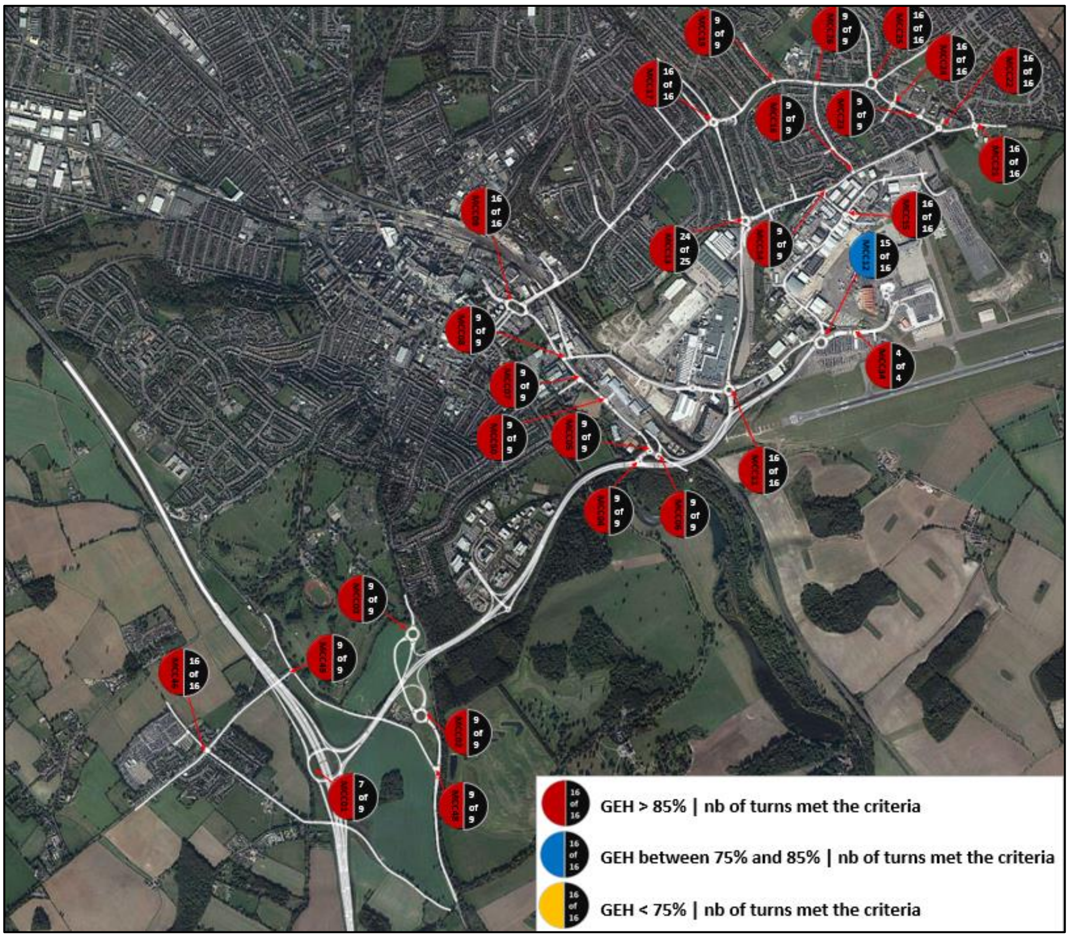

Figure 4.5 Junctions Analysis – AM Peak Hour

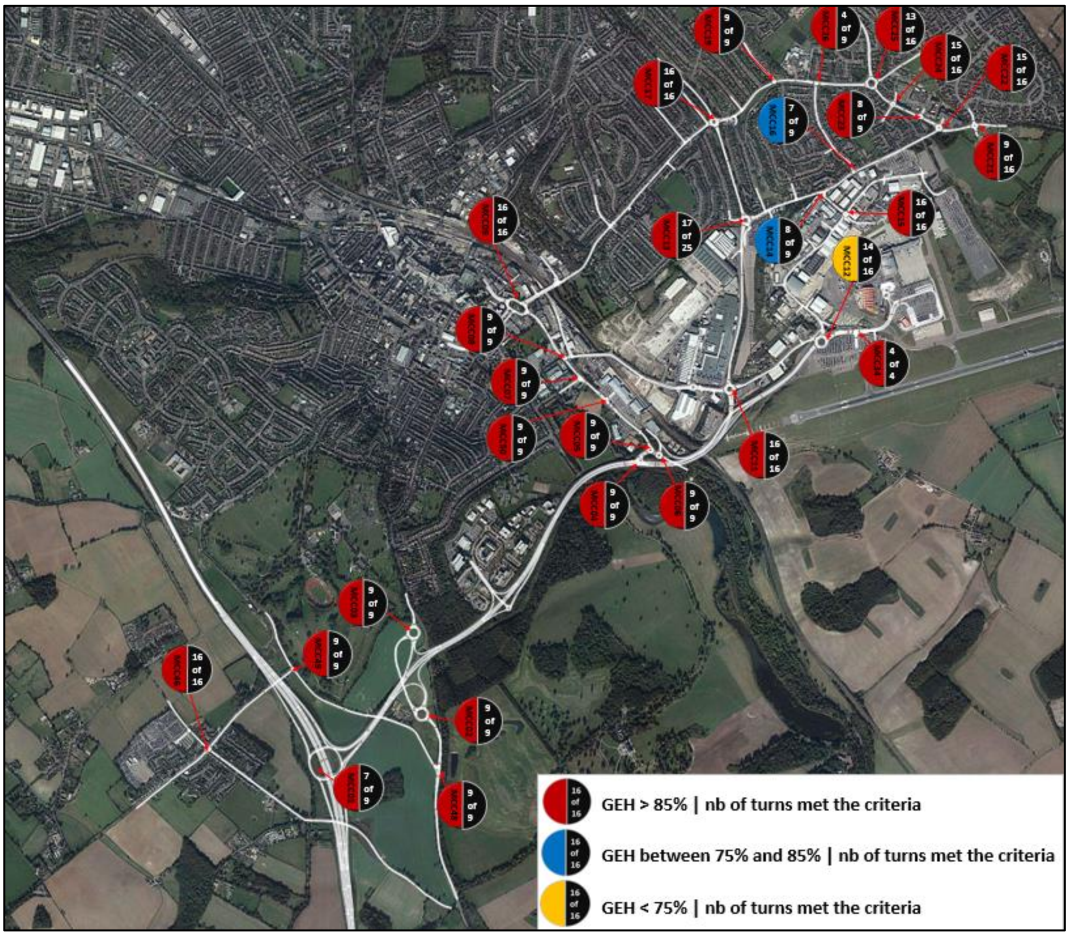

Figure 4.6 Junctions Analysis – PM Peak Hour

4.5.2 Journey Time Validation

Journey times were recorded over various segments along five separate routes within the study area. The average travel time along each segment, and the whole route, are compared with the average time output from the Vissim model. The segments along the three routes where journey times were recorded are illustrated in **Figure 4.7** to **Figure 4.12**.

Figure 4.7 Journey Time – Route 1

Figure 4.8 Journey Time – Route 2

Figure 4.9 Journey Time – Route 3

Figure 4.10 Junction 10

Figure 4.11 M1 Southbound

Figure 4.12 M1 Northbound

Table 4.8 provides a comparison between the journey times extracted from the model and the surveyed journey times. The results were compared against the criteria defined in **Table 3.6.3** and they highlight that 32 out of 34 and 30 out of 34 segments satisfy the journey time validation criteria for the AM and PM peak hour respectively. Therefore, the model is considered validated in term of journey time criteria. In the case of non-compliance, the difference between the modelled and surveyed data is not problematic and is unlikely to impose any modelling problems.

Table 4.8 Journey Time Validation

Route	Segment	AM Peak Hour			PM Peak Hour		
		Survey	Model	Within 15%	Survey	Model	Within 15%
Route 1	A – B	2min 42sec	2min 34sec	Yes	2min 58sec	2min 39sec	Yes
	B – E	1min 28sec	1min 24sec	Yes	1min 34sec	1min 28sec	Yes
	E – D	1min 04sec	1min 02sec	Yes	1min 03sec	1min 06sec	Yes
	D – E	1min 18sec	1min 15sec	Yes	1min 05sec	1min 07sec	Yes
	E – B	1min 32sec	1min 37sec	Yes	1min 39sec	1min 40sec	Yes
	B – A	2min 23sec	2min 00sec	No	2min 18sec	2min 00sec	Yes
	A – E	4min 10sec	3min 58sec	Yes	4min 32sec	4min 07sec	Yes
	E – A	3min 55sec	3min 37sec	Yes	3min 57sec	3min 40sec	Yes
Route 2	M – B	1min 33sec	1min 27sec	Yes	1min 37sec	1min 30sec	Yes
	B – D	0min 56sec	1min 02sec	Yes	1min 28sec	1min 04sec	No
	D – B	0min 55sec	0min 59sec	Yes	0min 56sec	1min 01sec	Yes
	B – M	1min 08sec	1min 02sec	Yes	1min 08sec	1min 02sec	Yes
	M – D	2min 29sec	2min 29sec	Yes	3min 05sec	2min 34sec	No
	D – M	2min 03sec	2min 01sec	Yes	2min 04sec	2min 03sec	Yes
Route 3	E – F	2min 38sec	2min 19sec	Yes	2min 24sec	2min 12sec	Yes
	F – G	1min 18sec	1min 17sec	Yes	1min 26sec	2min 03sec	No
	G – H	0min 56sec	0min 52sec	Yes	1min 09sec	1min 08sec	Yes
	H – G	0min 53sec	1min 00sec	Yes	1min 04sec	1min 12sec	Yes
	G – F	1min 52sec	1min 53sec	Yes	1min 11sec	1min 06sec	Yes
	F – E	2min 18sec	2min 14sec	Yes	2min 42sec	2min 38sec	Yes
	E – H	4min 52sec	4min 28sec	Yes	4min 59sec	5min 23sec	Yes
	H – E	5min 03sec	5min 07sec	Yes	4min 57sec	4min 56sec	Yes
2018 Survey	M1_Southbound_B to C	2min 09sec	2min 13sec	Yes	1min 36sec	1min 38sec	Yes
	M1_Southbound_C to D	3min 00sec	3min 48sec	No	1min 02sec	1min 03sec	Yes
	M1_Southbound_D to E	3min 01sec	3min 22sec	Yes	1min 36sec	1min 37sec	Yes
	M1_Southbound_B to E	8min 10sec	9min 23sec	Yes	4min 14sec	4min 18sec	Yes
	M1_Northbound_A to B	2min 07sec	2min 15sec	Yes	2min 39sec	2min 42sec	Yes
	M1_Northbound_B to C	1min 41sec	1min 41sec	Yes	1min 23sec	1min 24sec	Yes
	M1_Northbound_C to D	1min 42sec	1min 42sec	Yes	1min 32sec	1min 33sec	Yes
	M1_Northbound_A to D	5min 30sec	5min 38sec	Yes	5min 34sec	5min 39sec	Yes
	J10_ B to C	6min 52sec	7min 26sec	Yes	1min 12sec	1min 19sec	Yes
	J10_ C to B	1min 40sec	1min 35sec	Yes	2min 33sec	2min 02sec	No
	J10_ B to A	2min 33sec	2min 25sec	Yes	2min 53sec	2min 56sec	Yes
	J10_ A to B	1min 05sec	1min 02sec	Yes	0min 49sec	0min 54sec	Yes

4.5.3 Screenlines Validations

Screenlines are considered additional criteria used for model validation. Five screenlines were defined throughout the modelled network as illustrated in **Figure 4.13**. For each screenline, the combined flows from the model were compared against the associated traffic survey data.

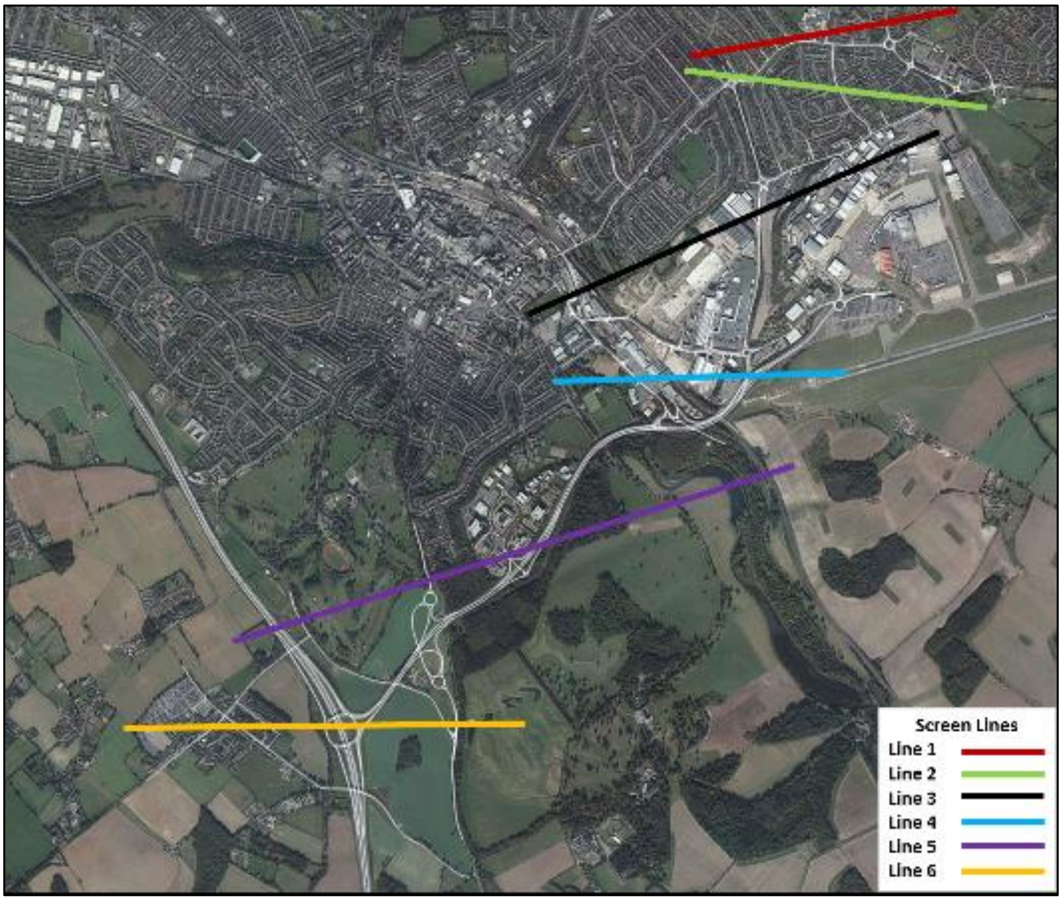

Figure 4.13 Screenlines Locations

Table 4.9 identifies that during the AM and PM peak hour, 12 out of 12 screenlines have a GEH value less than 4, as per the design criteria. For the second criteria where the difference should not exceed 5%, 11 out of 12 were satisfactory. Examining the values within **Table 4.9**, it is noticeable that all the values exceeding the 5% threshold are not considered to be far from the target values since they fall between 6% and 7%. Therefore, it can be concluded that the model is validated based on the Screenline criteria.

Table 4.9 Screenlines Validation

Screenline	Direction	AM Peak Hour		PM Peak Hour	
		GEH	Difference (M-C)*	GEH	Difference (M-C)*
1	North	0.15	0.38%	0.67	-1.30%
2	South	0.12	-0.25%	0.05	-0.10%
2	North	0.41	0.95%	2.71	-4.77%
2	South	0.65	-1.25%	0.53	1.10%
3	North	2.36	-4.43%	1.39	-2.34%
3	South	1.73	-2.95%	1.72	-3.21%
4	North	2.35	-4.74%	0.55	-1.04%
4	South	3.52	-6.34%	3.93	-7.26%
5	North	1.41	-1.44%	2.76	-2.62%
5	South	1.37	-1.39%	1.60	-1.60%
6	North	1.33	-1.38%	1.69	-1.73%
6	South	0.54	-0.58%	1.45	-1.44%

* Flow from the model minus flow from the survey counts

5 Summary and Conclusions

5.1 Summary

This report summarises the Vissim model development, calibration and validation of the London Luton Airport local area network. It outlines the adopted methodology and details the modelling outputs. It also demonstrates that the AM and PM peak hour models are suitable for the use in the assessment of the future year scenarios, and specifically the appraisal of potential expansion and growth forecasts at London Luton Airport.

The study area defined for the Vissim model focused on the strategic and local road network in the vicinity of London Luton Airport. The vehicular demand on this road network was derived from the origin/destination (OD) matrix obtained from a cordoned area of the CBLTM model of year 2016, as well as a comprehensive survey programme conducted in 2017. A matrix estimation procedure was conducted for both the AM and PM peak period OD matrices based on the cordoned model and survey data.

In accordance with DMRB, various modelling results were compared with observed data in order to identify the degree of model calibration and validation. The calibration process relied on traffic volumes on links as well as total volumes on approach arms of the junctions. The validation procedure was based on turning volume counts on junctions, screenline analysis, and journey time comparisons.

The calibration and validation data identified that all of the modelling results are in accordance, or within reasonable compliance with the DMRB guidelines.

5.2 Conclusions

The calibration and validation results showed that the modelling results are in compliance with DMRB guidelines. Therefore, the model is considered fit for purpose. The developed models for the AM and PM peak hours can be used to test future scenarios associated with the expansion of London Luton Airport. **Table 5.1** summarises the calibration and validation results.

Table 5.1 Summary of Calibration and Validation Results

Data Type	Criteria	Target	AM Peak Hour Model Results	PM Peak Hour Model Results
Link Flows	Individual flows GEH < 5	More than 85% of the cases	97.1%	91.8%
	For flows <700vph: to be within 100vph	More than 85% of cases	98.1%	93.7%
	For flows 700vph-2,700vph: to be within 15%	More than 85% of cases	96.7%	85.7%
	For flows >2,700vph: to be within 400vph	More than 85% of cases	100%	100%
Turning Counts	Individual flows GEH <5	More than 85% of the cases	94.6%	91.6%
	For flows <700vph: to be within 100vph	More than 85% of cases	99.7%	96.3%
	For flows 700vph-2,700vph: to be within 15%	More than 85% of cases	92.3%	88.9%
Journey Time	Total journey time to be within 15%	All (or nearly all) journey times	32 out of 34 sub routes	30 out of 34 sub routes
Screenlines	Individual Flows GEH <4	All or nearly all screenlines	12 out of 12	12 out of 12
	Total screenline flows to be within 5%	All or nearly all screenlines	11 out of 12	11 out of 12

Appendix A

Junction Turning Movement Validation Results

A1 Turning Movement Validation

Junction	Origin	Destination	Counts		Vissim Results		GEH	
			AM Peak	PM Peak	Model AM	Model PM	Model AM	Model PM
MCC1	M1 (N)	New Airport Way	1177	1021	1211	1004	0.98	0.53
	M1 (N)	M1 (S)	14	1	0	0	5.29	1.41
	M1 (N)	M1 (N)	12	0	11	0	0.29	0.00
	New Airport Way	M1 (N)	750	1561	772	1518	0.80	1.10
	New Airport Way	M1 (S)	1018	1737	1037	1710	0.59	0.65
	New Airport Way	New Airport Way	101	43	1	0	14.00	9.27
	M1 (S)	M1 (N)	1	4	0	0	1.41	2.83
	M1 (S)	New Airport Way	1726	1655	1708	1613	0.43	1.04
	M1 (S)	M1 (S)	45	5	39	5	0.93	0.00
MCC2	Caddington Rd	New Airport Way	284	513	294	519	0.59	0.26
	Caddington Rd	London Rd	518	345	470	324	2.16	1.15
	Caddington Rd	Caddington Rd	7	3	0	0	3.74	2.45
	New Airport Way	Caddington Rd	53	133	54	150	0.14	1.43
	New Airport Way	London Rd	584	623	507	595	3.30	1.13
	New Airport Way	New Airport Way	7	12	0	0	3.74	4.90

	London Rd	Caddington Rd	728	481	724	457	0.15	1.11
	London Rd	New Airport Way	170	265	166	256	0.31	0.56
	London Rd	London Rd	2	0	0	0	2.00	0.00
MCC3	London Rd (N)	New Airport Way	205	86	210	83	0.35	0.33
	London Rd (N)	London Rd (S)	582	640	553	636	1.22	0.16
	London Rd (N)	London Rd (N)	2	8	0	0	2.00	4.00
	New Airport Way	London Rd (N)	482	744	475	735	0.32	0.33
	New Airport Way	London Rd (S)	236	207	214	212	1.47	0.35
	New Airport Way	New Airport Way	7	4	0	0	3.74	2.83
	London Rd (S)	London Rd (N)	188	311	185	324	0.22	0.73
	London Rd (S)	New Airport Way	593	287	594	279	0.04	0.48
	London Rd (S)	London Rd (S)	3	2	0	0	2.45	2.00
MCC4	B653	New Airport Way (E)	193	258	177	219	1.18	2.53
	B654	New Airport Way (W)	556	663	644	665	3.59	0.08
	B655	B655	0	0	0	0	0.00	0.00
	New Airport Way (E)	B656	53	28	0	0	10.30	7.48
	New Airport Way (E)	New Airport Way (W)	1977	1861	1822	1815	3.56	1.07
	New Airport Way (E)	New Airport Way (E)	1	0	1	0	0.00	0.00

	New Airport Way (W)	B659	640	603	678	604	1.48	0.04
	New Airport Way (W)	New Airport Way (E)	1628	1759	1540	1711	2.21	1.15
	New Airport Way (W)	New Airport Way (W)	0	0	0	0	0.00	0.00
MCC5	Gipsy Ln	B653 (E)	613	381	568	394	1.85	0.66
	Gipsy Ln	B653 (W)	310	376	395	415	4.53	1.96
	Gipsy Ln	Gipsy Ln	6	1	0	0	3.46	1.41
	B653 (E)	Gipsy Ln	267	446	258	445	0.56	0.05
	B653 (E)	B653 (W)	424	542	431	480	0.34	2.74
	B653 (E)	B653 (E)	1	1	0	0	1.41	1.41
	B653 (W)	Gipsy Ln	317	376	311	353	0.34	1.20
	B653 (W)	B653 (E)	362	245	370	249	0.42	0.25
	B653 (W)	B653 (W)	4	4	0	0	2.83	2.83
MCC6	Parkway Rd	Lower Harpenden Rd	8	26	0	0	4.00	7.21
	Parkway Rd	B654	93	211	91	174	0.21	2.67
	Parkway Rd	Parkway Rd	0	1	0	0	0.00	1.41
	Lower Harpenden Rd	Parkway Rd	18	10	0	0	6.00	4.47
	Lower Harpenden Rd	B657	600	783	598	751	0.08	1.16
	Lower Harpenden Rd	Lower Harpenden Rd	0	1	0	0	0.00	1.41
	B659	Parkway Rd	241	136	247	135	0.38	0.09

	B660	Lower Harpenden Rd	738	490	692	508	1.72	0.81
	B661	B661	0	1	0	0	0.00	1.41
MCC7	Windmill Rd	Gipsy Ln	740	705	805	722	2.34	0.64
	Windmill Rd	Osborne Rd	116	99	98	86	1.74	1.35
	Windmill Rd	Windmill Rd	0	1	0	0	0.00	1.41
	Gipsy Ln	Windmill Rd	477	747	481	778	0.18	1.12
	Gipsy Ln	Osborne Rd	99	107	106	118	0.69	1.04
	Gipsy Ln	Gipsy Ln	22	76	0	0	6.63	12.33
	Osborne Rd	Windmill Rd	179	210	178	219	0.07	0.61
	Osborne Rd	Gipsy Ln	199	161	204	174	0.35	1.00
	Osborne Rd	Osborne Rd	0	1	0	0	0.00	1.41
MCC8	Windmill Rd (N)	Kimpton Rd	233	219	251	224	1.16	0.34
	Windmill Rd (N)	Windmill Rd (S)	606	526	705	526	3.87	0.00
	Windmill Rd (N)	Windmill Rd (N)	0	0	0	0	0.00	0.00
	Kimpton Rd	Windmill Rd (N)	317	253	271	272	2.68	1.17
	Kimpton Rd	Windmill Rd (S)	250	279	199	284	3.40	0.30
	Kimpton Rd	Kimpton Rd	1	0	0	0	1.41	0.00
	Windmill Rd (S)	Windmill Rd (N)	493	712	498	781	0.22	2.53
	Windmill Rd (S)	Kimpton Rd	165	245	161	219	0.31	1.71
	Windmill Rd (S)	Windmill Rd (S)	0	0	0	0	0.00	0.00
MCC11	Vauxhall Way	Airport Way	66	84	2	5	10.98	11.84
	Vauxhall Way	New Airport Way	967	911	840	873	4.23	1.27

	Vauxhall Way	Kimpton Rd	431	264	385	206	2.28	3.78
	Vauxhall Way	Vauxhall Way	0	0	0	0	0.00	0.00
	Airport Way	Vauxhall Way	72	210	58	175	1.74	2.52
	Airport Way	New Airport Way	28	33	27	25	0.19	1.49
	Airport Way	Kimpton Rd	210	241	235	292	1.68	3.12
	Airport Way	Airport Way	13	6	0	0	5.10	3.46
	New Airport Way	Vauxhall Way	760	821	773	823	0.47	0.07
	New Airport Way	Airport Way	31	21	60	48	4.30	4.60
	New Airport Way	Kimpton Rd	59	29	61	33	0.26	0.72
	New Airport Way	New Airport Way	3	3	0	0	2.45	2.45
	Kimpton Rd	Vauxhall Way	181	312	165	326	1.22	0.78
	Kimpton Rd	Airport Way	173	160	183	169	0.75	0.70
	Kimpton Rd	New Airport Way	56	92	59	95	0.40	0.31
	Kimpton Rd	Kimpton Rd	18	23	20	23	0.46	0.00
MCC12	Percival Way	Airport Way (E)	138	83	238	166	7.29	7.44
	Percival Way	New Airport Way	500	400	419	314	3.78	4.55
	Percival Way	Airport Way (W)	84	75	124	180	3.92	9.30
	Percival Way	Percival Way	2	0	0	0	2.00	0.00
	Airport Way (E)	Percival Way	48	74	41	93	1.05	2.08
	Airport Way (E)	New Airport Way	456	506	481	506	1.16	0.00

	Airport Way (E)	Airport Way (W)	123	192	166	233	3.58	2.81
	Airport Way (E)	Airport Way (E)	7	6	0	0	3.74	3.46
	New Airport Way	Percival Way	516	594	411	565	4.88	1.20
	New Airport Way	Airport Way (E)	378	434	411	496	1.66	2.88
	New Airport Way	Airport Way (W)	74	115	0	2	12.17	14.77
	New Airport Way	New Airport Way	6	3	0	0	3.46	2.45
	Airport Way (W)	Percival Way	109	127	134	173	2.27	3.76
	Airport Way (W)	Airport Way (E)	163	185	102	96	5.30	7.51
	Airport Way (W)	New Airport Way	23	13	0	0	6.78	5.10
	Airport Way (W)	Airport Way (W)	4	4	0	0	2.83	2.83
MCC13	Vauxhall Way (N)	Eaton Green Rd	218	140	281	211	3.99	5.36
	Vauxhall Way (N)	Eaton Green R’about	0	1	1	0	1.41	1.41
	Vauxhall Way (N)	Vauxhall Way (S)	825	637	595	486	8.63	6.37
	Vauxhall Way (N)	Harrowden Rd	1	3	2	1	0.82	1.41
	Vauxhall Way (N)	Vauxhall Way (N)	0	2	0	0	0.00	2.00
	Eaton Green Rd	Vauxhall Way (N)	104	167	90	151	1.42	1.27
	Eaton Green Rd	Eaton Green R’about	0	0	1	0	1.41	0.00
	Eaton Green Rd	Vauxhall Way (S)	553	606	570	561	0.72	1.86

	Eaton Green Rd	Harrowden Rd	17	101	14	99	0.76	0.20
	Eaton Green Rd	Eaton Green Rd	1	10	0	0	1.41	4.47
	Eaton Green R'about	Eaton Green R'about	0	0	0	0	0.00	0.00
	Eaton Green R'about	Vauxhall Way (N)	0	2	0	0	0.00	2.00
	Eaton Green R'about	Eaton Green Rd	2	4	0	7	2.00	1.28
	Eaton Green R'about	Vauxhall Way (S)	4	14	8	14	1.63	0.00
	Eaton Green R'about	Harrowden Rd	0	0	0	0	0.00	0.00
	Vauxhall Way (S)	Vauxhall Way (N)	506	737	441	658	2.99	2.99
	Vauxhall Way (S)	Eaton Green Rd	517	529	521	558	0.18	1.24
	Vauxhall Way (S)	Eaton Green R'about	18	12	22	13	0.89	0.28
	Vauxhall Way (S)	Harrowden Rd	4	89	3	91	0.53	0.21
	Vauxhall Way (S)	Vauxhall Way (S)	2	1	0	0	2.00	1.41
	Harrowden Rd	Vauxhall Way (N)	12	2	12	2	0.00	0.00
	Harrowden Rd	Eaton Green Rd	30	14	29	11	0.18	0.85
	Harrowden Rd	Eaton Green R'about	0	0	0	0	0.00	0.00
	Harrowden Rd	Vauxhall Way (S)	58	12	61	15	0.39	0.82
	Harrowden Rd	Harrowden Rd	0	0	0	0	0.00	0.00

MCC14	Eaton Green Rd (W)	Eaton Green Rd (E)	293	504	299	550	0.35	2.00
	Eaton Green Rd (W)	Frank Lester Way	283	119	311	185	1.62	5.35
	Eaton Green Rd (W)	Eaton Green Rd (W)	1	1	0	0	1.41	1.41
	Eaton Green Rd (E)	Eaton Green Rd (W)	466	446	536	453	3.13	0.33
	Eaton Green Rd (E)	Frank Lester Way	613	173	574	155	1.60	1.41
	Eaton Green Rd (E)	Eaton Green Rd (E)	1	1	0	0	1.41	1.41
	Frank Lester Way	Eaton Green Rd (W)	97	274	60	159	4.18	7.82
	Frank Lester Way	Eaton Green Rd (E)	194	673	191	628	0.22	1.76
	Frank Lester Way	Frank Lester Way	1	0	0	0	1.41	0.00
MCC15	Frank Lester Way	President Way (N)	266	79	279	81	0.79	0.22
	Frank Lester Way	Airport Approach Rd	27	4	21	5	1.22	0.47
	Frank Lester Way	Percival Way (S)	599	205	585	254	0.58	3.23
	Frank Lester Way	Frank Lester Way	0	2	0	0	0.00	2.00
	President Way (N)	Frank Lester Way	78	251	56	215	2.69	2.36
	President Way (N)	Airport Approach Rd	6	3	0	0	3.46	2.45

	President Way (N)	Percival Way (S)	132	275	161	363	2.40	4.93
	President Way (N)	President Way (N)	0	2	0	0	0.00	2.00
	Airport Approach Rd	Frank Lester Way	8	31	9	31	0.34	0.00
	Airport Approach Rd	President Way (N)	5	2	0	0	3.16	2.00
	Airport Approach Rd	Percival Way (S)	15	16	17	20	0.50	0.94
	Airport Approach Rd	Airport Approach Rd	1	0	0	0	1.41	0.00
	Percival Way (S)	Frank Lester Way	204	651	183	551	1.51	4.08
	Percival Way (S)	President Way (N)	357	106	372	122	0.79	1.50
	Percival Way (S)	Airport Approach Rd	25	6	41	9	2.79	1.10
	Percival Way (S)	Percival Way (S)	8	6	0	0	4.00	3.46
MCC16	Lalleford Rd	Eaton Green Rd (E)	39	46	32	49	1.17	0.44
	Lalleford Rd	Eaton Green Rd (W)	464	45	437	49	1.27	0.58
	Lalleford Rd	Lalleford Rd	0	1	0	0	0.00	1.41
	Eaton Green Rd (E)	Lalleford Rd	19	51	38	51	3.56	0.00
	Eaton Green Rd (E)	Eaton Green Rd (W)	598	567	676	565	3.09	0.08
	Eaton Green Rd (E)	Eaton Green Rd (E)	0	0	0	0	0.00	0.00
	Eaton Green Rd (W)	Lalleford Rd	33	229	127	536	10.51	15.70

	Eaton Green Rd (W)	Eaton Green Rd (E)	461	939	361	637	4.93	10.76
	Eaton Green Rd (W)	Eaton Green Rd (W)	0	1	0	0	0.00	1.41
MCC17	Vauxhall Way (N)	Crawley Green Rd (E)	61	182	60	176	0.13	0.45
	Vauxhall Way (N)	Vauxhall Way (S)	625	566	618	577	0.28	0.46
	Vauxhall Way (N)	Crawley Green Rd (W)	122	151	122	150	0.00	0.08
	Vauxhall Way (N)	Vauxhall Way (N)	0	0	0	0	0.00	0.00
	Crawley Green Rd (E)	Vauxhall Way (N)	105	146	98	139	0.69	0.59
	Crawley Green Rd (E)	Vauxhall Way (S)	156	98	113	67	3.71	3.41
	Crawley Green Rd (E)	Crawley Green Rd (W)	451	430	442	442	0.43	0.57
	Crawley Green Rd (E)	Crawley Green Rd (E)	0	2	0	0	0.00	2.00
	Vauxhall Way (S)	Vauxhall Way (N)	428	701	434	666	0.29	1.34
	Vauxhall Way (S)	Crawley Green Rd (E)	68	111	47	54	2.77	6.28
	Vauxhall Way (S)	Crawley Green Rd (W)	65	67	59	60	0.76	0.88
	Vauxhall Way (S)	Vauxhall Way (S)	1	2	0	0	1.41	2.00
	Crawley Green Rd (W)	Vauxhall Way (N)	154	180	149	176	0.41	0.30

	Crawley Green Rd (W)	Crawley Green Rd (E)	484	472	485	449	0.05	1.07
	Crawley Green Rd (W)	Vauxhall Way (S)	253	82	155	55	6.86	3.26
	Crawley Green Rd (W)	Crawley Green Rd (W)	9	3	0	0	4.24	2.45
MCC19	Ashcroft Rd	Crawley Green Rd (E)	135	109	132	107	0.26	0.19
	Ashcroft Rd	Crawley Green Rd (W)	137	115	144	121	0.59	0.55
	Ashcroft Rd	Ashcroft Rd	1	0	0	0	1.41	0.00
	Crawley Green Rd (E)	Ashcroft Rd	74	119	76	122	0.23	0.27
	Crawley Green Rd (E)	Crawley Green Rd (W)	268	471	209	436	3.82	1.64
	Crawley Green Rd (E)	Crawley Green Rd (E)	0	1	0	0	0.00	1.41
	Crawley Green Rd (W)	Ashcroft Rd	101	170	112	176	1.07	0.46
	Crawley Green Rd (W)	Crawley Green Rd (E)	377	517	338	420	2.06	4.48
	Crawley Green Rd (W)	Crawley Green Rd (W)	1	2	0	0	1.41	2.00
MCC21	Eaton Green Rd (W)	Colwell Rise	115	303	121	280	0.55	1.35
	Eaton Green Rd (W)	Eaton Green Rd (E)	145	206	156	196	0.90	0.71
	Eaton Green Rd (W)	Eaton Green Rd	30	13	16	8	2.92	1.54
	Eaton Green Rd (W)	Eaton Green Rd (W)	0	0	0	0	0.00	0.00

	Colwell Rise	Eaton Green Rd (E)	57	10	41	5	2.29	1.83
	Colwell Rise	Eaton Green Rd	6	2	0	0	3.46	2.00
	Colwell Rise	Eaton Green Rd (W)	226	173	313	251	5.30	5.36
	Colwell Rise	Colwell Rise	0	0	0	0	0.00	0.00
	Eaton Green Rd (E)	Eaton Green Rd (W)	167	157	112	132	4.66	2.08
	Eaton Green Rd (E)	Eaton Green Rd	17	2	41	15	4.46	4.46
	Eaton Green Rd (E)	Colwell Rise	9	41	11	41	0.63	0.00
	Eaton Green Rd (E)	Eaton Green Rd (E)	0	0	0	0	0.00	0.00
	Eaton Green Rd	Colwell Rise	6	16	2	29	2.00	2.74
	Eaton Green Rd	Eaton Green Rd (E)	0	8	12	22	4.90	3.61
	Eaton Green Rd	Eaton Green Rd (W)	9	28	0	0	4.24	7.48
	Eaton Green Rd	Eaton Green Rd	0	0	0	0	0.00	0.00
MCC22	Wigmore Ln	Wigmore Pl	87	23	84	20	0.32	0.65
	Wigmore Ln	Eaton Green Rd (E)	182	174	174	169	0.60	0.38
	Wigmore Ln	Eaton Green Rd (W)	379	305	411	333	1.61	1.57
	Wigmore Ln	Wigmore Ln	1	6	0	0	1.41	3.46
	Wigmore Pl	Wigmore Ln	21	74	18	74	0.68	0.00
	Wigmore Pl	Eaton Green Rd (E)	3	20	4	17	0.53	0.70
	Wigmore Pl	Eaton Green Rd (W)	37	98	39	107	0.32	0.89

	Wigmore Pl	Wigmore Pl	0	1	0	0	0.00	1.41
	Eaton Green Rd (E)	Wigmore Ln	123	186	128	198	0.45	0.87
	Eaton Green Rd (E)	Wigmore Pl	29	4	31	4	0.37	0.00
	Eaton Green Rd (E)	Eaton Green Rd (W)	251	168	265	180	0.87	0.91
	Eaton Green Rd (E)	Eaton Green Rd (E)	0	0	0	0	0.00	0.00
	Eaton Green Rd (W)	Wigmore Ln	205	638	150	346	4.13	13.16
	Eaton Green Rd (W)	Wigmore Pl	113	36	125	36	1.10	0.00
	Eaton Green Rd (W)	Eaton Green Rd (E)	108	326	116	301	0.76	1.41
	Eaton Green Rd (W)	Eaton Green Rd (W)	3	3	0	0	2.45	2.45
MCC23	Wigmore Ln (N)	Wigmore Ln (N)	0	0	0	0	0.00	0.00
	Wigmore Ln (N)	Wigmore Ln (E)	163	233	155	201	0.63	2.17
	Wigmore Ln (N)	Wigmore Ln (W)	114	417	106	450	0.76	1.58
	Wigmore Ln (E)	Wigmore Ln (N)	160	301	177	344	1.31	2.39
	Wigmore Ln (E)	Wigmore Ln (E)	11	12	0	0	4.69	4.90
	Wigmore Ln (E)	Wigmore Ln (W)	179	610	118	274	5.01	15.98
	Wigmore Ln (W)	Wigmore Ln (N)	247	395	248	339	0.06	2.92
	Wigmore Ln (W)	Wigmore Ln (E)	488	263	517	322	1.29	3.45
	Wigmore Ln (W)	Wigmore Ln (W)	1	2	0	0	1.41	2.00
MCC24	Wigmore Ln (N)	Twyford Dr	96	59	96	57	0.00	0.26

	Wigmore Ln (N)	Wigmore Ln (S)	639	559	659	557	0.79	0.08
	Wigmore Ln (N)	Raynham Way	58	54	52	50	0.81	0.55
	Wigmore Ln (N)	Wigmore Ln (N)	1	1	0	0	1.41	1.41
	Twyford Dr	Wigmore Ln (N)	68	38	53	32	1.93	1.01
	Twyford Dr	Wigmore Ln (S)	44	35	62	38	2.47	0.50
	Twyford Dr	Raynham Way	1	5	1	5	0.00	0.00
	Twyford Dr	Twyford Dr	0	0	0	0	0.00	0.00
	Wigmore Ln (S)	Wigmore Ln (N)	226	914	157	620	4.99	10.62
	Wigmore Ln (S)	Twyford Dr	33	28	33	25	0.00	0.58
	Wigmore Ln (S)	Raynham Way	26	74	32	76	1.11	0.23
	Wigmore Ln (S)	Wigmore Ln (S)	2	1	0	0	2.00	1.41
	Raynham Way	Wigmore Ln (N)	74	80	74	74	0.00	0.68
	Raynham Way	Twyford Dr	4	4	4	4	0.00	0.00
	Raynham Way	Wigmore Ln (S)	48	56	50	65	0.29	1.16
	Raynham Way	Raynham Way	0	0	0	0	0.00	0.00
MCC25	Wigmore Ln (N)	Crawley Green Rd (N)	110	122	108	119	0.19	0.27
	Wigmore Ln (N)	Wigmore Ln (S)	478	341	511	359	1.48	0.96
	Wigmore Ln (N)	Crawley Green Rd (S)	365	118	337	97	1.49	2.03
	Wigmore Ln (N)	Wigmore Ln (N)	1	0	0	0	1.41	0.00
	Crawley Green Rd (N)	Wigmore Ln (N)	145	94	144	93	0.08	0.10

	Crawley Green Rd (N)	Wigmore Ln (S)	78	54	86	59	0.88	0.67
	Crawley Green Rd (N)	Crawley Green Rd (S)	160	110	147	101	1.05	0.88
	Crawley Green Rd (N)	Crawley Green Rd (N)	1	0	0	0	1.41	0.00
	Wigmore Ln (S)	Wigmore Ln (N)	177	622	123	377	4.41	10.96
	Wigmore Ln (S)	Crawley Green Rd (N)	42	65	39	42	0.47	3.14
	Wigmore Ln (S)	Crawley Green Rd (S)	135	310	121	304	1.24	0.34
	Wigmore Ln (S)	Wigmore Ln (S)	0	0	0	0	0.00	0.00
	Crawley Green Rd (S)	Wigmore Ln (N)	150	261	211	522	4.54	13.19
	Crawley Green Rd (S)	Crawley Green Rd (N)	95	130	99	145	0.41	1.28
	Crawley Green Rd (S)	Wigmore Ln (S)	208	230	209	244	0.07	0.91
	Crawley Green Rd (S)	Crawley Green Rd (S)	2	1	0	0	2.00	1.41
MCC26	Crawley Green Rd (W)	Crawley Green Rd (E)	376	510	331	415	2.39	4.42
	Crawley Green Rd (W)	Lalleford Rd	131	101	137	109	0.52	0.78
	Crawley Green Rd (W)	Crawley Green Rd (W)	0	3	0	0	0.00	2.45
	Crawley Green Rd (E)	Crawley Green Rd (W)	277	435	222	398	3.48	1.81
	Crawley Green Rd (E)	Lalleford Rd	403	106	382	102	1.06	0.39

	Crawley Green Rd (E)	Crawley Green Rd (E)	0	0	0	0	0.00	0.00
	Lalleford Rd	Crawley Green Rd (W)	59	148	64	159	0.64	0.89
	Lalleford Rd	Crawley Green Rd (E)	111	200	193	492	6.65	15.70
	Lalleford Rd	Lalleford Rd	0	0	0	0	0.00	0.00
MCC34	Airport Way	Airport Approach Rd (N)	654	664	703	704	1.88	1.53
	Airport Way	Airport Way	6	2	0	0	3.46	2.00
	Airport Approach Rd (N)	Airport Way	601	718	638	750	1.49	1.18
	Airport Approach Rd (N)	Airport Approach Rd (N)	3	1	0	0	2.45	1.41
MCC46	Church Rd	Front St	46	16	0	0	9.59	5.66
	Church Rd	Markyate Rd	155	202	184	209	2.23	0.49
	Church Rd	Grove Rd	36	63	37	56	0.17	0.91
	Church Rd	Church Rd	0	0	0	0	0.00	0.00
	Front St	Church Rd	14	22	0	0	5.29	6.63
	Front St	Markyate Rd	72	111	75	117	0.35	0.56
	Front St	Grove Rd	40	76	37	77	0.48	0.11
	Front St	Front St	0	0	0	0	0.00	0.00
	Markyate Rd	Church Rd	189	162	202	166	0.93	0.31
	Markyate Rd	Front St	155	69	166	76	0.87	0.82
	Markyate Rd	Grove Rd	26	35	23	29	0.61	1.06

	Markyate Rd	Markyate Rd	0	0	0	0	0.00	0.00
	Grove Rd	Church Rd	50	47	54	50	0.55	0.43
	Grove Rd	Front St	139	31	144	32	0.42	0.18
	Grove Rd	Markyate Rd	30	15	26	12	0.76	0.82
	Grove Rd	Grove Rd	0	0	0	0	0.00	0.00
MCC48	London Rd (N)	London Rd (S)	690	466	749	463	2.20	0.14
	London Rd (N)	Newlands Rd	222	460	222	452	0.00	0.37
	London Rd (N)	London Rd (N)	0	0	0	0	0.00	0.00
	London Rd (S)	London Rd (N)	421	443	402	446	0.94	0.14
	London Rd (S)	Newlands Rd	80	179	69	164	1.27	1.15
	London Rd (S)	London Rd (S)	0	0	0	0	0.00	0.00
	Newlands Rd	London Rd (N)	502	273	488	268	0.63	0.30
	Newlands Rd	London Rd (S)	186	82	170	76	1.20	0.68
	Newlands Rd	Newlands Rd	0	0	0	0	0.00	0.00
MCC49	Newlands Rd (N)	Newlands Rd (S)	478	216	473	224	0.23	0.54
	Newlands Rd (N)	Church Rd	107	77	96	72	1.09	0.58
	Newlands Rd (N)	Newlands Rd (N)	0	0	0	0	0.00	0.00
	Newlands Rd (S)	Newlands Rd (N)	170	423	174	416	0.30	0.34
	Newlands Rd (S)	Church Rd	126	211	122	190	0.36	1.48
	Newlands Rd (S)	Newlands Rd (S)	0	0	0	0	0.00	0.00
	Church Rd	Newlands Rd (N)	68	91	63	90	0.62	0.11

	Church Rd	Newlands Rd (S)	200	128	191	125	0.64	0.27
	Church Rd	Church Rd	0	0	0	0	0.00	0.00
MCC50	Luton Retail Pk	Gipsy Ln (S)	41	99	39	96	0.32	0.30
	Luton Retail Pk	Gipsy Ln (N)	21	134	23	129	0.43	0.44
	Luton Retail Pk	Luton Retail Pk	0	0	0	0	0.00	0.00
	Gipsy Ln (S)	Luton Retail Pk	0	0	8	38	4.00	8.72
	Gipsy Ln (S)	Gipsy Ln (N)	576	768	561	760	0.63	0.29
	Gipsy Ln (S)	Gipsy Ln (S)	0	0	0	0	0.00	0.00
	Gipsy Ln (N)	Luton Retail Pk	84	218	76	189	0.89	2.03
	Gipsy Ln (N)	Gipsy Ln (S)	902	762	931	708	0.96	1.99
	Gipsy Ln (N)	Gipsy Ln (N)	0	0	0	0	0.00	0.00
MCC9	Saint Mary's Rd	Crawley Green Rd	20	109	18	106	0.46	0.29
	Saint Mary's Rd	Windmill Rd	184	144	182	152	0.15	0.66
	Saint Mary's Rd	Park Viaduct	124	187	129	185	0.44	0.15
	Saint Mary's Rd	Saint Mary's Rd	6	1	0	0	3.46	1.41
	Crawley Green Rd	Saint Mary's Rd	22	30	20	27	0.44	0.56
	Crawley Green Rd	Windmill Rd	443	250	518	270	3.42	1.24
	Crawley Green Rd	Park Viaduct	567	431	556	436	0.46	0.24
	Crawley Green Rd	Crawley Green Rd	2	0	0	0	2.00	0.00
	Windmill Rd	Saint Mary's Rd	307	296	304	274	0.17	1.30

	Windmill Rd	Crawley Green Rd	147	506	133	451	1.18	2.51
	Windmill Rd	Park Viaduct	342	378	320	331	1.21	2.50
	Windmill Rd	Windmill Rd	0	0	0	0	0.00	0.00
	Park Viaduct	Saint Mary’s Rd	174	143	174	143	0.00	0.00
	Park Viaduct	Crawley Green Rd	297	494	299	502	0.12	0.36
	Park Viaduct	Windmill Rd	274	324	262	328	0.73	0.22
	Park Viaduct	Park Viaduct	0	0	0	0	0.00	0.00

Appendix B

AM and PM Vissim Results with 10 Seeds

AM Runs	Average Delay (seconds)	Average Speed (mph)	Vehicles Arrived
Run 1	75.42	27.20	24,340
Run 2	71.43	27.54	24,329
Run 3	64.86	28.09	24,392
Run 4	63.32	28.23	24,462
Run 5	62.41	28.30	24,500
Run 6	63.09	28.22	24,295
Run 7	57.57	28.73	24,372
Run 8	65.33	28.04	24,355
Run 9	67.78	27.84	24,283
Run 10	61.98	28.33	24,373

PM Runs	Average Delay (seconds)	Average Speed (mph)	Vehicles Arrived
Run 1	84.68	29.93	25,575
Run 2	85.03	29.98	25,427
Run 3	90.76	29.39	25,087
Run 4	84.96	29.93	25,225
Run 5	91.32	29.42	25,284
Run 6	81.91	30.19	25,446
Run 7	97.37	28.85	24,840
Run 8	79.65	30.47	25,448
Run 9	76.94	30.71	25,308
Run 10	78.46	30.56	25,486

Appendix C

Highways England - Initial Comments

<table>
<tr><th>Comment</th><th>Response</th></tr>
<tr><td>3-hour (10800 seconds) AM and PM peak models. Exact start/end times of models unclear</td><td>The exact start time for the simulation is reported within the LMVR, however the Vissim models were updated accordingly to show representative start times. The 'Start Time' was changed under 'Simulation Parameters' as well as under the 'Matrices' in 'Dynamic Assignment'. This does not have any impact on the results.</td></tr>
<tr><td>No background files provided however the models appears to have been built with care and attention.</td><td>The model was coded based on the background map that can be switched on in Vissim.</td></tr>
<tr><td>No reduced speed areas have been coded on the approaches to M1 Junction 10. As a result, vehicles can travel at desired speeds of 50mph</td><td>The posted speed on Junction 10 gyratory is 50mph. The off-ramp along the M1 northbound and the southern part of the gyratory are signal controlled. Therefore, at these locations, the speeds will be controlled by the traffic signal. The off-ramp along the M1 southbound is a dedicated left turn and therefore does not have any interaction with the traffic using the gyratory. Speed reduction can be coded for the entry arm from the A1081.

With reduced speed areas on the approaches, all vehicles crossing the area will slow. This is not the case when the traffic surveillance cameras were examined.</td></tr>
<tr><td>15mph desired speed decisions coded on the M1 southbound mainline immediately north of the southbound on-ramp</td><td rowspan="2">A journey time survey was conducted along M1 in both directions. The travel speeds along the segments of the journey routes were coded to reflect the real condition. This is considered as a boundary condition in the model based on video cameras observations.</td></tr>
<tr><td>Any delays associated with the southbound merge need to be modelled in full rather than being proxied</td></tr>
<tr><td>‘Behaviour at red/amber signals’ left at the default value of ‘go (same as green)’. This is seen as a possible source of error. In keeping with Transport for London Traffic Modelling Guidelines (v3) we suggest that this parameter is set to ‘red (same as stop)’</td><td>The driving behaviour was updated.</td></tr>
</table>

to better reflect the actual reaction times of drivers	
The model utilises 'dynamic' assignment due to the availability of route choice within the local road network	The dynamic assignment and the convergence were described in the report.
No information on the convergence process or results achieved has been provided	
Demand has been assigned in 1-hour time slices. This could be potentially underestimating congestion and delay	The reported results for each of the AM and PM model are based on the average of 10 runs with random seed increment for the same file. The 10 seed increments cover all possible vehicles input profiles per hour.
The entry link on PT line 11 is 10552 i.e. a mid link	This was fixed and updated.
Phase maximums used in the AM and PM peak models are the same at M1 Junction 10. It is unclear if the actual controller specification running on-site has been used or if the control logic has been simplified	It is confirmed that the actual controller specification running on site were adopted for modelling purposes
It is unclear how many seed runs have been undertaken	10 runs with random seed increments were adopted.
Both models achieve an acceptable 'goodness of fit' however journey time routes are limited to the local road network. No comparison of observed/modelled times on the M1 mainline and approaches to/from the A1081 junction have been undertaken. Of particular concern for Highways England is southbound congestion on the M1 mainline and on-ramp	Journey times at M1 and J10 were compared and added to the revised presentation and report.
Concerns still exist regarding the calibration of traffic flows within the model	The model calibration was reviewed to achieve better results. The current version of the report provides the updated results as well as the introduced modifications
Concerns still exit regarding the proxying of delays from outside the study area using artificial speed	The boundary conditions of the model were revised. The current version of the report

	provides the updated results as well as the introduced modifications

Appendix E1: Highway LMVR

London Luton Airport Expansion Development Consent Order

Strategic Modelling: Highway Local Model Validation Report

15 January 2020

Report ref: LLADCO-3B-AEC-00-00-RP-CH-0001

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1 OVERVIEW

1.1 Introduction

1.1.1 London Luton Airport Limited is preparing to secure the necessary consents through a Development Consent Order (DCO) to allow London Luton Airport to grow from the current permitted capacity of 18 million passengers per annum (mppa) to 32 mppa by 2039.

1.1.2 The Surface Access Strategy Position paper (July 2017) discusses the existing strategic transport modelling tools developed in and around the Luton Airport area which can potentially be used to first understand the existing transport provision and constraints, secondly to understand the impact of growth on the highway and public transport network, and finally to develop and examine multi-modal interventions required to deliver the airport expansion as part of the Airport Masterplan.

1.1.3 In order to assess the strategic impacts of the proposed expansion, the existing Central Bedfordshire and Luton Transport Model (CBLTM) has been identified as the best available tool.

1.1.4 The original version of the CBLTM was developed in 2009 by Halcrow (now CH2M) with a base year of 2009. In 2016 AECOM was commissioned to update this model to reflect a 2016 base year, which included the collection of new travel demand data (mobile network data and public transport ticket data).

1.1.5 As part of the assessment of the proposed Luton Airport expansion, a *'Model Specification Report'* (September 2018) has been produced detailing the updates to be implemented to the CBLTM for the purposes of assessing the proposed development, creating a new version of the model suite, hereafter referred to as CBLTM-LTN. This updated CBLTM-LTN retains the base year of 2016.

1.1.6 The CBLTM-LTN model is a suite of programs that contains:

- a highway assignment model;
- a public transport assignment model;
- a variable demand model; and
- a trip-end forecasting tool (based on the DfT's CTripEnd software).

1.1.7 When producing a model forecast, all of these elements of the CBLTM-LTN suite are used, using user-defined inputs and passing information between the individual components of the suite.

1.1.8 The CBLTM-LTN model will be used to firstly understand the existing transport provision and constraints, secondly to understand the impact of growth on the highway and public transport network, and finally to develop and examine multi-modal interventions required to deliver the airport expansion as part of the Airport Masterplan.

1.1.9 As defined within the *'Transport Assessment Scoping Report'*, the key objectives and outcomes for the strategic modelling are:

- to provide strategic growth forecasts for the microsimulation modelling (covering M1 Junction 10, the A1081 between the M1 and Luton Airport, and areas of southern Luton);
- to provide traffic flows for the Air Quality and Noise assessments of the traffic component of the scheme, to be reported in the Environmental Statement; and
- to provide a strategic assessment of the potential offsite pressure points on the transport network resulting from the proposed development.

1.1.10 This report details on how the CBLTM-LTN highway assignment model was updated for the assessment of the proposed expansion at Luton Airport. Separate reports have been produced detailing the development of the public transport assignment model and variable demand model contained within CBLTM-LTN.

1.2 Structure of the Local Model Validation Report

1.2.1 The structure of this Model Validation Report follows that set out in Appendix F of WebTAG Unit M3.1. Following this introduction, this Model Validation Report contains the following sections:

- Section 2 - Proposed Uses of the Model and Key Model Design Considerations: this section outlines the known and expected uses of the model, and how the CBLTM-LTN highway model was specified in response to these objectives.
- Section 3 - Model Standards: this section details the measures used to assess the model in terms of modelled flows and journey times, and also discusses the convergence criteria and standards adopted within the model.
- Section 4 - Key Features of the Model: this section considers the main characteristics of the CBLTM-LTN highway model, including the zone system, the network

detail, the time periods modelled, the assignment user classes, and the relationship of the highway model with the wider CBLTM-LTN suite.

- Section 5 - Calibration and Validation Data: this section details the source and processing of the observed data used for the calibration and validation of the highway model in terms of both traffic flows and journey times.
- Section 6 - Network Development: this section details the methods and processes adopted in the development of the highway network including junction modelling and the speed-flow relationships applied within the network. It also explains how the Hertfordshire COMET network was used to expand the highway model as part of this model update.
- Section 7 - Trip Matrix Development: this section details the sources and methodology used to develop the highway prior trip matrices.
- Section 8 - Network Calibration and Validation: this section details the checks on the network coding using observed count and journey time data to identify any potential errors in the network coding or observed data.
- Section 9 - Route Choice Calibration and Validation: this section considers the calibration of route choice in the model, and in particular the representation of HGV routeing, and reviews the routeing within the highway assignment between key urban centres.
- Section 10 - Prior Matrix Assignment Results: this section details the performance of the prior matrices before the application of matrix estimation, and discusses the impact of matrix estimation on the prior matrices.
- Section 11 - Assignment Calibration and Validation: this section details the performance of the model against the observed traffic flows and journey times using the standards defined in Section 3.
- Section 12 - Summary of Model Development, Standards Achieved, and Fitness for Purpose: this section summaries the results of the model calibration and validation, and assesses the outcome of this process against the known applications of the model.

1.2.2 This report also contains the following appendices:

- Appendix A – Matrix Changes Following Matrix Estimation: this appendix presents the changes to the prior matrices through matrix estimation for matrix cell changes, trip-end changes and trip-length profiles.

- Appendix B – Detailed Screenline Performance: this appendix provides further details on the performance of the base year highway model against observed screenline flows.
- Appendix C – Link Flow Performance Figures: this appendix contains figures detailing the performance of the base year highway model against individual link counts by time period and vehicle type.
- Appendix D – Journey Time Validation Graphs: this appendix contains the journey time validation graphs for all journey time routes in the AM Peak, interpeak and PM Peak hours.
- Appendix E – Route Choice Validation: this appendix contains additional detail on the route choice validation undertaken on the network, in addition to that reported in Section 9.

2 PROPOSED USES OF THE MODEL AND KEY MODEL DESIGN CONSIDERATIONS

2.1 Proposed Uses of the Model

2.1.1 The CBLTM-LTN suite will be required to assess the impacts on the transport network of the proposed Luton Airport expansion. At the time of writing, the assumed phasing of the airport expansion is as follows:

- 2020 – 18 million passengers per annum (mppa) (current approved maximum capacity);
- 2024 – 21 mppa;
- 2029 – 25 mppa; and
- 2039 – 32 mppa.

2.1.2 As stated in Paragraph 1.1.2, and as defined within the *'Transport Assessment Scoping Report'*, the key objectives and outcomes for the strategic modelling are:

- to provide strategic growth forecasts for the microsimulation modelling;
- to provide traffic flows for the Air Quality and Noise assessments of the traffic component of the scheme, to be reported in the Environmental Statement; and
- to provide a strategic assessment of the potential offsite pressure points on the transport network resulting from the proposed development.

2.1.3 It is expected that the strategic modelling will be potentially required to assess different growth assumptions for Luton Airport, alternative growth scenarios for Luton Borough and the surrounding areas, and offsite mitigation measures.

2.1.4 The specification of the updated model is focussed on assessing the proposed expansion of Luton Airport, including testing alternative growth scenarios and infrastructure assumptions in the vicinity of Luton Airport. The model is less suitable for testing schemes further away from Luton Airport such as East-West Rail or the proposed Oxford to Cambridge Expressway. Representations of these schemes can be included in the model; however, there will be an additional range of uncertainty around the modelling of their impact.

2.1.5 To date, the existing version of the CBLTM suite has been used for the following broad purposes:

- as part of the evidence base for the development of Local Plans;

- to inform route strategic assessments; and
- for Strategic Outline Business Case development (with model enhancements proposed as part of any potential Outline Business Case development).

2.1.6 The performance of the previous version of the CBLTM highway model is discussed in detail in Sections 7 and 8 of the *'Strategic Modelling: Model Specification Report'*. It concludes, with supporting text from the existing CBLTM Local Model Validation Report (issued August 2017), that the previous version of the CBLTM was not appropriate for assessing the proposed expansion of Luton Airport.

2.1.7 In order to improve the model to meet the expected requirements of the DCO process, a number of areas of the model development have been revisited. This is in part to improve the model performance against observed data, and to incorporate latest industry guidance and best-practice.

2.2 Key Model Design Considerations

2.2.1 The CBLTM-LTN suite has been developed to forecast travel demand in the vicinity of Luton Airport. Given the specific characteristics of airport-related travel, the forecasts for travel demand to / from Luton Airport (for employees, passengers and freight) have been generated outside the CBLTM-LTN suite, and are an input into the model.

2.2.2 The forecasting approach adopted within the existing CBLTM (using the trip-end model, CTripEnd, which underpins TEMPro forecasts) does not specifically provide forecasts to airport passenger travel. It was therefore a requirement for this assessment that airport passenger forecasts are produced externally.

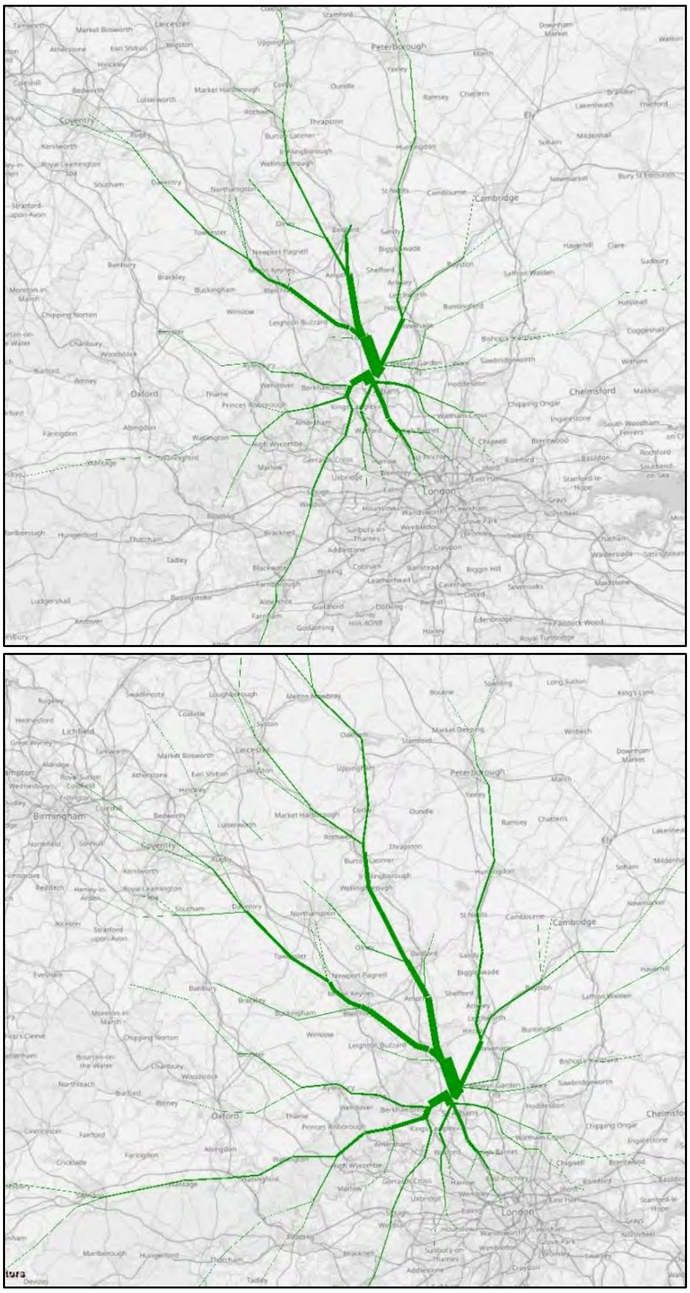
2.2.3 Similarly, trips generated by airport employees are also forecast and produced externally, primarily due to the specific shift-patterns at the airport compared with other commuting trips within the area.

2.2.4 The existing CBLTM focuses on Central Bedfordshire and Luton Borough, with limited model detail outside these areas. Using information from the CAA Passenger survey at Luton Airport, desire lines of travel to the airport have been produced, and are shown for car drop-off and parking trips in Figure 2.1.

Figure 2.1 CAA Passenger Desire Lines

Car Drop-Off

Car Parking



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2.2.5 This analysis of the CAA Passenger survey shows that there are trips to / from Luton Airport on routes to the south of the existing detailed model area (on the M1 towards London and the M25, and local routes towards Harpenden and St Albans), and to the east (along the A505 towards Hitchin and the A1(M)).

2.2.6 It was therefore proposed to enhance the model detail within the CBLTM-LTN highway model, particularly to the south and east of Luton Airport, to include key routes to / from the airport.

This included the use of Hertfordshire County Council's COMET transport model to enhance network detail.

2.2.7 Another consideration in the specification of the CBLTM-LTN was the consistency with the microsimulation modelling. The microsimulation models have a base year of 2017, and represent the AM Peak (08:00 to 09:00) and PM Peak (17:00 to 18:00) hours.

2.2.8 The CBLTM-LTN has a base year of June 2016, and without significant new demand data collection it was recommended that the base year of the strategic model be maintained at June 2016.

2.2.9 The strategic model represents the same AM Peak and PM Peak hours as defined for the microsimulation models. Adopting alternative time period definitions within the strategic modelling would have introduced inconsistency between the two models.

2.2.10 In addition to this, wherever possible, consistency between the highway network links and zones represented within the microsimulation model and those included within the strategic model was sought. However, the microsimulation model will include additional zonal and network detail to that contained within the strategic model.

3 MODEL STANDARDS

3.1 Introduction

3.1.1 This section details the model standards against which the CBLTM-LTN base year highway model is to be assessed. These standards are derived from WebTAG Unit M3.1.

3.1.2 WebTAG also states that in cases where these guidelines cannot be achieved, matrix estimation should not be allowed to make changes to the prior matrix beyond the limits set out in Table 5 of WebTAG Unit M3.1. In these cases the effect of matrix estimation should be reduced so that the changes in the prior matrix do not become significant, and a lower standard of link and journey time validation reported.

3.2 Validation Criteria and Acceptability Guidelines

3.2.1 The differences between modelled and observed data need to be assessed against some criteria with subsequent conclusions regarding the acceptability of the model performance. WebTAG Unit M3.1 §3.2 provides a detailed set of criteria and acceptability guidelines against which model performance should be assessed.

3.2.2 Each of these measures has its own set of criteria which should be adopted in the model validation process. Table 3.1 is a compilation of these criteria from WebTAG Unit M3.1 Tables 1 to 3.

Table 3.1: WebTAG Calibration and Validation Criteria and Acceptability Guidelines

Measure	WebTAG Criteria	Acceptability Guideline
Cordon / Screenline counts	Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines
Turning counts and individual links	Individual flows within 100 veh/h of counts for flows less than 700 veh/h Individual flows within 15% of counts for flows from 700 to 2,700 veh/h Individual flows within 400 veh/h of counts for flows more than 2,700 veh/h or GEH < 5 for individual flows	> 85% of cases
Journey times	Modelled times along routes should be within 15% of surveyed times (or 1 minute, if higher than 15%)	> 85% of cases

3.2.3 In addition to the above criteria regarding the performance of the highway model against observed data, WebTAG also provides guidance as to the acceptable changes to the highway prior matrices that should result from the application of matrix estimation.

3.2.4 WebTAG Unit M3.1 §8.3 provides a set of four measures and corresponding significance criteria for matrix estimation, against which changes from the prior matrix should be continually monitored in order to ensure that the underlying observed trip distributions are not being distorted. The significance criteria from Table 5 of WebTAG Unit M3.1 are reproduced in Table 3.2.

Table 3.2: Criteria to Assess Matrix Change following Matrix Estimation

Measure	Significance Criteria
Matrix zonal cell values	Slope within 0.98 and 1.02 Intercept near zero R^2 in excess of 0.95
Matrix zonal trip ends	Slope within 0.99 and 1.01 Intercept near zero R^2 in excess of 0.98
Trip length distributions	Means within 5% Standard deviations within 5%
Sector to sector level matrices	Differences within 5%

3.3 Convergence Criteria and Standards

3.3.1 When using the highway model in forecasting mode, achieving a good level of convergence is important for a number of reasons. A tight level of convergence reduces ‘model noise’ allowing easier comparison of assignment flows and times between scenarios. Tight convergence also results in lower levels of noise in the cost skims (time, distance and potentially tolls) between scenarios, which are used as part of the demand model element of CBLTM-LTN suite.

3.3.2 Wardrop’s first principle of traffic equilibrium is that all users will seek to minimise their cost of travel between their origin and destination. A number of different routes will normally be used between zone pairs. This results from differences in the relative values of time and distance between users; and changes in route costs as a result of congestion.

3.3.3 The assignment process takes account of the impact of flows on route costs by running a series of iterations. In the first iteration, trips will be assigned to the best route in uncongested conditions. Costs will be recalculated under these flow conditions and the demand assigned again for the next iteration. This iterative process will be complete when all trips are minimising their costs under prevailing traffic conditions, within a tolerable 'convergence error'.

3.3.4 Convergence criteria and standards are set to ensure stability of flows and costs between successive iterations which is important for the reporting of flows and delays. This is usually measured by the percentages of links with small flow or cost changes between iterations, which provide pragmatic views of the stability of the assignment.

3.3.5 Though this report is concerned with the 2016 base year CBLTM-LTN highway assignment validation, it is important that the same assignment procedures and standards are used for forecasting and the target measure of convergence should be the same for 'with-scheme' and 'without-scheme' assignments. This may require a different number of iterations for different network configurations and different matrices. Convergence is generally harder to achieve in congested conditions, hence further iterations may be required in the 'with-scheme' network and in later forecast years.

3.3.6 The SATURN stopping criterion has been set to terminate the assignment when the convergence measure (STPGAP, also known as the '%GAP') is met. STPGAP measures the difference between the costs on the chosen routes and those along the minimum cost routes summed across the network as a percentage of the minimum costs. STPGAP was set to 0.01% for the CBLTM-LTN highway model, significantly below the 0.1% recommended in Table 3 of WebTAG Unit M3.1. This criterion must be achieved in four consecutive iterations for an assignment to have reached convergence.

3.3.7 Table 3.3 provides convergence statistics for each modelled hour and demonstrates that all three models are suitably converged against the adopted %GAP criteria. This table also includes the percentage of turn delays within the model which change by less than 1% between iterations, demonstrating a high level of stability within the converged assignments.

Table 3.3: 2016 Base Year Highway Convergence Statistics

Iteration	AM Peak Hour		Interpeak Hour		PM Peak Hour	
	%GAP	%Delays	%GAP	%Delays	%GAP	%Delays
1	0.111	94.7%	0.259	12.7%	0.152	93.8%
2	0.036	95.8%	0.030	95.5%	0.072	96.4%
3	0.021	96.7%	0.012	98.5%	0.052	96.9%
4	0.012	97.4%	0.013	99.3%	0.041	97.2%
5	0.0095	98.2%	0.0056	99.4%	0.029	97.7%
6	0.0065	98.7%	0.0027	99.5%	0.014	98.1%
7	0.0083	98.6%	0.0038	99.6%	0.012	98.4%
8	0.0046	98.8%	0.0016	99.6%	0.0075	98.7%
9					0.0072	99.0%
10					0.0099	98.9%
11					0.0054	99.0%

3.3.8 The stopping criteria for the highway assignment can be set to include both the convergence (STPGAP) and the stability of modelled flows (measured by the parameter ISTOP). ISTOP measures the percentage of links with a flow change between iterations of less than a given threshold (PCNEAR) across a defined number of consecutive iterations (NISTOP).

3.3.9 During the base year model development, a sensitivity test using both the convergence and flow stability criteria was undertaken. These model assignment results were compared those generated using only the convergence (STPGAP) criterion. The differences in flow resulting from both assignment measures were deemed insignificant. It was decided to maintain use of only the convergence criterion, as when using this approach the model assignment time was greatly reduced.

4 KEY FEATURES OF THE MODEL

4.1 Introduction

4.1.1 This section looks at some of the key dimensions and structures within the CBLTM-LTN highway model. This includes the network coverage and coding, including the use of speed-flow relationships, as well as the model zone system. Also covered in this section are the time periods and user classes of demand represented in the highway model, along with the assignment procedures and the generalised cost formulation and parameters used in the assignment.

4.1.2 The base year model was developed to represent a typical weekday (Monday to Thursday) within June 2016, with the network, counts and journey times defined on this basis.

4.2 Fully Modelled Area and External Area

4.2.1 WebTAG Unit M3.1 §2.2.5 states that the modelled area should comprise the 'Fully Modelled Area' (which includes the 'Area of Detailed Modelling' and the 'Rest of the Fully Modelled Area') and the 'External Area'. This has been reflected in the construction of the networks and zoning system for the CBLTM-LTN suite. Network and zoning detail is greatest in Luton Borough and the surrounding districts (Central Bedfordshire, North Hertfordshire, St Albans District and Dacorum), and gradually reduces with distance from this area.

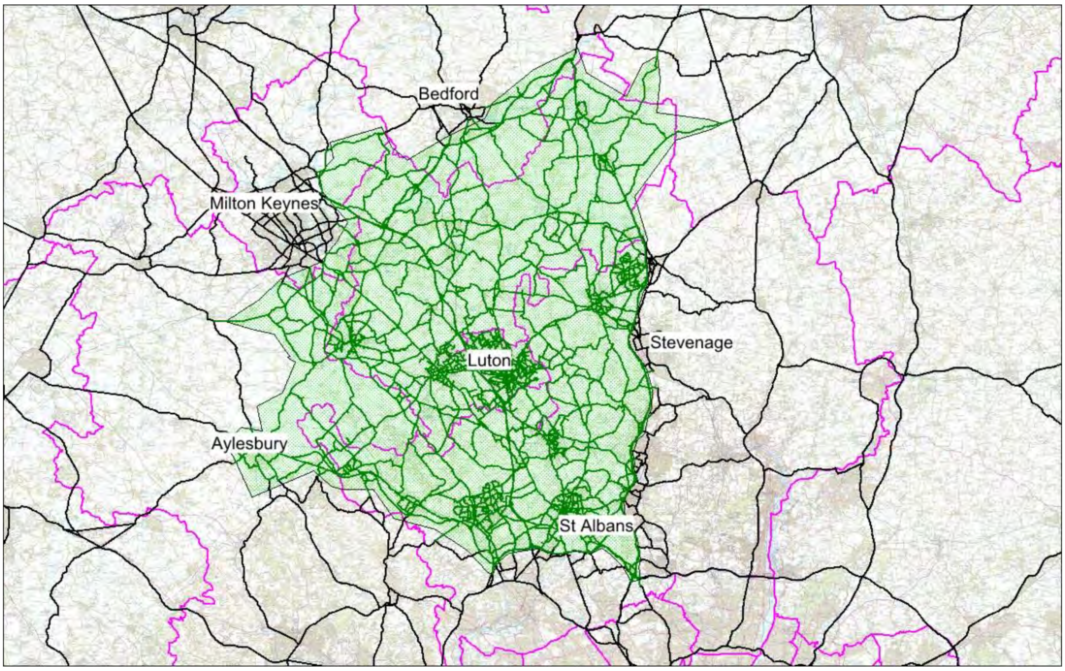
4.2.2 WebTAG Unit M3.1 §2.2.1 and §2.2.5 state that *"the geographic coverage of highway assignment models generally needs to allow for the strategic rerouteing impacts of interventions"* and that the Fully Modelled Area should be that over which the effects of the proposed intervention have influence. The Area of Detailed Modelling should encompass all areas over which it is certain that the proposed intervention will have significant impacts.

4.2.3 To ensure potential re-routeing impacts from the proposed expansion are captured, additional network was included to the south and east of the existing CBLTM Fully Modelled Area. In addition, the extent of the Fully Modelled Area was extended to the south-west to include the A41 corridor from the M25 to Aylesbury. The CBLTM-LTN highway network was expanded using Hertfordshire County Council's 'County Model of Transport' (COMET) highway model. This is discussed in detail in Section 6.3.

4.2.4 In highway network coding terms, the Fully Modelled Area forms the simulation network in SATURN, and the external area, the buffer network. The primary purpose of the buffer network is to provide the correct access for trips to the simulation area, therefore, detailed junction coding is not required.

4.2.5 Figure 4.1 shows the network coverage of the Fully Modelled Area, highlighted in green, with the External Area network shown in black. The Fully Modelled Area is comprised entirely of simulation coding, further detail of which is provided in Section 6.

Figure 4.1 CBLTM-LTN Fully Modelled Area



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4.3 Zoning System

4.3.1 The model zoning system has been created in-line with the considerations set out in WebTAG Unit M3.1 §2.3.

4.3.2 The detail of this zoning system reduces with distance from the study area. Census, district and county boundaries; land-use, potential loading points and natural boundaries such as rivers; rail network and the Strategic Road Network, have all been taken into consideration in the development of the zones, along with the likely volume of origin and destination trips.

4.3.3 The original CBLTM suite contained 570 zones and this was increased to 991 zones in the CBLTM-LTN. The increase in the number of zones was required for several reasons:

- More zonal detail was required in and around Luton Airport. Luton Airport itself was represented by a single zone in the previous version of the CBLTM, and this was expanded to 11 zones to allow identification of the different land-uses around the airport. This includes the existing terminal, the short-, mid- and long-stay car parks, and other key attractors such as the employment along Percival Way.
- Existing zones were disaggregated adding additional zones in Luton Borough Council and Dunstable so that traffic accessing and exiting the network would be represented more accurately.
- A review of the existing CBLTM trip-ends was undertaken and zones expected to generate/attract more than 300 trips per hour were disaggregated to avoid unrealistically high loads appearing at some point in the network (as suggested by WebTAG Unit M3.1 §2.3.11).
- An increase in the number zones to better represent urban areas such as Hitchin, St Albans, Hemel Hempstead, and Letchworth Garden City to the south and east of Luton Airport. This zone disaggregation followed zone boundaries adopted within the COMET model, and reflects the increased network detail in the Fully Modelled Area.

4.3.4 Figure 4.2 displays the existing CBLTM zone system (in black) overlaid with the updated and disaggregated CBLTM-LTN zone system (in red). Most ‘new’ zones outside Luton Borough Council and Dunstable were defined and added from the COMET model, discussed further in Section 6.3.

4.3.5 Figure 4.3 shows where the existing CBLTM zones were disaggregated to form the CBLTM-LTN zone system within Luton Borough. As shown within Figure 4.3, Luton Airport has been disaggregated from a single zone to 11 zones in the CBLTM-LTN zone system.

Figure 4.2 CBLTM-LTN Zone System

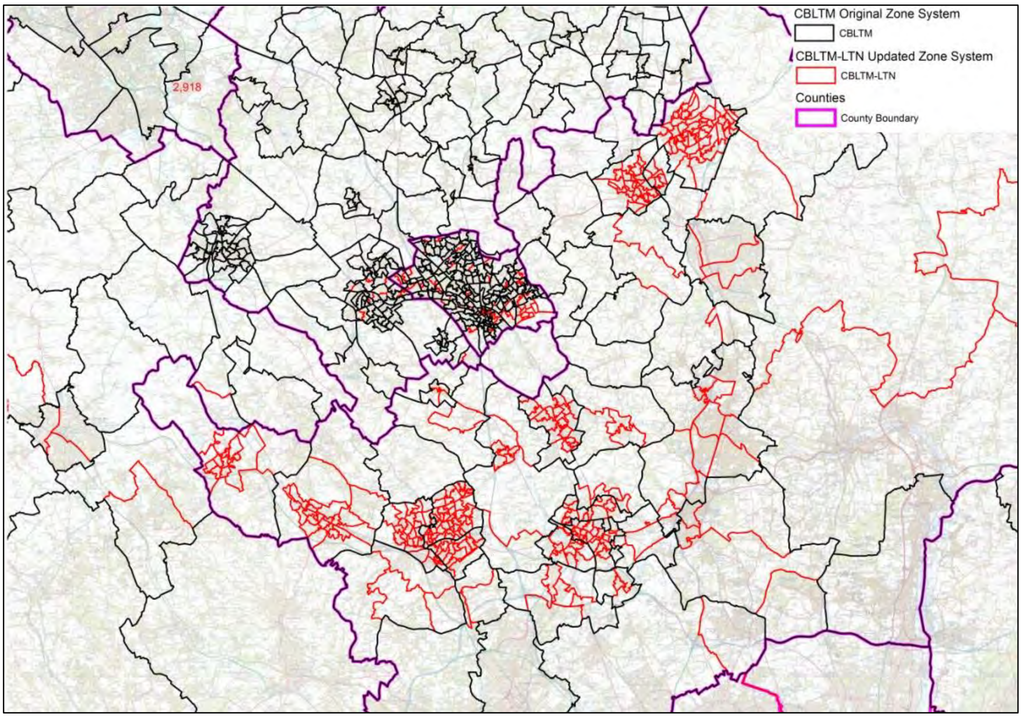

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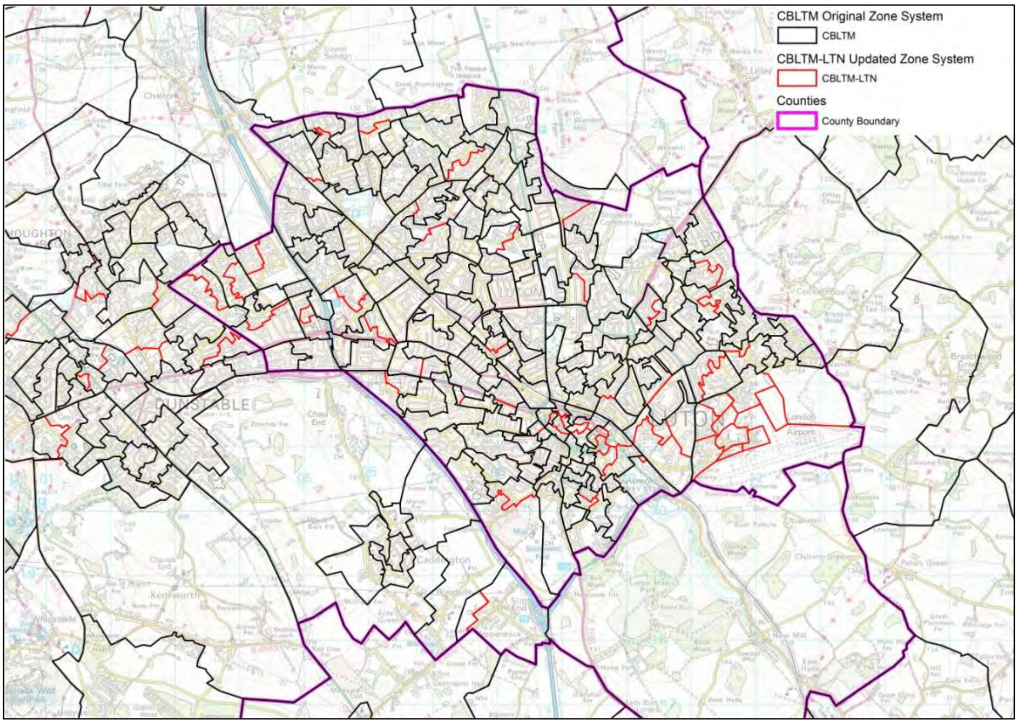
Figure 4.3 CBLTM-LTN Zone System (Zoomed-in)



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4.3.6 Where disaggregation of the existing CBLTM zone system took place, other zone systems were considered from which data may be required as part of the model development. These include:

- 2011 Census Output Areas and Workplace Zones;
- district and county boundaries;
- National Trip-End Model (NTEM) zoning; and
- COMET zone systems.

Consistency with these boundaries was used within the disaggregation of the existing CBLTM zone system.

4.3.7 50 'spare' zones were maintained from the existing CBLTM within the model to provide development zones for future model forecasting. 20 of these development zones have been allocated to large developments which have been identified as part of the forecasting assumptions, where the current zone does not suitably represent the characteristics of the proposed development. For the larger developments, more than one development zone has been allocated.

4.4 Network Structure

4.4.1 Within the Area of Detailed Modelling and the Fully Modelled Area, a high level of network detail has been adopted. This covers the Strategic Road Network (SRN), all A-roads, B-roads, main unclassified routes (including known 'rat-runs'), and some minor roads in residential areas.

4.4.2 The level of detail reduces farther from the study area, corresponding with the level of detail in the zone system. The external network has been coded to reflect key strategic routes, with less detail farther from the study area. Links within this area have been coded as buffer links with no detailed junction coding.

4.5 Centroid Connectors

4.5.1 Centroid connectors are the means by which traffic from a zone loads onto the network. The preferred approach to coding a zone loading point is to load every zone onto the network via a single 'spigot' style connector. Each zone within the simulation area was initially coded with a single spigot centroid connector. More than one spigot was coded when there was:

- either a requirement for some geographically larger zones at the edge of the simulation area to have more than one connector based on the local access / egress points for the zone; or
- to reduce the possibility of delays limiting the amount of traffic that can exit / enter the zones, with this assessment undertaken during model calibration as part of the review of significant delays in the model.

4.5.2 The centroid connector loading points in the simulation area represent actual junctions and the most likely means of demand to / from a given zone entering / leaving the network, in-line with WebTAG Unit M3.1 guidance.

4.5.3 These junctions were coded in-line with the junction coding standards for all other priority, signalised and roundabout junctions.

4.5.4 When coding a zone loading point in the CBLTM-LTN highway network, it has been assumed that the speed on the spigot represents is the speed of the road it is representing.

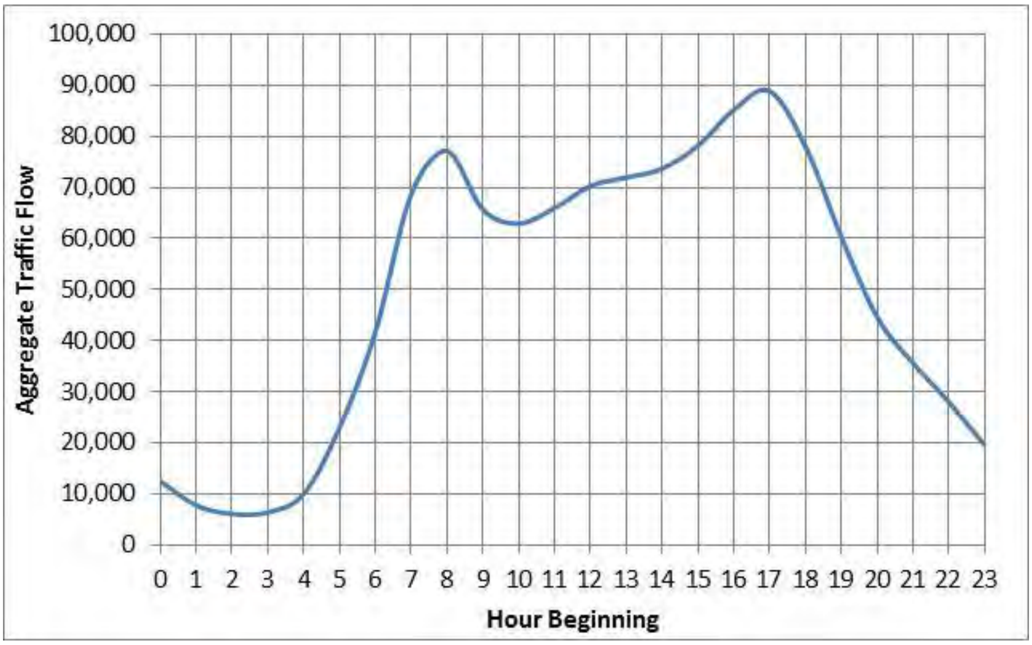
4.6 Time Periods

4.6.1 The CBLTM-LTN highway model includes three hourly periods, the definitions of these time periods are:

- AM Peak hour between 08:00 and 09:00;
- Interpeak hour (an average hour between 10:00 to 16:00); and
- PM Peak hour between 17:00 and 18:00.

4.6.2 Figure 4.4 presents the aggregated traffic flow levels for the Automatic Traffic Count (ATC) data collated as part of the development of the CBLTM-LTN highway model across an average weekday. This shows that the hours between 08:00 and 09:00 and between 17:00 and 18:00 are the peak hours within the morning and evening peaks, verifying the choice of peak hours represented within the highway model.

Figure 4.4: Daily Aggregate Traffic Flow Profile



4.6.3 The AM Peak and the PM Peak highway assignments both have pre-peak hours modelled with queues passed to the start of the peak hour. This is achieved through the use of the PASSQ facility in SATURN.

4.6.4 Pre-peak hour matrices were derived from the peak hour matrices using a global factor for all user classes. These factors have been adopted from the existing CBLTM highway model, which were based on observed traffic count data, and are defined as follows:

- AM Peak PassQ factor: 0.9788
- PM Peak PassQ factor: 0.9421

For both the pre-peak hours, the highway networks are identical to those of the respective peak hour.

4.7 User Classes

4.7.1 The highway model considers three vehicles classes: cars, Light Goods Vehicles (LGVs) and Heavy Goods Vehicles (HGVs) and is consistent with the existing CBLTM.

4.7.2 Cars are divided into three sub-classes based on trip purposes. As a result, there are five user classes defined within the highway model:

- UC1: Car Commuting;

- UC2: Car Business;
- UC3: Car Other;
- UC4: LGV; and
- UC5: HGV.

4.7.3 Additional user classes for airport users (passengers, employees and freight) were considered for the CBLTM-LTN model; however, additional assignment user classes would increase the model run times, both in terms of forecast model runs and the during the calibration process.

4.7.4 Airport-related traffic will be the only demand with an origin or destination at the Luton Airport model zones, allowing for trips to / from Luton Airport to be isolated within the assignment results. This removes the need to include additional user classes within the assignment for these trips.

4.7.5 In terms of the allocation of airport-related trips to the highway assignment user classes, airport employees have been added to the 'car commuting' user class, airport passengers were added to the 'car business' user class (due to their high value of time), and airport freight demand added to the LGV and HGV user classes as appropriate.

4.7.6 For the purpose of correctly representing road capacity, buses were included through the use of fixed routes within the model, with frequencies specified by time periods.

4.7.7 Bus routes from the existing CBLTM highway model were retained in the CBLTM-LTN highway model. Bus service routeings were reviewed, especially those around Luton Airport and those which routed into Hertfordshire where the network changed significantly.

4.7.8 Coaches to and from Luton Airport were included in the same format as buses flows. The coach companies included were:

- EasyBus;
- National Express; and
- AirLink.

4.8 Assignment Methodology

4.8.1 The assignment technique uses the Wardrop equilibrium assignment for multiple user classes. The latest available version of SATURN was used, version 11.4.07H.

4.8.2 The model uses passenger car units (PCUs) to account for the different sizes of vehicles, where:

- cars and LGVs are assumed to have a PCU factor of 1.0; and
- HGVs and buses have a PCU factor of 2.0.

4.8.3 The PCU values noted above are in line with guidance supplied in WebTAG Unit M3.1. An HGV PCU factor of 2.0 is between the values of 2.0 and 2.5 suggested by WebTAG Unit M3.1 §D.7.2.

4.9 Generalized Cost Formulations and Parameter Values

4.9.1 The route choice is based on generalised cost, where:

$$GenCost = (ValueOfTime * Time) + (OperatingCost * Dist)$$

4.9.2 The generalised cost parameters have been updated from the latest available version of the WebTAG data book at the time of developing the model (November 2018), considering latest guidance on:

- resource cost;
- values of time;
- vehicle occupancy;
- vehicle operating costs;
- fuel and resource costs; and
- fleet splits.

4.9.3 These values were individually defined for each time period and assignment user class with the majority of data taken from WebTAG data book. The values used in CBLTM-LTN base year highway assignment are provided in Table 4.1.

Table 4.1: CBLTM-LTN Generalised Cost Parameters

User Class	Value of Time (pence per minute)			Value of Distance (pence per km)		
	AM Peak	Interpeak	PM Peak	AM Peak	Interpeak	PM Peak
Car Commuting	20.27	20.60	20.34	5.75	5.75	5.75
Car Business	30.22	30.97	30.66	12.26	12.26	12.26
Car Other	13.98	14.89	14.64	5.75	5.75	5.75
LGV	21.36	21.36	21.36	13.19	13.19	13.19
HGV	43.37	43.37	43.37	45.69	45.69	45.69

4.9.4 It should be noted the HGV values of time are a factor of 2 higher than those in the WebTAG data book, to reflect operators' rather than drivers' value of time. This adjustment is based on guidance contained in WebTAG Unit M3.1 §2.8.8.

4.10 Capacity Restraint Mechanisms: Junction Modelling and Speed/Flow Relationships

Junction Modelling

4.10.1 As described in WebTAG Unit M3.1 §2.2.5 the model comprises the Fully Modelled Area (incorporating the Area of Detailed Modelling and the Rest of the Fully Modelled Area) and the External Area, as shown in Figure 4.1.

4.10.2 Within the Fully Modelled Area the network has been modelled with a greater level of detail, including detailed junction modelling with blocking back, signal timings, lane coding, and saturation flows by turn. Standard saturation flows have been used at all junctions, with turn radii (tight, average, wide) having been selected by observing junction dimensions in freely available aerial and 'street view' photography.

Speed Flow Relationships

4.10.3 Links in urban areas inside the Rest of the Fully Modelled Area are generally coded with fixed speeds. WebTAG Unit M3.1 §2.9.8 states that *"in urban areas within the Fully Modelled Area, the use of fixed cruise speeds is advised in conjunction with junction modelling, rather than using link-based speed/flow relationships"*. This is due to the fact that delays within these areas are more likely to be caused by interactions at closely spaced, at-grade junctions rather than the volume of traffic on links.

4.10.4 Within the Rest of the Fully Modelled Area speed flow curves were used to model congestion on longer links (typically greater than 500 metres) such as motorways where delays tend to be dictated by conditions on the link rather than the junction.

4.10.5 The external network was coded using buffer link coding assuming fixed link speeds, which may vary by time period, with no detailed node coding. The primary function of the external network is to ensure that trips access the simulation network at the right location and also to enable the rerouteing of longer distance (external) trips. No speed-flow curves are applied within the buffer network coding, and this external network was not reviewed as part of CBLTM-LTN enhancement.

4.11 Relationships with Demand Models and Public Transport Assignment Models

4.11.1 The overall CBLTM-LTN suite of models contains a number of additional elements to the highway model described in this report. The key components of the model are:

- a SATURN-based highway assignment model (as detailed in this report);
- an Emme-based public transport assignment model (as detailed in '*Strategic Modelling: Public Transport Model Validation Report'*); and
- an Emme-based variable demand model, (as detailed in '*Strategic Modelling: Demand Model Development Report*').

4.11.2 At a high-level the interrelationships between these three elements of the model are based on the highway and public transport supply models being used as inputs to the variable demand model.

4.11.3 Highway congestion is not modelled at a link level in the public transport assignment, which uses timetabled travel times. However, increases in highway congestion over time are added to bus travel times for variable demand modelling in forecasting, to ensure that congestion increases do not artificially favour bus travel. It is possible to model bus priority schemes at a corridor level using this mechanism, although detailed assessment of operation at a junction level is too detailed for the model scope.

4.11.4 It is also worth noting at this point the interrelationship between the highway and public transport supply models. Within the highway model the bus routes have been converted from the service coding contained within the base year public transport model. This ensures that there is consistency in terms of modelled route and frequency of bus services between the two models within the base year.

5 CALIBRATION AND VALIDATION DATA

5.1 Introduction

5.1.1 Traffic data were made available from a number of different sources, including:

- data collected as part of the existing CBLTM development for count, journey time and demand data;
- Highways England's count data available via WebTRIS;
- COMET data for locations within Hertfordshire (produced as part of an update to the COMET model which is being undertaken in parallel to the development of the CBLTM-LTN); and
- count and journey time data near Luton Airport collected as part of the microsimulation model development.

5.1.2 To help guide the process of defining where additional traffic count data may be required (see Section 5.2), a number of sectors, screenlines and cordons were defined for the calibration and validation of the CBLTM-LTN base year highway model.

5.1.3 Traffic data were required to undertake the following tasks in CBLTM-LTN:

- build prior matrices of the origin / destination trip patterns for the modelled periods;
- calibrate and validate the matrices for flows into and out of cordons or across screenlines;
- calibrate and validate the assignment for modelled flows at individual count locations; and
- calibrate the link and junction characteristics to replicate observed journey times.

5.1.4 For a more detailed description of count and journey time data please refer to the '*Strategic Modelling: Data Collection Report*'.

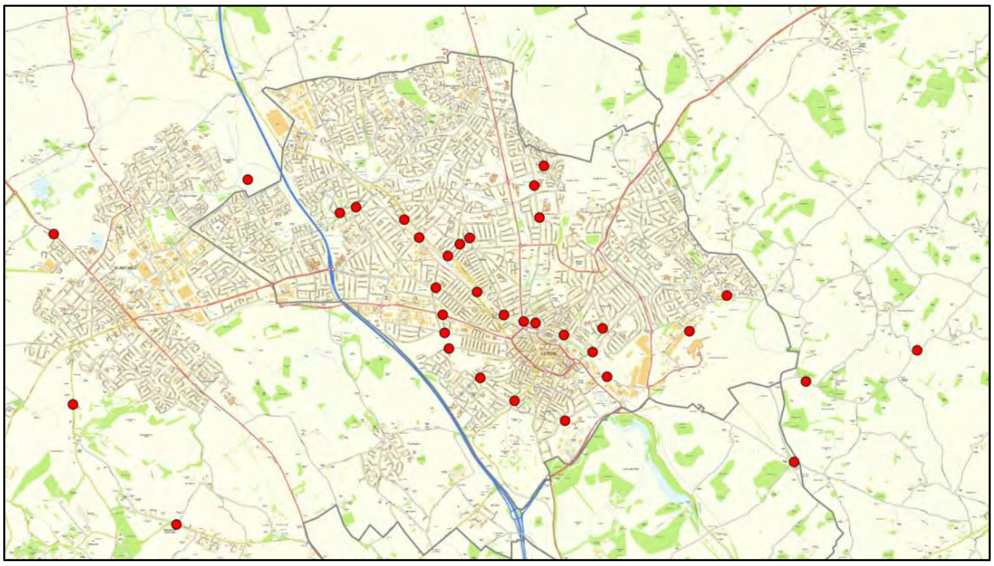
5.2 Traffic Count Data Collection

5.2.1 Two phases of traffic count data collection were undertaken as part of the development of the CBLTM-LTN. These were undertaken in July and September 2018 for phases 1 and 2 respectively. The data collected were in the form of Automatic Traffic Counts (ATCs) except where it was considered unsafe by the survey company to collect ATC data and Manual

Classified Counts (MCCs) were collected instead by way of video surveys.

5.2.2 Phase 1 traffic count surveys were conducted continuously for two full weeks in July at 38 sites. The surveys were undertaken on neutral dates prior to the school summer holidays (Monday 9th July to Friday 20th July) over a full 24-hour day. The locations of these traffic surveys are shown in Figure 5.1.

Figure 5.1 July 2018 Traffic Count Site Locations



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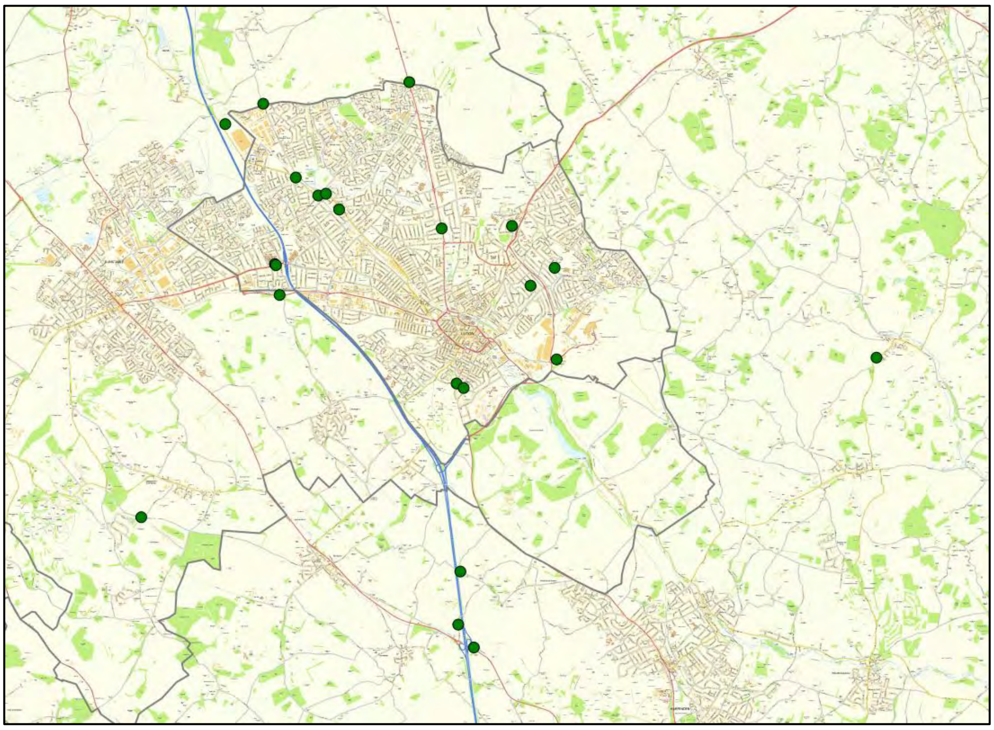
5.2.3 An additional 22 automated traffic count surveys were conducted after the school summer holidays for two full weeks in September (Monday 10th September to Friday 21st September). The surveys were undertaken on neutral dates over a full 24-hour day. The locations of these traffic surveys are shown in Figure 5.2.

Figure 5.2 September 2018 Traffic Count Site Locations



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5.3 Collated Traffic Count Survey Data

5.3.1 Figure 5.3 provides an overview of the collated traffic count survey data for the development of the CBLTM-LTN, along with the defined screenlines and cordons. Figure 5.4 provides the same information, focusing on Luton Borough.

5.3.2 It should be noted that not all counts shown are used within a screenline or cordon, and that some of these counts were used as individual count locations within the calibration and validation of the base year highway model (see Section 11). For example, a number of traffic count surveys were collated covering the Strategic Road Network, namely the M1, M25 and A1(M), and these count data will be used as part of the model development.

Figure 5.3 Collated Traffic Count Survey Data – Overview

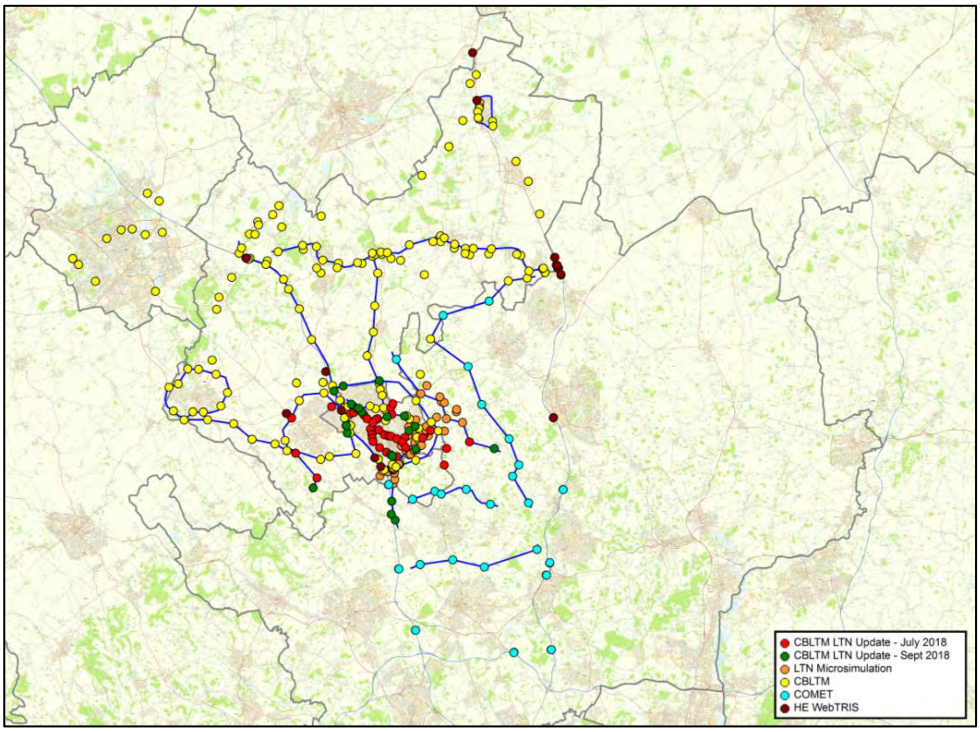

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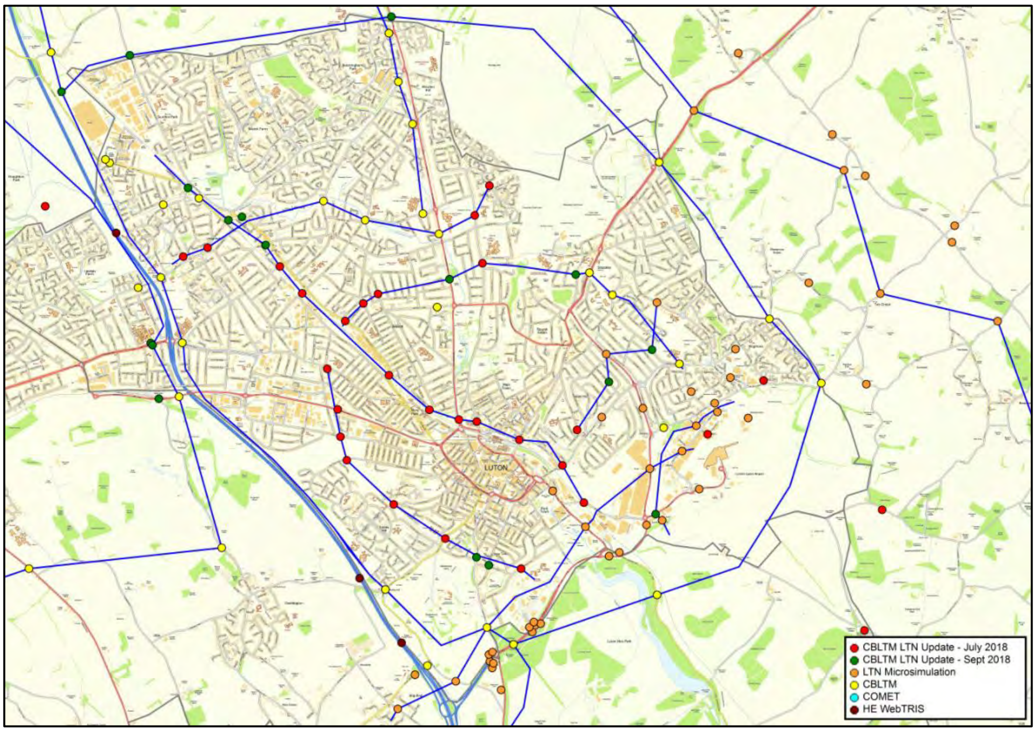
Figure 5.4 Collated Traffic Count Survey Data – Luton Borough



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5.3.3 The *'Strategic Modelling: Data Collection Report'* provides additional detail on the following count data processing:

- temporal adjustments to the June 2016 base year;
- data checking and cleaning; and
- application of vehicle spits using MCC data.

5.4 Journey Time Surveys

5.4.1 Journey time data were required to validate the highway model and ensure that a realistic representation of travel speeds throughout the network is achieved. The majority of journey time data were derived from Trafficmaster data.

5.4.2 Trafficmaster uses data collected from in-vehicle GPS systems installed in over 100,000 vehicles to provide historic journey time data across the UK road network. These data are mapped to the road network to provide average speeds and journey times, by vehicle type.

5.4.3 In total, three sources of journey time routes were identified:

- the existing CBLTM journey time routes used for validation based on Trafficmaster data, which were largely retained within CBLTM-LTN;
- six routes defined for the development of the microsimulation model on the local road network around Luton Airport, and collected using moving car observation surveys for the AM and PM Peak hours only; and
- routes defined for the validation of the COMET model within Hertfordshire, based on Trafficmaster data.

No new route data were collected as part of the CBLTM-LTN model update.

5.4.4 Figure 5.5 and Figure 5.6 show the locations of the journey time routes used for the development of the CBLTM-LTN model.

Figure 5.5 CBLTM-LTN Journey Time Routes

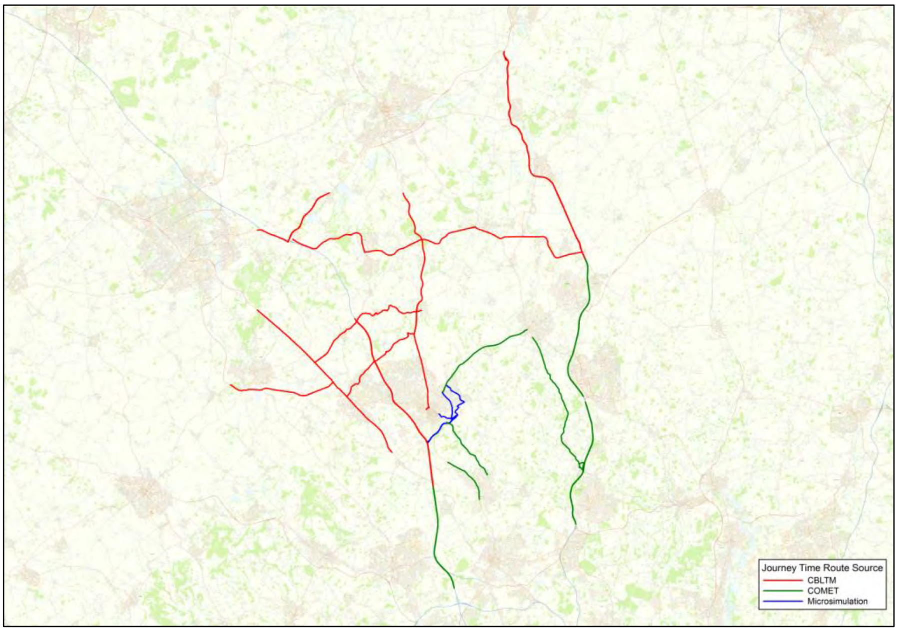

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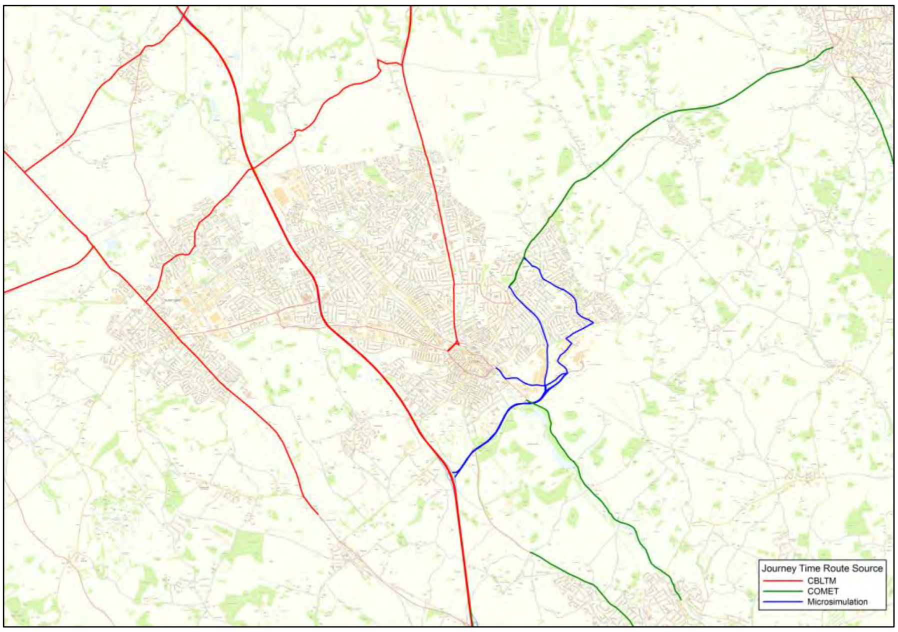
Figure 5.6 CBLTM-LTN Journey Time Routes – Luton Borough



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5.4.5 In total 24 journey time routes were defined for the AM and PM Peak hours, each defined in both directions of travel providing 48 observations. The journey times defined as part of the microsimulation modelling were not surveyed during the interpeak period, and therefore 18 journey time routes were defined for this modelled hour (36 in total).

5.4.6 Of these routes, five journey times were collected on the SRN. This included the M1 between Junction 6 to 12, the A1 Stotfold to the A421, and the A1(M) between Junctions 4 to 10.

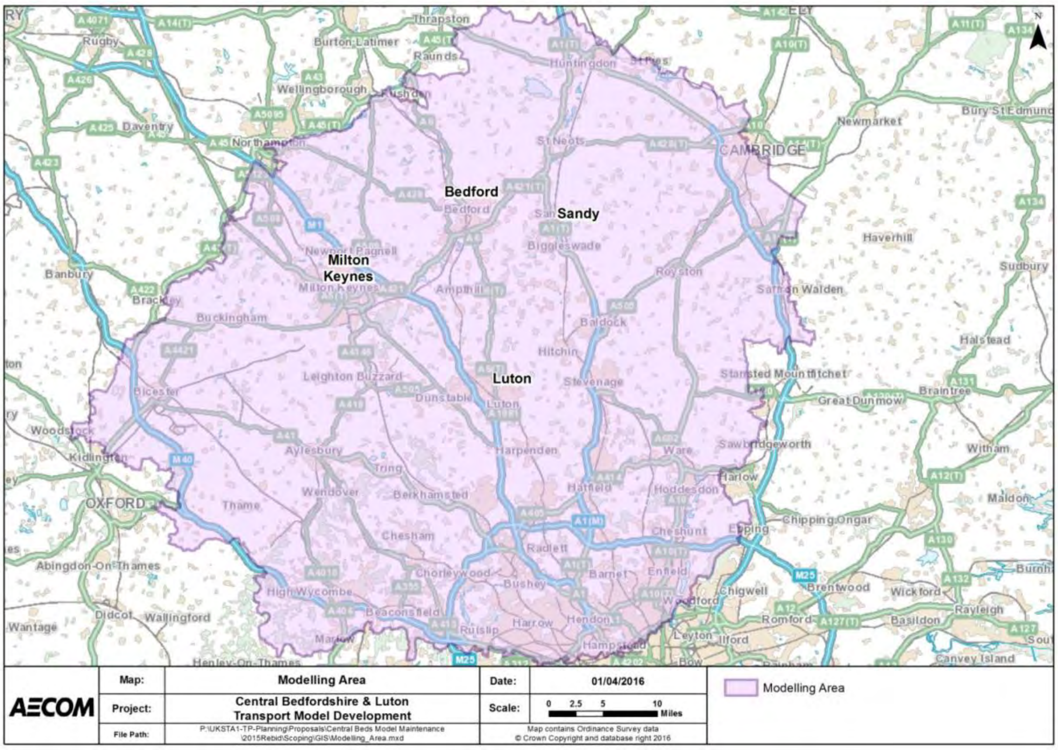
5.4.7 In addition to the journey time routes defined for the SRN, there are nine journey times on key routes in Central Bedfordshire, four in Hertfordshire, and six in Luton Borough (for the AM Peak and PM Peak hours only).

5.5 Demand Data

5.5.1 The CBLTM-LTN base year highway demand data are primarily based on mobile network data provided by Telefonica (primarily O_2 in the UK) covering the period from mid-April to mid-June 2016. This is the same data set used for the existing CBLTM. No additional data collection to capture highway demand data was undertaken as part of the CBLTM-LTN development.

5.5.2 Figure 5.7 shows the cordon area for which mobile network data were collected for the development of the existing CBLTM, and further information on this data set can be found in the existing CBLTM Local Model Validation Report (dated August 2017).

Figure 5.7 CBLTM-LTN Mobile Network Cordon



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5.5.3 A number of additional data sources were used in the development of the base year demand matrices. These include:

- data from Highways England's South East Regional Traffic Model (SERTM);
- data from the Continuing Survey of Road Goods Transport (CSRGT) collected by the Department for Transport; and
- National Travel Survey (NTS) data.

5.5.4 The processing of these highway demand data and how these complimentary data sources were used is detailed in Section 7.

6 NETWORK DEVELOPMENT

6.1 Introduction

6.1.1 The existing CBLTM SATURN highway network was adopted as the starting point for the CBLTM-LTN. The existing network was reviewed, updated and expanded where necessary for the CBLTM-LTN with particular focus on the area around Luton Airport and the Strategic Road Network.

6.1.2 The network was expanded to include the local road network around Luton Airport itself as well as additional routes to the east and south of Luton Airport. Any roads not included in the existing CBLTM but considered potentially important to the proposed Luton Airport expansion were included in CBLTM-LTN network.

6.1.3 The CBLTM-LTN network should reflect the actual infrastructure (for the June 2016 base year) with the appropriate level of detail for a strategic model to assess the proposed Luton Airport expansion.

6.2 Network Data, Coding and Checking – CBLTM

6.2.1 As part of the review process, a Highway Coding Manual was developed by AECOM for CBLTM-LTN. This Coding Manual details the coding assumptions that were adopted when reviewing and expanding the network for the CBLTM-LTN. It provides a consistent coding approach based on empirical evidence and testing.

6.2.2 The coding manual does not seek to replace the guidance and information contained within the SATURN User Manual, but rather supplement it with suggested values for some of the variables required when coding a highway network.

6.2.3 Areas and roads of importance in relation to trip routeing to and from Luton Airport were identified and reviewed in accordance with the coding manual. These included:

- an area broadly covering Luton Borough;
- an area broadly covering Dunstable town centre; and
- strategic routes including the M1, A1081, A5, A505 and A6.

6.2.4 A network coding log recorded all network edits made during the network review process and was maintained by the network reviewer. This coding log was then checked by an independent experienced network checker. This log included recording any changes to:

- node type;
- roundabout-specific attributes;
- signalised junction-specific attributes;
- node-specific GAP values;
- link lengths;
- number of lanes;
- speed-flow curve;
- fixed speeds;
- saturation flows;
- lane allocations;
- turn-priority markers and FLAREF / FLAREX parameters;
- stacking capacity; and
- signal timings.

6.2.5 In addition, a network consistency check was applied to the whole network. This checked and raised any inconsistencies such as speeds and distances differing by direction and enabled the modeller to identify and correct the network as necessary.

6.2.6 Within the area reviewed for this model enhancement Figure 6.1 to Figure 6.6 provide examples of the checks undertaken on the network coding. Figure 6.1 and Figure 6.2 show comparisons of the coding link lengths in the base year model against crow-fly distances and distances derived from GIS based on the shaped network links. These comparisons rely on the accuracy of the network coordinates and the detail in the network shaping, and any outliers in this analysis have been reviewed to ensure that the coded network distances are correct.

6.2.7 Figure 6.3 to Figure 6.5 show the allocation of a number of key link attributes, namely the number of lanes, the use of fixed speeds or a speed-flow curve, and the coded free-flow speed. These plots have been reviewed to ensure consistency of assumptions across the reviewed network and have been reviewed against online data sources (such as Google Maps).

6.2.8 Similarly, Figure 6.6 shows the coded junction type (priority, signalised, or roundabout (with and without U-turns) junction) within the reviewed network area. As with the coded link attributes, these have been reviewed against online data sources.

Figure 6.1 Coding Network Distance vs. Crow-Fly Distance (Review Area)

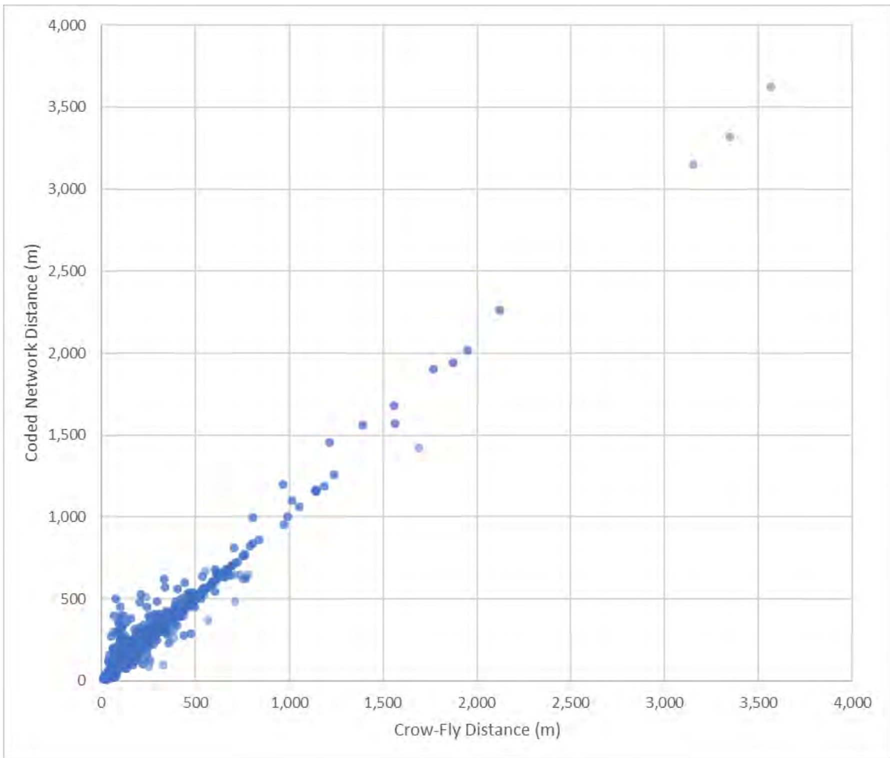

Figure 6.2 Coding Network Distance vs. GIS Distance (Review Area)

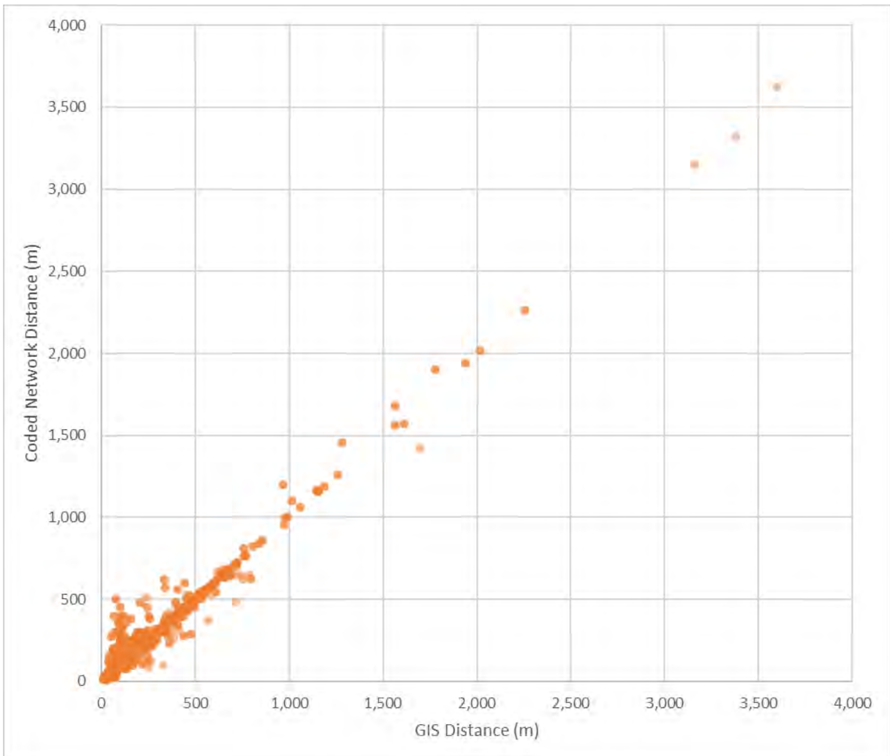

Figure 6.3 Coded Number of Lanes

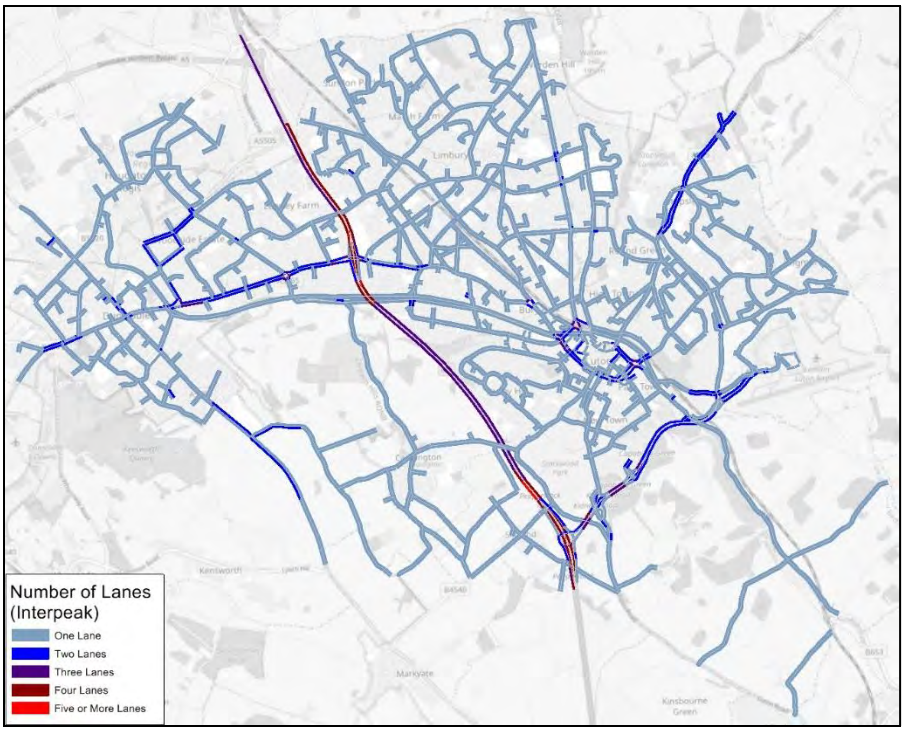

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Figure 6.4 Allocation of Fixed Speed or Speed-Flow Curves

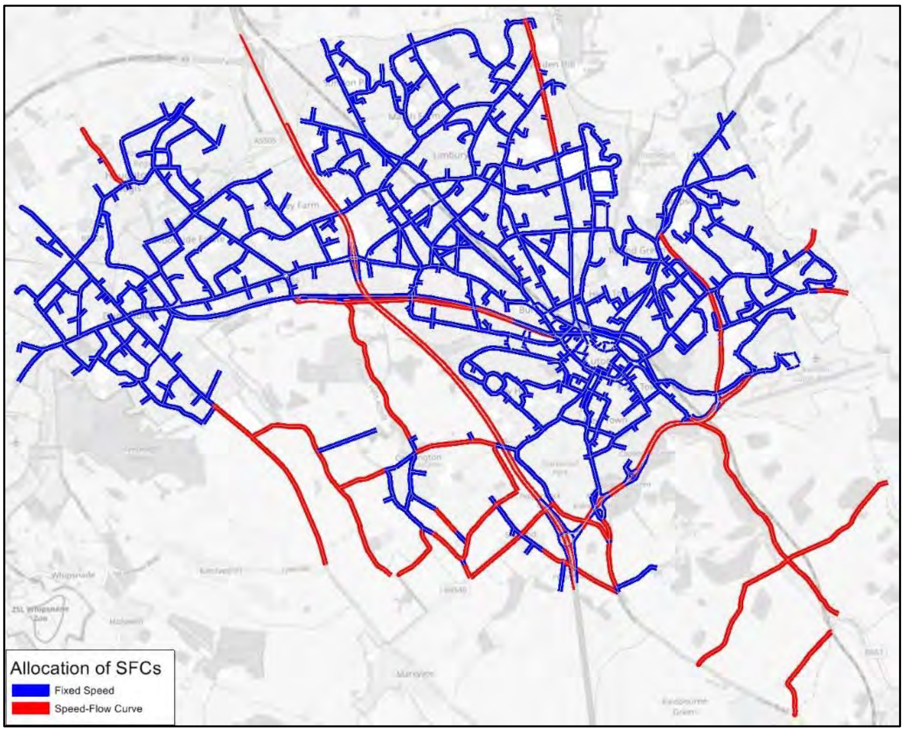

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Figure 6.5 Allocation of Free-Flow Speeds

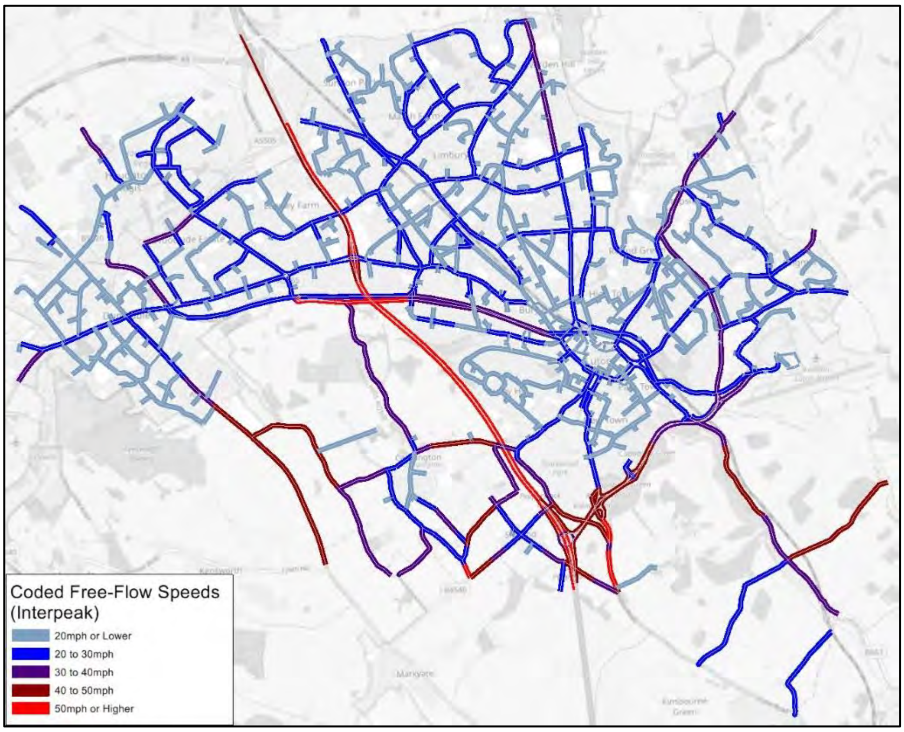

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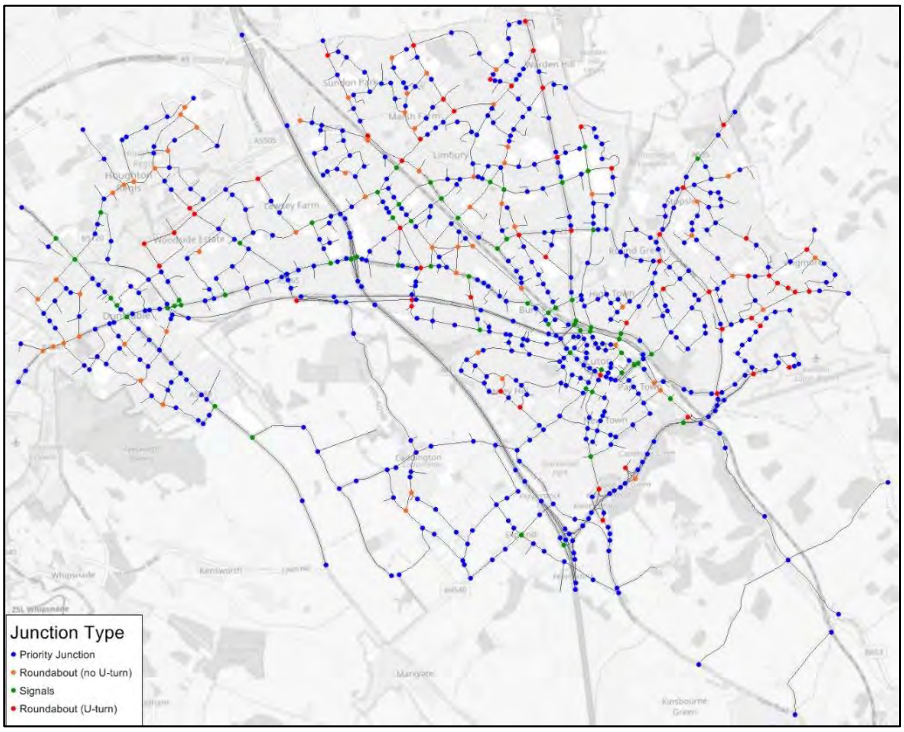
Figure 6.6 Coded Junction Types



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6.3 Network Data, Coding and Checking – COMET

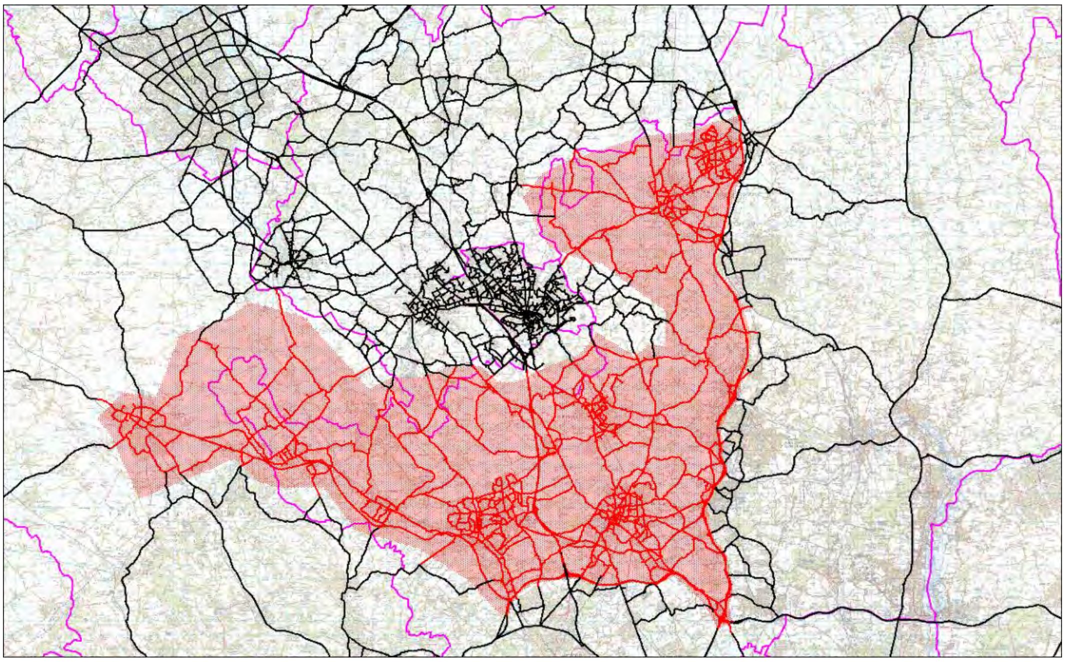
6.3.1 The network simulation area covered by Hertfordshire County Council's COMET model partially intersects the CBLTM-LTN simulation network to the east and south of Luton Borough within western Hertfordshire. The CBLTM-LTN had significantly less network detail covering this area, and it was decided to 'cut out' or 'cordon' some of the network detail from the COMET model and incorporate it into the CBLTM-LTN. Adding this network detail provided a more detailed and accurate representation of the road network outside Luton and Central Bedfordshire within western Hertfordshire.

6.3.2 The COMET model was originally developed during 2014 and 2015, and has undergone a number of updates since its development. In addition to the on-going programme of maintenance, the model has been used for a number of applications within Hertfordshire, including the assessment of Local Plans and business case development. The model is therefore considered to be a robust basis for the representation of highway network within western Hertfordshire.

6.3.3 The area identified for cordoning from COMET within western Hertfordshire is broadly bounded by the A1(M), M25 and A41 and covers several urban areas including Hitchin, St Albans and Hemel Hempstead and key strategic corridors including the A1(M), M25 and the A41. Figure 6.7 shows the location of the adopted network coding from COMET, shaded in red, used in the CBLTM-LTN model.

6.3.4 The COMET highway network has been developed using similar standards and assumptions to those adopted for the CBLTM-LTN, providing broad consistency between the two models. This allowed the network coding from COMET to be incorporated directly into the CBLTM-LTN.

Figure 6.7 Network Coding Adopted from COMET



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6.3.5 As well as network detail, the corresponding COMET zone system was used as the basis for disaggregation within western Hertfordshire within CBLTM-LTN. The CBLTM-LTN zone system can be seen in Figure 4.2.

6.3.6 It should be noted that bus routes from the COMET model were not incorporated into the CBLTM-LTN base year model as part of the cordoning process. However, the bus routes adopted from the existing CBLTM highway model included services extending into Hertfordshire, and these have been retained.

6.4 Saturation Flows at Junctions

6.4.1 A set of evidence based standardised saturation flows was produced for priority and signalised junctions which vary depending on the turn radii (either tight, average or wide), with lower and upper ranges given for tolerances within which values could be adjusted during model calibration. Roundabouts have a set of standardised coding based on the type of roundabout, with generic values also given for the circulatory capacity and circulatory time.

6.4.2 The central values, which have been used as the default values when coding the network are shown in Table 6.1 for signalised junctions, Table 6.2 for priority junctions and Table 6.3 for roundabouts. These values are detailed in the Coding Manual that formed the basis for the network review and expansion.

Table 6.1: Standard Turning Saturation Flows (PCUs) at Signalised Junctions

Standard	1-lane			2-lane			3-lanes	4-lanes
	Left	Ahead	Right	Left	Ahead	Right	All	All
Tight	1,300	1,500	1,360	2,610	3,000	2,730	-	-
Average	1,550	1,700	1,580	3,090	3,400	3,160	6,000	8,000
Wide	1,860	2,000	1,890	3,720	4,000	3,770	6,000	8,000

** Values have been rounded to the nearest ten*

Table 6.2: Standard Turning Saturation Flows (PCUs per lane) at Priority Junctions

Standard	Major-to-Minor			Minor-to-Major		
	Left	Ahead	Right	Left	Ahead	Right
Tight	1,300	1,500	1,300	1,300	1,500	1,360
Average	1,550	1,700	1,550	1,550	1,700	1,580
Wide	1,860	2,000	1,860	1,860	2,000	1,890

** Values have been rounded to the nearest ten*

Table 6.3: Generic Coding Assumptions for Roundabouts

Type of Roundabout	Circulating Capacity (PCUs/hr)	GAPR value (sec)	Lanes at Stop Line	Time to Circulate (sec)	Total Saturation Flow (PCUs/hr)
Mini	1,440	2.5	1	5	1,100
Normal (single-lane entry)	1,600	2.25	1	10	1,100
Normal (flared approach)	1,800	2.0	2	10	1,650
Large (Dual 2+ lane approach)	3,200	1.125	2	15	2,200
			3	15	3,200

** Values for saturation flows and circulating capacity have been rounded to the nearest ten*

6.4.3 Larger roundabouts (such as motorway gyratories and the A505 / A6 junction within Luton town centre) and signalised roundabouts have been coded as a series of individual priority or signalised nodes following the assumptions detailed in Table 6.1 and Table 6.2. Coding these junctions as a single roundabout node provides only a simplistic representation of these junctions, whereas representing these locations as a series of individual junctions better represents the operation of these junctions.

6.4.4 For nodes which form part of the Strategic Road Network, saturation flows have been applied in accordance with the capacities of the adopted speed-flow curves (see Section 6.6). These tend to be 2,190 PCUs/hr per lane for motorways and 2,010 PCUs/hr per lane for A-roads. Merges from slip roads also have standardised assumptions, which are detailed in the Coding Manual.

6.4.5 These assumptions for the Strategic Road Network are similar to those adopted within Highways England's Regional Traffic Models. The Regional Traffic Models assume between 2,050 and 2,120 PCUs/hr per lane on motorways, compared to 2,190 PCUs/hr per lane in the CBLTM-LTN. Both the Regional Traffic Models and the CBLTM-LTN assume 2,010 PCUs/hr per lane on A-roads.

6.4.6 For slip-roads, the CBLTM-LTN assumes 1,730 PCUs/hr per lane for both motorways and A-roads. The Regional Traffic Models contain the same assumption for A-roads, and a higher saturation flow of between 1,930 and 2,060 PCUs/hr per lane on motorway slip-roads.

6.5 Signal Timings

6.5.1 The stage diagrams and signal timings for signalised junctions were coded based on observed data of average signal timings within the given time periods from the existing CBLTM and COMET models. Signal data were provided by:

- Central Bedfordshire and Luton Borough Councils for a number of locations within the CBLTM model area; and
- Hertfordshire County Council, for the most part, for the adopted COMET model area.

These signals timings were adopted and retained for the CBLTM-LTN model.

6.5.2 In cases where observed signal timings were not available or where adjustments were required to improve the journey time validation or remove unrealistic delays, the following assumptions have been adopted:

- likely staging for the junction was estimated based on the available information (e.g. lane marking and traffic light configuration);
- stage timings were coded such that the majority of green time was allocated to the main movements, considering

similar junctions in the network with observed timings where possible; and

- some signal timings have been optimised using prior assignments ensuring that the optimisation process did not result in unrealistic signal timings.

6.6 Speed-Flow Relationships

6.6.1 Speed-flow curves are a means to represent delay on links that result from the volume of traffic travelling along a given link, and are independent of the delays that result from individual junctions. A general rule of thumb is that a speed-flow curve should only be applied where the majority of the delay along a link can be attributed to the link itself rather than the junction at the downstream end of the link. Based on this guidance, speed-flow curves should only be applied (in general) on rural links and motorways, with fixed speeds applied within the urban areas.

6.6.2 The default speed-flow curves used in the CBLTM-LTN are detailed in Table 6.4, which are based on advice contained in Appendix D of WebTAG Unit M3.1. It should be noted that the area of network adopted from the COMET model was not updated to reflect the default speed-flow curves listed below; however similar coding assumptions have been adopted within COMET. Similarly, areas of the existing CBLTM highway network which were not reviewed in detail were not updated using the speed-flow curves in Table 6.4.

6.6.3 Within the COMET model, where a corresponding speed-flow curve is defined for a given road type, the assumptions are identical to those detailed in Table 6.4 with the exception of the n value, which has been rounded to one decimal place within the COMET model. For example, for a 3-lane A-road, CBLTM-LTN assumes an n value of 2.75, whereas COMET assumes a value of 2.8.

Table 6.4: Default Speed-Flow Curves

Description	Free-flow speed – kph (mph)	Speed at Capacity – kph (mph)	Capacity (PCUs)	n
Rural, 6-lane motorway	112 (70)	79 (49)	13,140	3
Rural, 5-lane motorway	112 (70)	79 (49)	10,950	3
Rural, 4-lane motorway	112 (70)	79 (49)	8,760	2.9
Rural, 3-lane motorway	112 (70)	79 (49)	6,570	2.9
Rural, 2-lane motorway	108 (67)	72 (45)	4,380	2.9
Rural, 1-lane motorway	106 (66)	72 (45)	2,190	2.9
Rural 6-lane Motorway (60mph Smart motorway)	96 (60)	68 (42)	13,000	2.85
Rural 5-lane Motorway (60mph Smart motorway)	96 (60)	68 (42)	10,810	2.85
Rural 4-lane Motorway (60mph Smart motorway)	96 (60)	68 (42)	8,620	2.85
Rural 3-lane Motorway (60mph Smart motorway)	96 (60)	64 (40)	6,430	2.8
Rural 6-lane Motorway (50mph Smart motorway)	80 (50)	58 (36)	13,000	2.85
Rural 5-lane Motorway (50mph Smart motorway)	80 (50)	58 (36)	10,810	2.85
Rural 4-lane Motorway (50mph Smart motorway)	80 (50)	58 (36)	8,620	2.85
Rural 3-lane Motorway (50mph Smart motorway)	80 (50)	54 (34)	6,430	2.8
Rural 6-lane Motorway (60mph limit)	96 (60)	68 (42)	13,140	2.85
Rural 5-lane Motorway (60mph limit)	96 (60)	68 (42)	10,950	2.85
Rural 4-lane Motorway (60mph limit)	96 (60)	68 (42)	8,760	2.85
Rural 3-lane Motorway (60mph limit)	96 (60)	64 (40)	6,570	2.8
Rural 6-lane Motorway (50mph limit)	80 (50)	58 (36)	13,140	2.85
Rural 5-lane Motorway (50mph limit)	80 (50)	58 (36)	10,950	2.85
Rural 4-lane Motorway (50mph limit)	80 (50)	58 (36)	8,760	2.85
Rural 3-lane Motorway (50mph limit)	80 (50)	54 (34)	6,570	2.8
Rural, 5-lane A-Road / B-Road	112 (70)	75 (47)	10,050	2.75
Rural, 4-lane A-Road / B-Road	112 (70)	75 (47)	8,040	2.75
Rural, 3-lane A-Road / B-Road	112 (70)	75 (47)	6,030	2.75
Rural, 2-lane A-Road / B-Road	104 (65)	68 (42)	4,020	2.7
Rural, S10 Very Good A-Road / B-Road	96 (60)	55 (34)	1,730	3
Rural, S7.3 Good A-Road / B-Road	88 (55)	45 (28)	1,640	3
Rural, S7.0 Typical A-Road / B-Road	76 (47)	40 (25)	1,640	3.8
Rural, S6.5 Bad (B-Road Only)	64 (40)	30 (19)	1,640	3.8
Unclassified Roads (B-Road Only)	55 (34)	18 (11)	1,640	4
Suburban, 4-lane A-Road / B-Road Typical Development	64 (40)	35 (22)	6,800	1.75
Suburban, 3-lane A-Road / B-Road Typical Development	64 (40)	32 (20)	5,100	1.75
Suburban, 2-lane A-Road / B-Road Typical Development	64 (40)	31 (19)	3,400	1.75
Suburban, 1-lane A-Road / B-Road Typical	64 (40)	31 (19)	1,700	1.75

Description	Free-flow speed – kph (mph)	Speed at Capacity – kph (mph)	Capacity (PCUs)	n
Development				
Suburban, 4-lane A-Road / B-Road (30mph limit)	48 (30)	23 (14)	6,800	1.75
Suburban, 3-lane A-Road / B-Road (30mph limit)	48 (30)	23 (14)	5,100	1.75
Suburban, 2-lane A-Road / B-Road (30mph limit)	48 (30)	23 (14)	3,400	1.75
Suburban, 1-lane A-Road / B-Road (30mph limit)	48 (30)	23 (14)	1,700	1.75

6.6.4 Variations on these speed-flow curves were adopted for specific combinations of road type, number of lanes and speed limit, such as a two-lane A-road with a 50mph speed limit applied.

6.6.5 It should be noted that maximum HGV speeds were applied for a subset of speed-flow curves (predominately motorways and inter-urban A-roads) based on guidance contained in WebTAG Unit M3.1, and implemented using the 'CLIMAX' parameter within SATURN. For these road types, the modelled speeds for light and heavy vehicles are the same up to a defined HGV maximum speed, with light vehicles allowed to travel faster than this maximum but HGVs limited to this defined speed.

6.7 HGV Bans

6.7.1 Some roads carry restrictions regarding HGV traffic (e.g. due to height or weight limitations). These restrictions were introduced in the existing CBLTM highway model and have been reviewed in the vicinity of Luton Airport.

6.7.2 The coding of these restrictions in CBLTM-LTN relies on HGV-specific link penalties or bans. The area of the network adopted from the COMET model maintained the HGV bans coded into the network, but these were not explicitly reviewed as part of the network review. The locations of the HGV bans coded in CBLTM-LTN are detailed in Section 9.2.

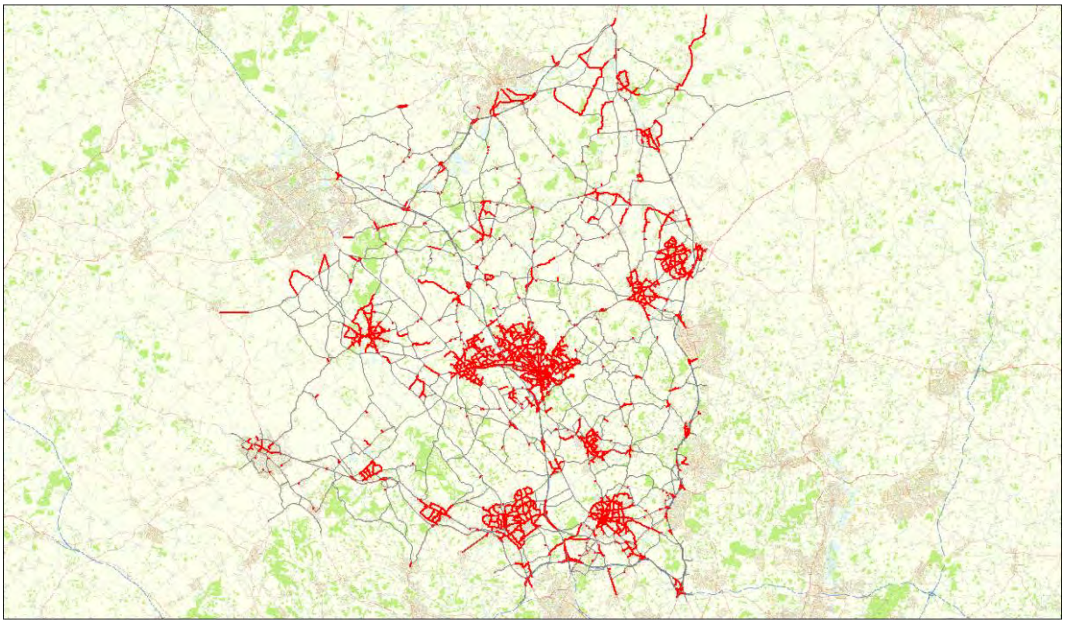
6.8 Fixed Speeds

6.8.1 Links in urban areas inside the Fully Modelled Area were generally coded with fixed speeds; where delays are more likely to be caused by junctions rather than volume of traffic on links. Fixed speeds were defined based on the speed limit identified in Google Maps imagery; however, the fixed speeds should, as accurately as possible, represent on-street conditions (e.g.

traffic calming) and therefore fixed speeds were not always coded at the speed limit.

6.8.2 Figure 6.8 shows the location of the links that were coded with fixed speeds (highlighted red). This illustrates that links in urban areas are predominantly coded with fixed speeds.

Figure 6.8 Location of Fixed Speed Links within CBLTM-LTN



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7 TRIP MATRIX DEVELOPMENT

7.1 Introduction

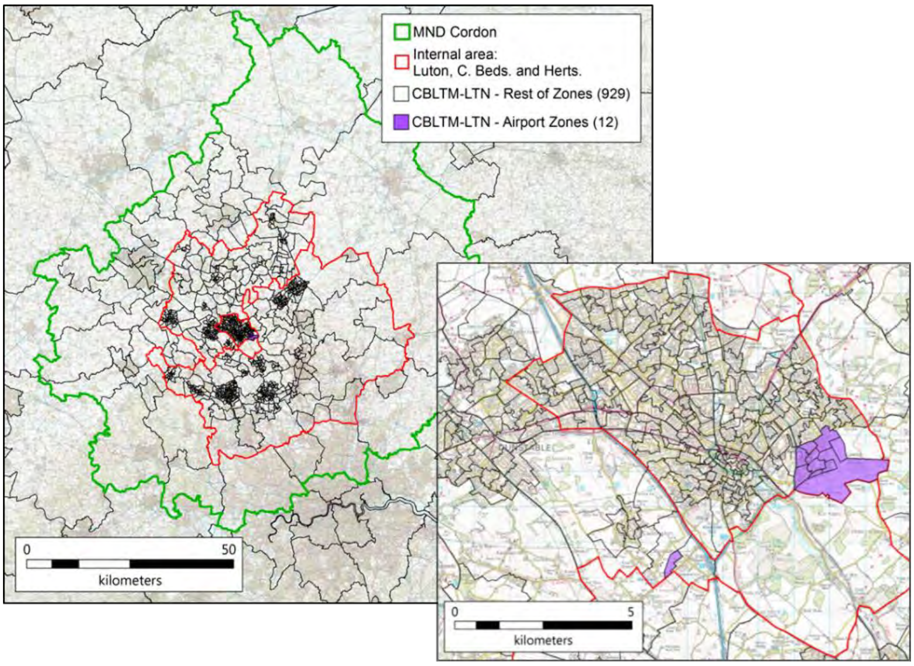
7.1.1 This section of the report focusses on describing the inputs, process, and outputs of the 2016 base year trip matrix development. The process makes use of the Mobile Network Data (MND) collected as part of the development of the existing CBLTM highway model, and provided by Telefonica (primarily known as O_2 in the UK).

7.2 Matrix Build Overview

7.2.1 CBLTM-LTN requires highway travel demand for five user classes (see Section 4.7), three of which are car trips split by purpose, while the remaining two are LGV and HGV trips. LGV and HGV matrices were taken and processed based on Highways England's South East Regional Traffic Model (SERTM).

7.2.2 The main processes for developing the highway prior matrices focus on travel by car and this followed two main work-streams. Travel demand to / from Luton Airport zones (as shown in Figure 7.1) has been developed from the CAA Passenger Survey data for Luton Airport and other data sources, with MND data used to derive all non-airport travel demand.

Figure 7.1 Luton Airport and Non-Airport CBLTM-LTN Zones



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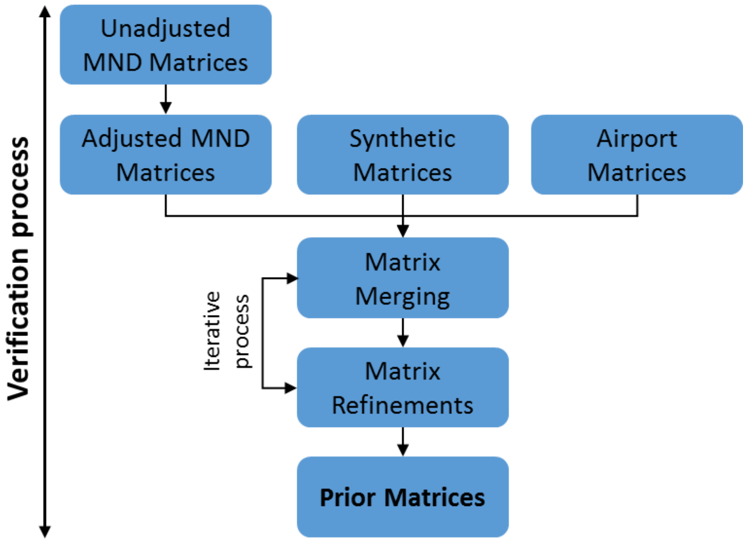
7.2.3 The process builds synthetic car demand matrices based on trip-ends developed for CBLTM-LTN. The developed synthetic matrices have been used as part of the processing of MND. In addition to this, a number of other data sources have been used as part of the matrix build, including goods vehicles demand from SERTM, and public transport demand from the existing CBLTM.

7.2.4 Synthetic and MND matrix build processes went through an iterative process of refinement based on a number of verification steps, which compared the demand matrices with external data sources such as the National Travel Survey (NTS). Additional refinements were undertaken where necessary based on the assignment results and a comparison of modelled and observed traffic flows at a screenline and cordon level.

7.2.5 Figure 7.2 provides a high-level overview of the highway demand matrix build process.

Figure 7.2 Overview of the Matrix Build Process



7.3 Data Preparation

7.3.1 The following section describes the uses of the following data sources:

- mobile network data (MND);
- SERTM LGV and HGV demand data;

- airport demand data;
- National Travel Survey (NTS) data;
- trip-ends based on base year planning data; and
- a distance-skim from CBLTM-LTN.

Mobile Network Data (MND)

7.3.2 The unadjusted MND data obtained to build trip matrices for the existing CBLTM highway model were reprocessed, using refined methods and updated secondary data sources for the purpose of CBLTM-LTN trip matrix building. It should be noted that the original MND data were collected and pre-processed by Telefonica.

7.3.3 The Origin-Destination (OD) matrices provided by Telefonica were segmented into:

- three modes: road, rail, and HGV;
- five time periods: AM Peak, interpeak, PM Peak, early off-peak, and late off-peak; and
- two peak hours: AM Peak and PM Peak.

7.3.4 The provided matrices were also split by ‘from-home’ / ‘to-home’ for home-based trips and into three trip purposes: home-based work (HBW), home-based other and business (HBOE), and non-home-based trips (NHB). These matrices were further split to the six trip purposes needed in the CBLTM-LTN model within the matrix build process. These six trip purposes are defined in Table 7.1.

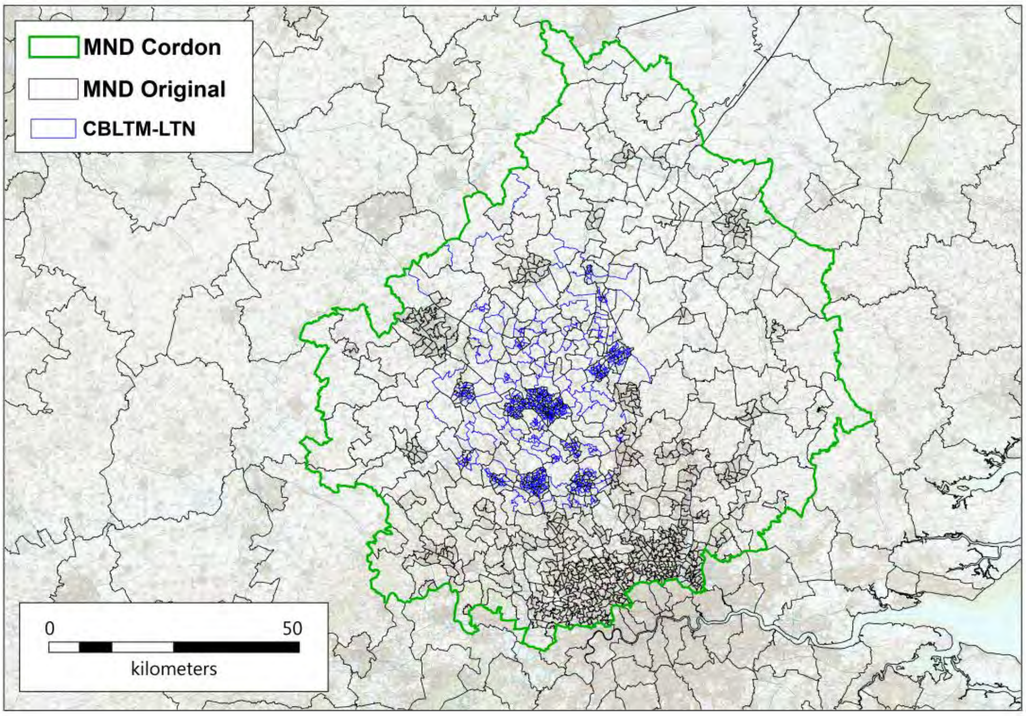
Table 7.1: Matrix Build Trip Purpose Definitions

Purpose	Definition
HBW	Home-based work
HBEd	Home-based education
HBO	Home-based other
HBEB	Home-based employers’ business
NHBO	Non-home-based other
NHBEB	Non-home-based employers’ business

7.3.5 The zoning system used for the MND is a combination of the 2011 Census MSOAs (Middle Layer Super Output Areas) within the modelled area (referred to as the 'MND Cordon') and an aggregation of districts/counties outside this area. This defines a total of 1,011 MND zones, shown in Figure 7.3.

7.3.6 The MND includes trips starting from / ending at, or crossing the MND cordon.

Figure 7.3 Original MND and CBLTM-LTN Zoning Systems



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Goods Vehicles SERTM Demand Data

7.3.7 Goods vehicle demand data from SERTM were used to:

- remove both LGV and HGV demand from all-mode MND matrices; and
- define the LGV and HGV demand matrices for these two user classes in the CBLTM-LTN assignment model.

7.3.8 HGV trips were assumed to be all NHB trips, while LGV trips were assumed to be split between NHB (75%) and HB (25%) trips, with symmetric directionality of HB trips (i.e. 12.5% of trips assumed as 'from-home' and 12.5% 'to-home'). In absence of any other reliable data, an analysis of NTS data was used to inform these purpose split assumptions.

7.3.9 The SERTM demand matrices were converted from the SERTM zone system (containing 2,306 zones) to the CBLTM-LTN zone system (with 991 zones) generally through the aggregation of SERTM zones. Where disaggregation was required, information from the base year CBLTM-LTN trip-ends were used as proportions within the disaggregation.

Luton Airport Demand Data

7.3.10 Demand to and from Luton Airport was developed independently to the rest of the matrices. The distribution of air passengers' surface access journeys to / from the airport was derived from the 2016 Civil Aviation Authority (CAA) passenger survey data.

7.3.11 Journey to Work data from the 2011 Census were used to derive the trip distribution for commuters (or employees). These data give commuting patterns by mode and is considered to be suitably robust, although the quantity of jobs at the airport has increased considerably since 2011. The number of workers and the modal split for airport employees were derived from London Luton Airport Limited's Annual Monitoring Reports for 2016 and 2017.

NTS Survey Data

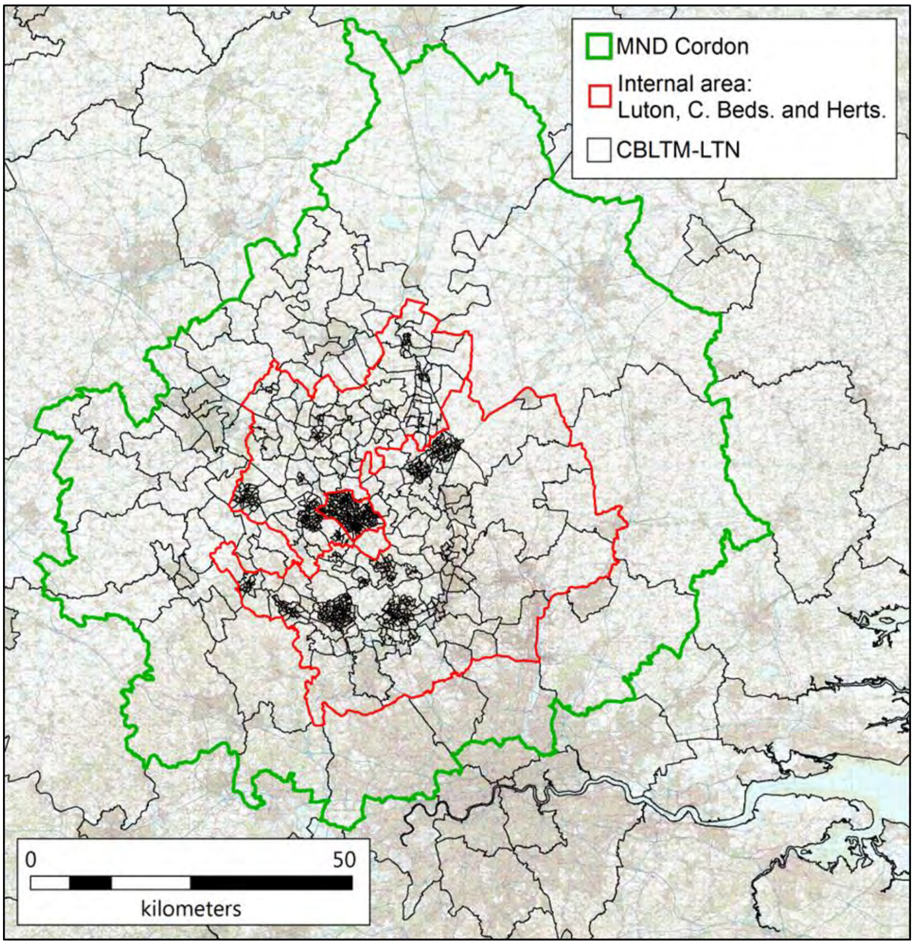
7.3.12 NTS data for three years (2012-2014) were used to prepare a number of inputs in the synthetic matrix build process, namely:

- target trip-length distributions (TLDs) by trip purpose for gravity model parameter estimation;
- 'from-home' and 'to-home' factors for HB trip purposes;
- time period factors by trip purpose; and
- vehicle occupancy factors by trip purpose and time period.

7.3.13 TLDs and trip rates from NTS were also used in the verification of the MND car matrices. All of the above were developed based on NTS trips produced within the internal area only.

7.3.14 The internal area for the highway matrix build was defined as a sub-region of the MND cordon covering Luton Borough, Central Bedfordshire and Hertfordshire, as shown in Figure 7.4.

Figure 7.4 Internal and MND Areas Defined for Matrix Build



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7.3.15 Where the sample size in NTS was too small, factors were derived using a more aggregate spatial area (i.e. county or government region area definitions), or using NTS records from a longer period of time.

CBLTM-LTN Trip-Ends

7.3.16 As part of the CBLTM-LTN suite, a trip-end model has been developed based on the DfT's CTripEnd software. This trip-end model has been adapted to reflect the adopted zone system within CBLTM-LTN, and is used to produce base year and forecast year trip-ends.

7.3.17 For the base year trip-ends planning data have been estimated from a number of sources. These sources include use of the 2011 Census, 2016 mid-year Census estimates for population, estimated employment changes by district from NOMIS, and data from TEMPro.

7.3.18 These base year planning data have been entered into the trip-end model to produce base year trip-ends by mode, trip purpose and time of day.

7.4 Car Synthetic Demand Matrix Build

Overview

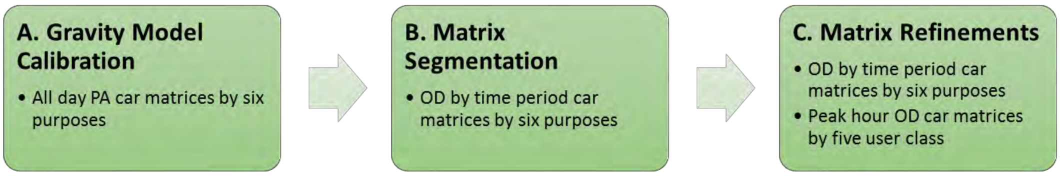
7.4.1 Figure 7.5 shows an overview of the synthetic car matrix build process, used primarily for three purposes (with detailed description of these provided in Sections 7.5 and 7.6):

- infilling short trips within the MND demand matrices (which are not fully observed);
- detailed purpose split of MND matrices; and
- merging with MND matrices to reduce errors and enhance the quality of final prior matrices.

7.4.2 The process is divided into three steps:

- Step A: preparing Production-Attraction (PA) matrices for the six trip purposes using a gravity model calibration process.
- Step B: preparing Origin-Destination (OD) matrices by direction ('from-home' / 'to-home') and time period.
- Step C: applying matrix refinements to get the necessary inputs for the MND matrix build process.

Figure 7.5 Overview of the Synthetic Car Matrix Build Process



Step A: Gravity Model Calibration

7.4.3 All-day synthetic matrices were built (reflecting quality of the observed data used for calibration), using a gravity model, for the five user classes represented in the CBLTM-LTN highway model, and for an additional home-based education (HBEd) purpose. The later was needed for the MND adjustment of education trips, as discussed later in Section 7.5.

7.4.4 The gravity model process requires three inputs:

- a set of trip-ends;

- a deterrence function which represents how sensitive travellers are to travel costs; and
- a set of parameters for the specified deterrence function.

Step B: Matrix Segmentation

7.4.5 More detailed segmentation is required for the synthetic matrices to be used within the processing of the MND. Segmentation includes splitting PA matrices by ‘from-home’ and ‘to-home’ for home-based purposes and allocating each matrix to relevant time periods.

7.4.6 ‘From-home’ factors based on NTS data for each home-based purpose were applied to produce PA matrices by ‘from-home’ and ‘to-home’. All-day synthetic matrices were then segmented into three time periods, as defined in Section 4.6. Determining time period factors was based on a number of iterations as described in Step 3 of the process.

7.4.7 The final sets of factors for each trip purpose were either ‘flat’ or distance-based, depending on whether the observed data suggested variation by trip distance.

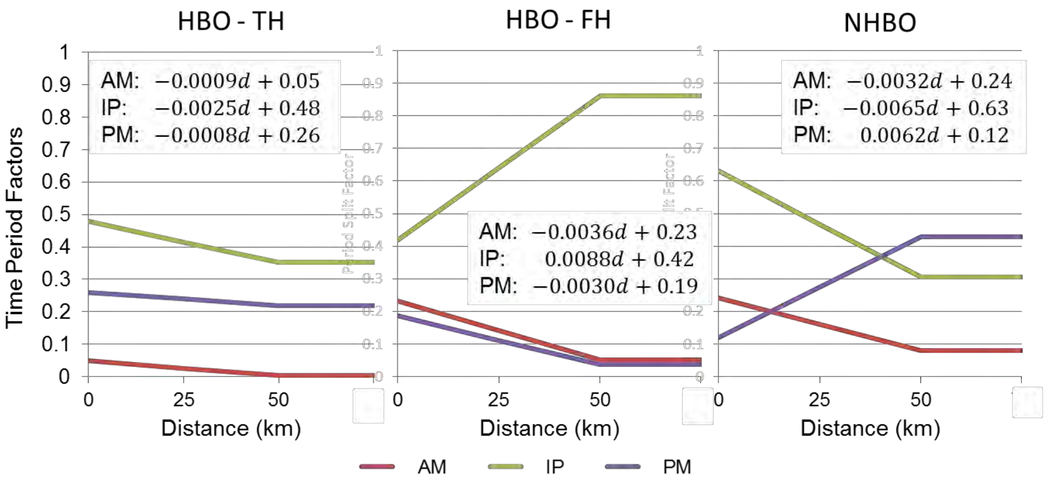
7.4.8 Flat factors were used for HBW, HBEB, HBEd and NHBEB, and are shown in Table 7.4. These were sourced from the internal production trip-ends, as described in Section 7.3.

Table 7.2 Time Period Factors by Purpose and Direction (‘from-home’ / ‘to-home’)

Purpose	AM	IP	PM	OP
HBW - 'To Home’	0.04	0.20	0.57	0.19
HBW - 'From Home’	0.66	0.13	0.06	0.15
HBEB - 'To Home’	0.03	0.28	0.47	0.22
HBEB - 'From Home’	0.56	0.27	0.08	0.09
HBEd - 'To Home’	0.18	0.58	0.19	0.05
HBEd - 'From Home’	0.19	0.66	0.13	0.02
NHBEB	0.74	0.23	0.03	0.00

7.4.9 For HBO and NHBO, time period factors were applied as a linear function of distance, with flat factors used for distances greater than 50km, as shown in Figure 7.6.

Figure 7.6 HBO and NHBO Time Period Factors



Step C: Matrix Refinements

7.4.10 As part of the matrix build process several improvements were made to the synthetic matrix build process. The merit of these improvements, and the approach chosen was based on the comparison of assigned flows with counts. The following main improvements were made:

- updating the observed TLDs, input to the gravity model, such that they reflected variation in TLDs between Luton, Central Bedfordshire and Hertfordshire; and
- changing the time period factors, with these going through several permutations, with both NTEM and NTS factors trialled, and an analysis made of whether the HBO and NHBO factors should be applied as a function of distance, with additional correction factors applied based on how the synthetic assignment (see below) compared with observed traffic flows.

Assigning the Synthetic Matrices

7.4.11 The OD synthetic matrices were assigned onto an interim version of the highway network, to analyse the performance of the synthetic process and investigate any significant difference between the modelled and observed traffic flows at a screenline / cordon level.

7.4.12 The synthetic matrices were developed for person trips, and therefore needed to be converted to vehicle trips prior to the assignment. All-day average vehicle occupancy factors were derived from NTS and applied for each purpose.

7.4.13 Peak hour factors were derived from the unadjusted MND matrices and applied, disaggregated based on whether each trip started or ended in Luton, Central Bedfordshire, Hertfordshire or elsewhere, and whether it was home-based or non-home-based.

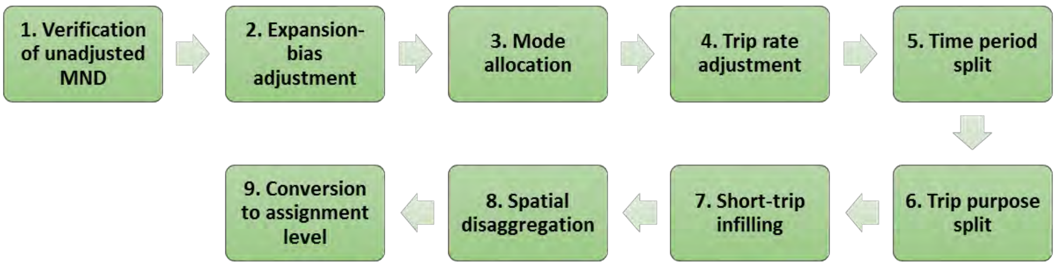
7.4.14 The assignment results were used to both refine all-day to time period factors; and to inform weights used to merge with MND matrices (see Section 7.5).

7.5 Car MND Demand Matrix Build

Overview

7.5.1 Figure 7.7 shows an overview of the MND matrix build process, divided into nine main steps, described in detail below. The process starts with verification tests of the unadjusted MND matrices obtained as described in Section 7.3, and ends with assignment level matrices.

Figure 7.7 Overview of Car MND Matrix Build Process



Step 1: Verification of MND

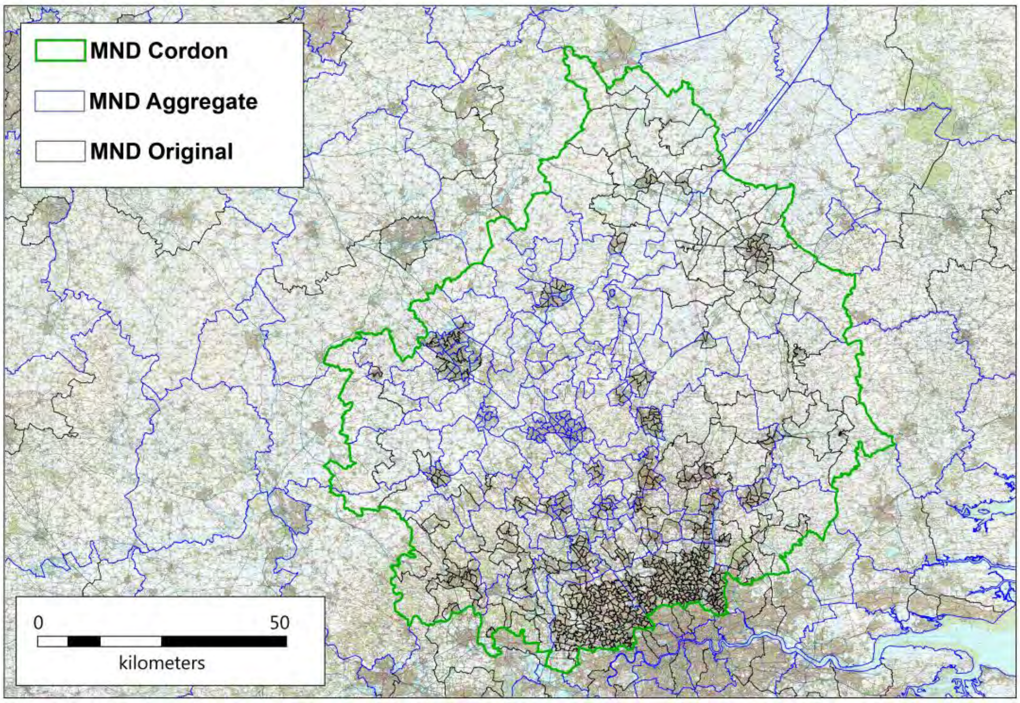
7.5.2 In the development of Highways England Regional Traffic Model (RTM), a number of verifications of the unadjusted MND were defined and undertaken prior to any adjustment of the underlying data.

7.5.3 Similarly here, trip-ends and TLD verification tests were undertaken in order to identify biases in the MND that needed to be corrected prior to any further adjustment.

7.5.4 Trip-end analysis included comparing trip totals for Luton and Central Bedfordshire from the trip-end model and the MND for three purposes: HBW, HBOE, and NHB.

7.5.5 Given that the MND and CBLTM-LTN have different zoning systems, a new zoning system was devised which is an aggregation of CBLTM-LTN and MND zoning systems. This is referred to as 'MND Aggregated' and constitutes 189 zones, as shown in Figure 7.8. The MND are also not reliable in their mode allocation to road / rail / HGV at the MND zone level, hence defining at the 'MND Aggregated' zone system is essential for the mode allocation (Step 3) of the MND matrix build.

Figure 7.8 Original and 'MND Aggregate' Zoning Systems



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7.5.6 The analysis showed that when HBEd trips from the trip-end model were considered as HBO trips, large discrepancies were found in the HBW and HBOE in comparison for MND. This is shown in Table 7.3.

Table 7.3 Comparison of CBLTM-LTN Trip-Ends and MND

Purpose	Trip-End Model	MND
HBW	26%	38%
HBOE	62%	44%
HB Combined	88%	82%
NHB Combined	12%	18%

7.5.7 When combined, the proportion of home-based trips within the MND was considered to be comparable with those from the trip-end model (82% compared with 88%). This bias in trip purpose allocation from home-based trips largely related to education trips, and needed to be taken into account and corrected.

7.5.8 In developing highway matrices for Highways England's Regional Traffic Models (RTMs), an analysis of TLDs between mobile user trips and population-weighted trips showed significant trip-length bias towards longer trips, and correction factors were derived and applied to correct for this bias. A similar bias was included in the MND matrices given the same source of data and same methodology used for expansion, therefore adjusting for such bias in the MND data was considered necessary (see below).

Step 2: Expansion-bias Adjustment

7.5.9 Distance-based correction factors calculated when developing the Regional Traffic Models are shown in Table 7.4. These factors were used directly, at all day, all purposes, and all mode level, to MND matrices.

7.5.10 It should be noted that the total number of MND trips was retained as part of this correction.

Table 7.4 Distance-based Correction Factors

Distance Band (km)	Correction Factor
0-5	1.06
5-10	0.98
10-15	0.958
15-20	0.946
20-30	0.936
30-40	0.926
40-50	0.92
50-100	0.912
100+	0.898

7.5.11 The output from this step was three all day, all mode MND trip matrices in OD format, representing the three demand segments: 'from-home' HB trips, 'to-home' HB trips, and NHB trips.

Step 3: Mode Allocation

7.5.12 Due to uncertainty in the MND mode allocation process between road, rail, and HGV, the three matrices were combined, and secondary data were used to remove public transport and goods vehicle trips.

7.5.13 All modes were thus consolidated at an all-day level and split into three simplified demand segments: 'from-home' HB trips, 'to-home' HB trips, and NHB trips.

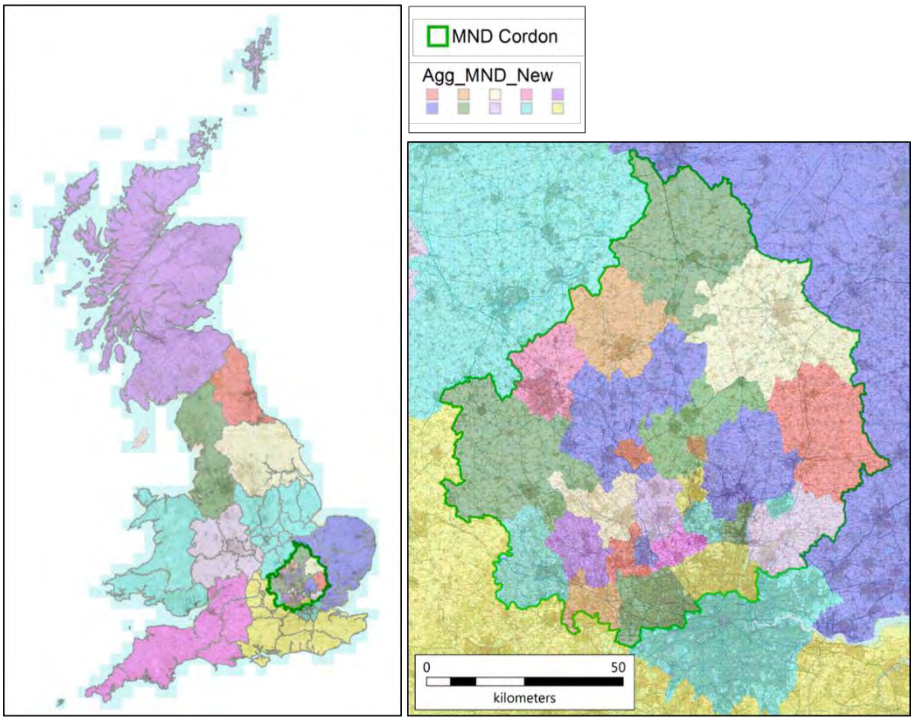
7.5.14 Existing matrices of public transport and freight were then used to subtract trips from MND at sector-to-sector level, as described below, reflecting variations of mode shares between different movements and different distances.

7.5.15 Short trips are partially observed in the MND, and further analysis for identifying short car trips is undertaken later in the process (Step 7). Therefore mode allocation was undertaken for trips longer than 4km, considered as an indicative threshold, to ensure the majority of trips are included within MND.

7.5.16 The level of spatial aggregation (i.e. the sectoring system) at which mode allocation process is undertaken is key. Zonal information will be lost if the aggregation level is too large, and misallocation or negative trips can occur if the zones are too small.

7.5.17 By testing the 'MND Aggregated' system defined in Step 1, it was concluded that more aggregate sectoring system was required. This is referred to here as 'MND-Sectors'. After a number of iterations to determine the best level of spatial aggregation, the number of zones was set at 38 zones covering the modelling area. This is shown in Figure 7.9.

Figure 7.9 'MND Sector' System



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7.5.18 Proportions of public transport trips (from the existing CBLTM public transport matrices) and freight trips (from SERTM) were calculated using the 'MND Sector' system. These proportions were applied to the all day, all mode matrices, with the remaining trips defined as car trips.

7.5.19 The output of this step was three all-day car MND trip matrices in an OD format representing the two purposes by direction: inbound HB, outbound HB, and NHB.

Step 4: Trip Rate Adjustment

7.5.20 Using population data, for both synthetic and MND matrices, trip rates were calculated based on internal productions excluding short-distance trips for each of Luton, Central Bedfordshire and Hertfordshire. These are shown in Table 7.5.

Table 7.5 Synthetic and MND All-Day Car Trip Rates per Person (excluding short trips)

Area	Population	Synthetic Trip Rate		MND Trip Rate	
		HB	NHB	HB	NHB
Luton	216,307	0.71	0.10	0.95	0.16
Central Bedfordshire	278,937	1.05	0.11	1.35	0.20
Luton and Central Bedfordshire	495,244	0.90	0.10	1.17	0.18
Hertfordshire	1,177,204	1.05	0.14	1.17	0.20

7.5.21 MND trip rates for Hertfordshire were controlled to NTS. Given the small sample size for Luton and Central Bedfordshire within the NTS data (which underpin the trip-rates represented within the trip-end model), Luton and Central Bedfordshire were combined as part of this adjustment.

Step 5: Time Period Split

7.5.22 Time period factors were retained from the MND and reapplied. In order to retain time period data for HBW and HBOE trip purposes within the MND, an initial trip purpose split was undertaken using the unadjusted MND, with a refinement of this process undertaken as part of Step 6.

7.5.23 These factors were then applied to the trip-rate adjusted MND car matrices from Step 4. The output from this step of the process is MND car trip matrices in OD format representing the four time periods (AM Period, interpeak Period, PM Period and off-peak Period) and three demand segments: ‘from-home’ HB trips, ‘to-home’ HB trips, and NHB trips.

Step 6: Detailed Trip Purpose Split

7.5.24 The three existing MND purpose classes (HBW, HBOE, and NHB) were split into more detailed purposes using factors derived from the synthetic matrices at OD level, based on the correspondence detailed in Table 7.6. This allocation to detailed trip purposes was undertaken at ‘MND Aggregated’ zone system.

Table 7.6 Correspondence of MND to CBLTM-LTN Purposes

Purpose	Split to
Home based work (HBW)	Home based work (HBW) Home based education (HBEd)
Home based other & employers' business (HBOE)	Home based other (HBO) Home based employers' business (HBEB)
Non-home based (NHB)	Non-home based other (NHBO) Non-home based employers' business (NHBEB)

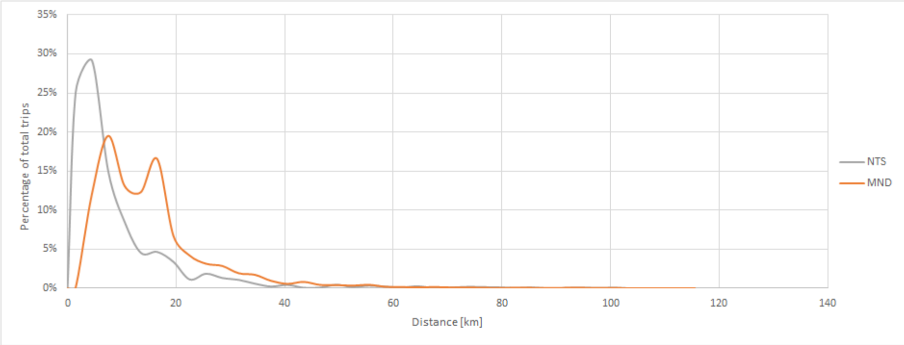
Step 7: Short-trip Infilling

7.5.25 This step in the matrix build process considered the infilling of short trips of each time period matrix. This process has made use of the synthetic matrices.

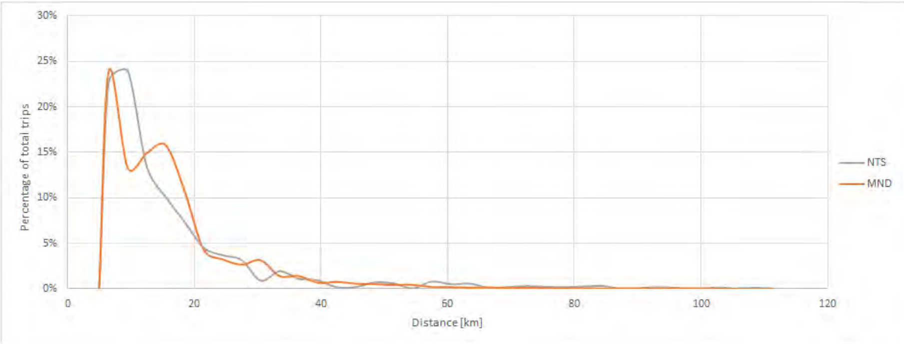
7.5.26 Trip-length distribution comparisons between NTS data and MND for each trip purpose were undertaken to identify the distance below which MND do not reliably capture all trips. Figure 7.10 shows an example of this analysis for home-based 'other' car trips. The first comparison (including all trips) shows an understatement in short-distance trips within the MND matrices; however a better correlation between NTS and MND trip-lengths is shown when excluding shorter distance trips.

Figure 7.10 Comparison of NTS and MND Trip-Length Distributions for HBO (internal productions)

All trips



Excluding trips less than 5km in length



7.5.27 Based on this analysis, distance thresholds were defined by trip purpose. These were defined as 5km for all trip purposes, with the exception of home-based education where a threshold of 4km was selected.

7.5.28 The MND matrices include partial inclusion of external-to-external trips. Certain external-to-external movements such as those crossing the MND cordon can be fully observed in MND; however, detailed analysis was needed to identify those OD movements which are fully captured within the MND data. Due to the uncertainty in the outcome of this analysis, synthetic matrices were used to infill all external to external movements.

7.5.29 It should be noted that SERTM car matrices were considered as an option to infill external-to-external trips. The development of SERTM matrices (consistent with other RTM matrices) included steps to correct for significant trip-length biases which existed in the original MND data (referred to as provisional data). The focus of these adjustments for each RTM was the defined internal area of the model; therefore, external-to-external trips in SERTM matrices were left unadjusted.

7.5.30 Given the scale of biases found during the verification of provisional data, the external-to-external trips in SERTM matrices were considered unreliable and biased towards longer distance trips; hence were discarded as the source of data for external-to-external movements in building CBLTM-LTN matrices.

Step 8: Spatial Disaggregation

7.5.31 The process until this point has taken place in an aggregate zoning system of 189 zones, reflecting the spatial accuracy of MND. Before converting to assignment level, the matrices have to be spatially disaggregated to the zoning system of the assignment network (i.e. 991 zones).

7.5.32 For each time period and trip purpose, a disaggregation factor was calculated at OD level for each CBLTM-LTN zone using the synthetic demand matrices. The factors were applied to the processed MND matrices obtained from Step 7.

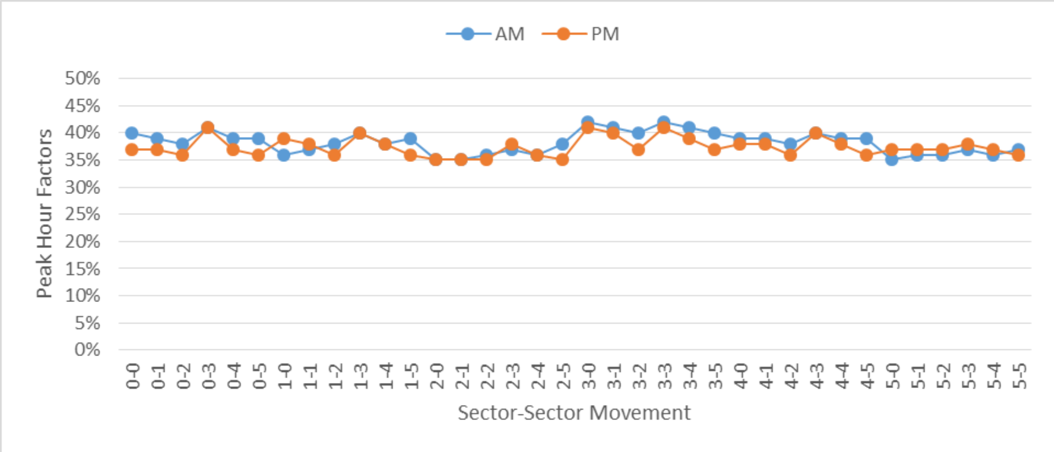
Step 9: Conversion to Assignment Level

7.5.33 The final step of the matrix build process is the conversion of matrices to assignment level. This is undertaken through the following three steps:

- converting time period to peak hour trips;
- converting person to vehicle trips; and
- aggregating demand segments to assignment user classes.

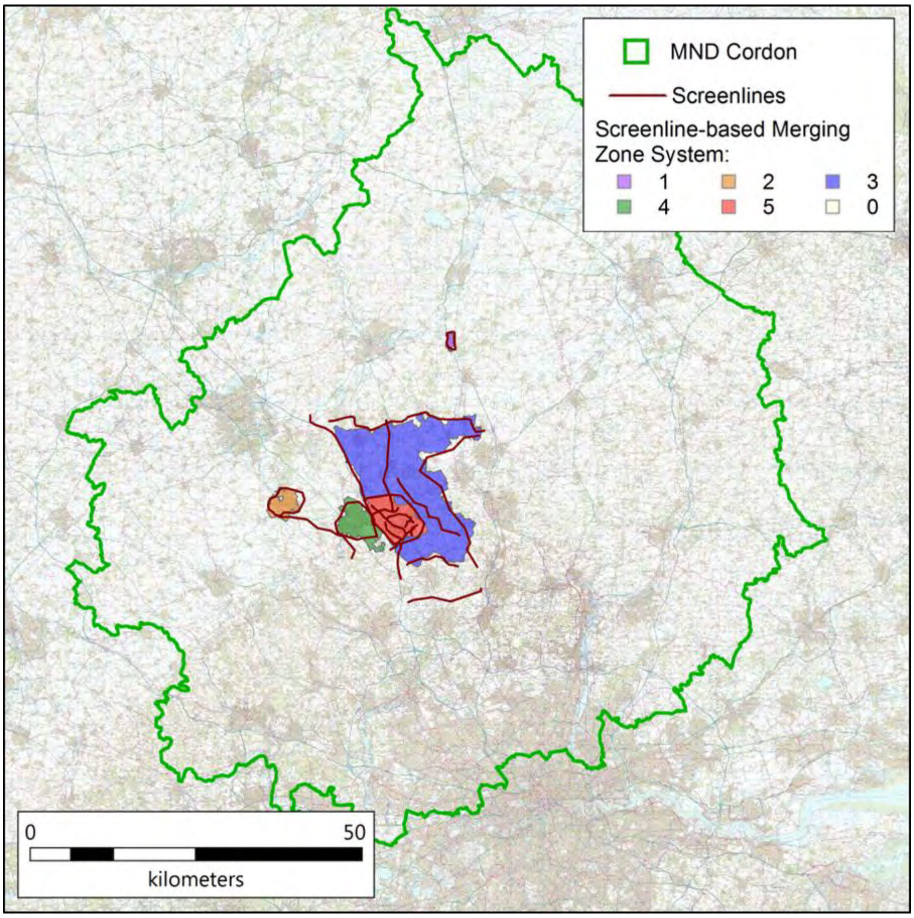
7.5.34 The unadjusted highway MND data included peak hour matrices. As shown in Figure 7.11, factors range between 35% and 42% for the AM Period, and between 35% and 41% for the PM Period. For the interpeak and off-peak, an average factor of 1/6 was used.

Figure 7.11 Peak Hour Factors used for Conversion of MND Matrices to Assignment Level Matrices



7.5.35 Peak hour factors were derived using the sector system adopted in the merging process in Section 7.6. This sectoring system separated movements based on screenline definitions used for the performance assessment of the assigned matrices, shown in Figure 7.12.

Figure 7.12 Screenlines used for Matrix Conversion



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7.5.36 AM Peak and PM Peak hour factors for the LGV and HGV matrices were derived based on LGV and HGV count data. These were 0.368 and 0.359 for the AM Peak, respectively for LGV and HGV, and 0.359 and 0.356 for the PM Peak.

7.5.37 Peak hour car, LGV, and HGV matrices were then converted to vehicle matrices by applying occupancy factors derived from NTS data by purpose and by time period, and using internal productions trips only. Factors were highest for education trips (2.162 for the AM Period) and lowest for employers' business trips (1.082 for the interpeak and off-peak periods).

7.5.38 An occupancy factor of 1.1 is assumed for LGV trips (derived from NTS), and 1 for HGV trips.

7.6 Matrix Merging

7.6.1 It is recognised that there are underlying errors in both travel demand matrices derived from MND and synthetic matrices, and that some of these errors are difficult to quantify. In order to combine the benefits of the MND and synthetic matrices, a merging process for the two demand estimates has been undertaken.

7.6.2 The merging process relies mainly on the performance of the MND and synthetic matrices against observed cordon flows, with higher scores given to better performing cordons. These scores are translated to scores for each sector-to-sector movements corresponding to each cordon-to-cordon movement. The sectoring system used is defined based solely on cordon locations, and was introduced previously in Figure 7.12.

7.6.3 The merging process then derives weights for each of the MND and synthetic sector-to-sector demand. The higher the weight in MND, the higher the confidence in the number of MND trips travelling from the specified sector-to-sector.

7.6.4 It should be noted that the merging process heavily favours MND demand in order to reflect the larger errors found in synthetic matrices. This is done by ensuring that the weight is always equal or higher than that of synthetic for each movement. It is also worth noting that a higher weight is given to the MND for longer distance sector-to-sector movements.

7.7 On-going Verification and Refinements

7.7.1 There were two areas of on-going verification throughout the highway matrix build that has led to a number of refinement iterations.

7.7.2 The first was conducting trip-length distribution and trip-rate analysis against NTS for the developed matrices at the individual steps of the matrix build process.

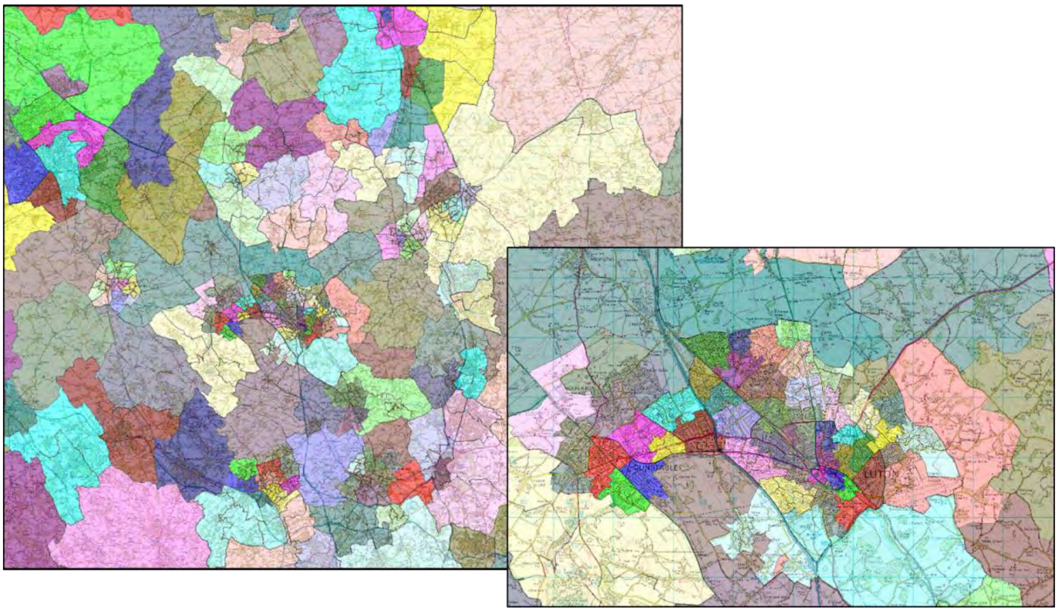
7.7.3 The second area of verification was a flow comparison of the assigned matrices on the road network against observed flows at a screenline level. This has also led to detecting issues with certain inputs to the process and correcting for them, in particular those related to SERTM HGV matrices. To improve the SERTM HGV matrices, information on the distribution of HGV movements from CSRGT at a sector-sector level was used to refine the freight demand matrices.

7.8 Refinements to Prior Matrices

7.8.1 Following the development of the highway prior matrices, a series of matrix adjustments was undertaken to address various remaining errors in the estimated trip patterns. A methodology was developed to adjust the prior matrices at a sector-level based on an initial comparison of total observed and modelled flows across screenlines and cordons.

7.8.2 In this update, all counts along a given screenline / cordon were used as a single constraint. This minimised the impact of any localised routeing issues in the model at the time, and the results of this process were used to update the matrices at a sector level. This sector system adopted for this process was based on the MND zone system and the defined screenlines / cordons, and is shown in Figure 7.13.

Figure 7.13 Sector System for Prior Matrix Refinements



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7.8.3 An important issue that should be taken into consideration is the resulting changes in the prior matrices through this update. The adjusted matrices must retain as much of the information as possible from the observed data. The application of a sector-based factoring, as compared with a cell-based factoring, would significantly reduce changes to the developed matrices and would retain as much of the information as possible from the observed data.

7.8.4 It is also noted that these updates to the prior matrices were applied after the network was reviewed to remove significant routeing discrepancies. This was an essential precursor as the routeing needs to be reliable enough to ensure that the movements that were adjusted were reasonable.

7.8.5 Table 7.7 shows the regression analysis for the matrix cell changes through the application of the sector-based updates by time period and vehicle class. This table shows that both the slope and R^2 values are close to 1 for all time periods for car and LGV traffic, with lower values of R^2 for HGV movements. This reflects the greater level of uncertainty in the HGV trip matrices due to the available observed data on HGV trip patterns, which results in larger changes to the prior matrices to reflect screenline / cordon observed flows.

Table 7.7: Regression Statistics for Matrix Zone-to-Zone Changes (Prior Matrix Update): Internal Origins

Time Period	Vehicle Type	Slope	R^2
AM Peak	Car	1.00	1.00
	LGV	1.02	0.97
	HGV	0.99	0.67
Interpeak	Car	1.00	1.00
	LGV	1.01	0.99
	HGV	0.88	0.60
PM Peak	Car	1.00	1.00
	LGV	1.01	0.97
	HGV	0.80	0.53

7.8.6 In addition to checks on the updates to the prior matrices at a cell-level, Figure 7.14 includes a selection of plots showing the change in matrix trip-ends within the 'internal area' for origins and destinations, by modelled hour and by vehicle class.

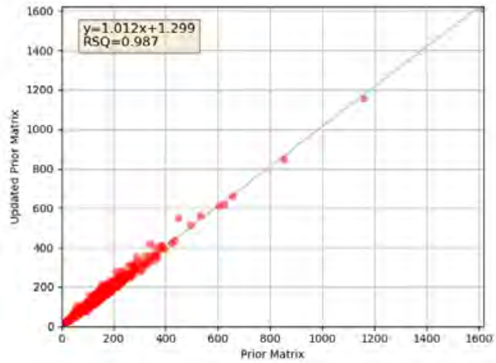
7.8.7 As with the changes at a zone-level, the scale of changes to the matrix trip-ends corresponds with the relative level of confidence in the underlying demand data. The trip-ends for HGV traffic show the greatest change as part of this prior matrix update, corresponding with the higher level of uncertainty for this vehicle class, with lower levels of change for car and LGV traffic.

7.8.8 Figure 7.15 also presents the change in trip-length profiles resulting from this update to the prior matrices by time period and vehicle class. As with the analysis of matrix cells and trip-ends, there is little change in the modelled trip-length profiles for car trips, with minor changes in the trip-length profile for LGV traffic (a small increase in the proportion of short-distance trips), and larger changes for HGV traffic.

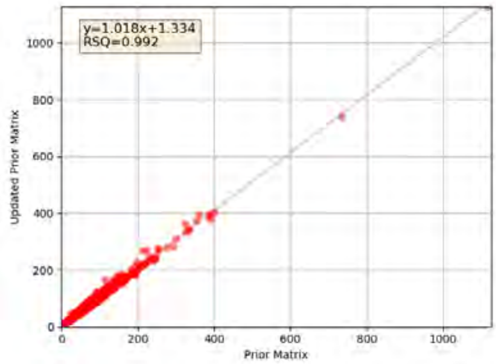
7.8.9 Although the changes in trip-length distributions are greatest for HGV traffic, the trip-length distributions for HGV traffic in the updated prior matrices are similar to those in the original prior matrices.

Figure 7.14 Selected Matrix Trip-End Changes (Prior Matrix Update): Internal Origins / Destinations

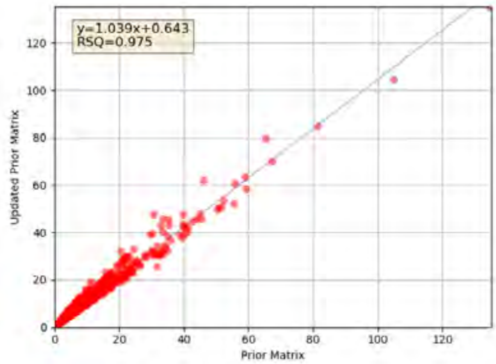
AM Peak Car Origins



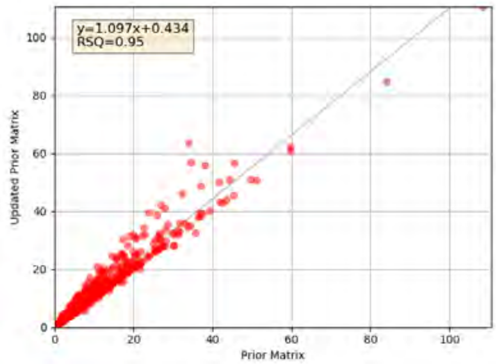
Interpeak Car Destinations



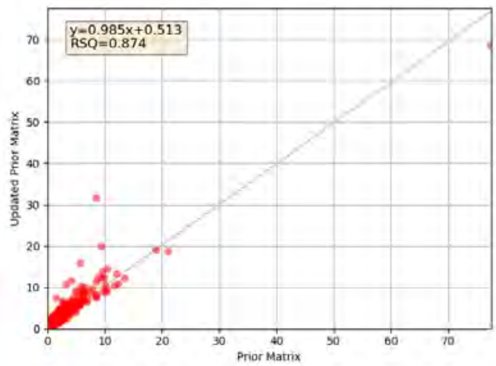
Interpeak LGV Origins



PM Peak LGV Destinations



AM Peak HGV Destinations



PM Peak HGV Origins

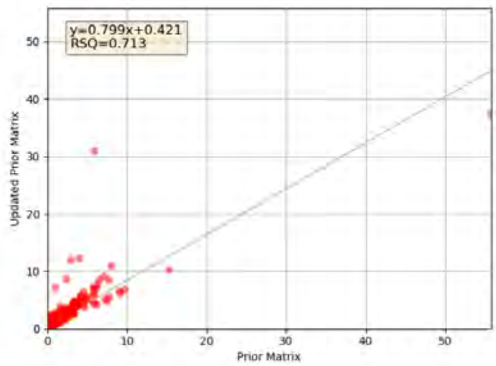
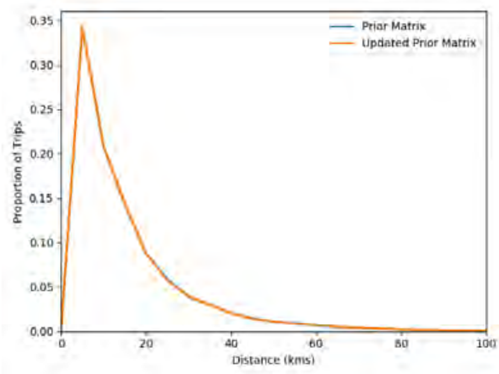
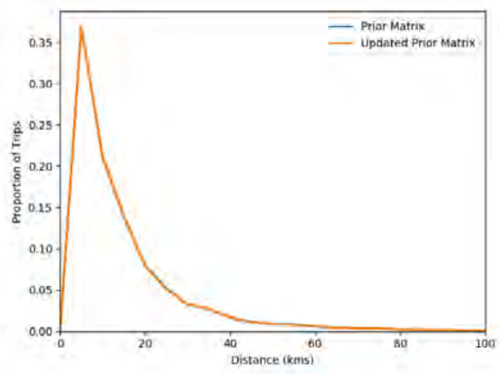


Figure 7.15 Selected Matrix Trip-Length Distribution Changes (Prior Matrix Update): Internal Origins

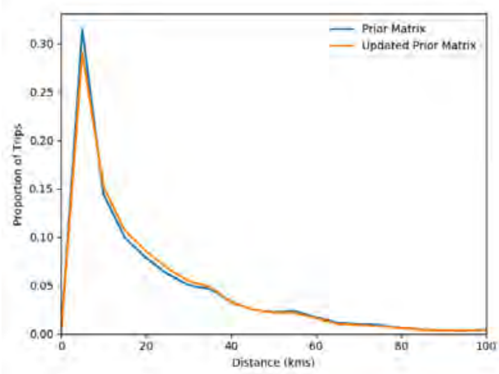
AM Peak Car



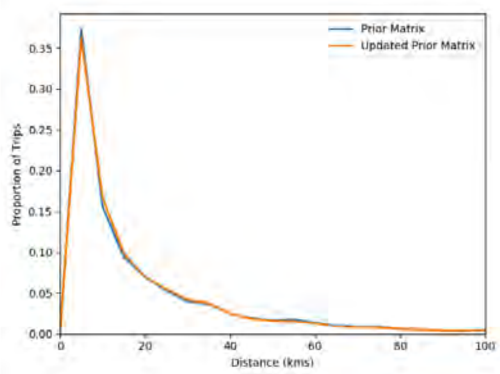
PM Peak Car



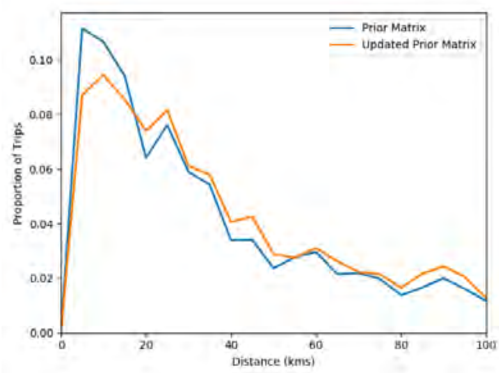
AM Peak LGV



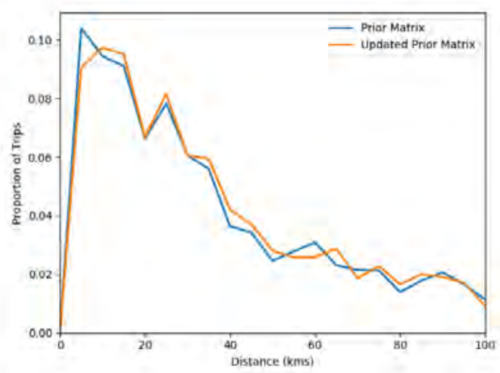
Interpeak LGV



AM Peak HGV



PM Peak HGV



8 NETWORK CALIBRATION AND VALIDATION

8.1 Introduction

8.1.1 As discussed in Section 6.1 and 6.3 a number of network checks were performed on the existing CBLTM and adopted COMET network coding as part of the review and expansion of the CBLTM-LTN highway network.

8.1.2 This section looks at other data sources which have been used for additional checking, or calibration, of the highway network based on observed data.

8.2 Network Calibration

8.2.1 The network calibration was performed on the assigned model, using the prior matrices and compared with observed data such as counts, journey times and Google Maps which provide a useful source of information to compare modelled data.

8.2.2 Observed count information was used to compare against the modelled capacities at chosen count locations. If the calculated modelled capacity is less than the observed count then this suggests there is an error in the observed count or network. It would also mean that matrix estimation would be unable to match this count.

8.2.3 This comparison identified a small number of links with an incorrectly applied link capacity index, incorrect saturation flow or locations where adjustments were required to the provided signal time data. These errors were corrected prior to the application of matrix estimation.

8.2.4 Observed journey time validation data were compared with modelled journey time information. The following checks were made, in combination with available observed count data:

- Compare and identify any excessive delays along journey time routes. Where excessive delays were identified in the model, appropriate adjustments were made to remove these delays.
- Compare if modelled journey times were too fast or slow and review speeds in the network.

8.2.5 This comparison led to a number of modelled link speeds that were adjusted accordingly to reflect observed speed information.

8.2.6 In addition to the route choice validation checks described in Section 9, Google Maps data were used, particularly where observed count and journey time validation data were not available, to compare the modelled routes through the network with the corresponding routes identified in Google Maps. This was performed by time period using "typical" traffic conditions for that modelled hour. This identified a limited number of modelled routes that needed to be reviewed in the model.

8.2.7 This comparison led to a small number of modelled link speeds being adjusted to reflect routeing in Google Maps.

8.3 Network Validation

8.3.1 No independent validation of the highway network was performed during the development of the CBLTM-LTN highway model. WebTAG Unit M3.1 §6.3.1 states that:

"It is not possible to validate a network in isolation, since the output traffic flows and travel times will reflect not only errors in the network, but also those inherited from the input trip matrix. This is a particularly important consideration in congested urban areas, where relatively small discrepancies in a trip matrix can have a disproportionate impact on junction delays and hence on the routes taken by vehicles through the network."

8.3.2 The route choice calibration and validation (as discussed in Section 9), the trip matrix calibration and validation (as discussed in Section 10), and the assignment calibration and validation results (as discussed in Section 11) form the most appropriate validation of the network itself.

9 ROUTE CHOICE CALIBRATION AND VALIDATION

9.1 Introduction

9.1.1 WebTAG Unit M3.1 §7.1.3 notes that modelled route choice will depend on:

- appropriateness of zones;
- accuracy of network coding and appropriateness of simplifications;
- accuracy with which link journey times and junction delays are modelled; and
- accuracy of the trip matrices.

9.1.2 Accuracy of routeing by the model should be examined and its plausibility checked in order to ensure robust results. This is a somewhat iterative process, with calibration of routeing being intrinsically linked to the update of the network and matrices.

9.1.3 This section of the report provides detail on the calibration of routeing in the model and subsequent validation checks.

9.2 Implementation of HGV Bans

9.2.1 The balance of the generalised costs for HGVs is more heavily weighted towards distance which can lead to local routes being favoured over motorway and trunk road routes. WebTAG Unit M3.1 §7.2.4 suggests that adjustments may be considered such as the use of HGV specific penalties to counteract this effect.

9.2.2 In CBLTM-LTN, HGV maximum speeds have been capped according to road type based on advice within Appendix D of WebTAG Unit M3.1, and detailed in Section 6.6.

9.2.3 In addition to this, HGV bans and penalties have been introduced in the model network. The difference between bans and penalties is that penalties still allow access for vehicles with an origin or destination in that area. The location of these penalties is shown in Figure 9.1, whilst bans are presented in Figure 9.2.

Figure 9.1 Location of HGV Penalties (red) in CBLTM-LTN Highway Network

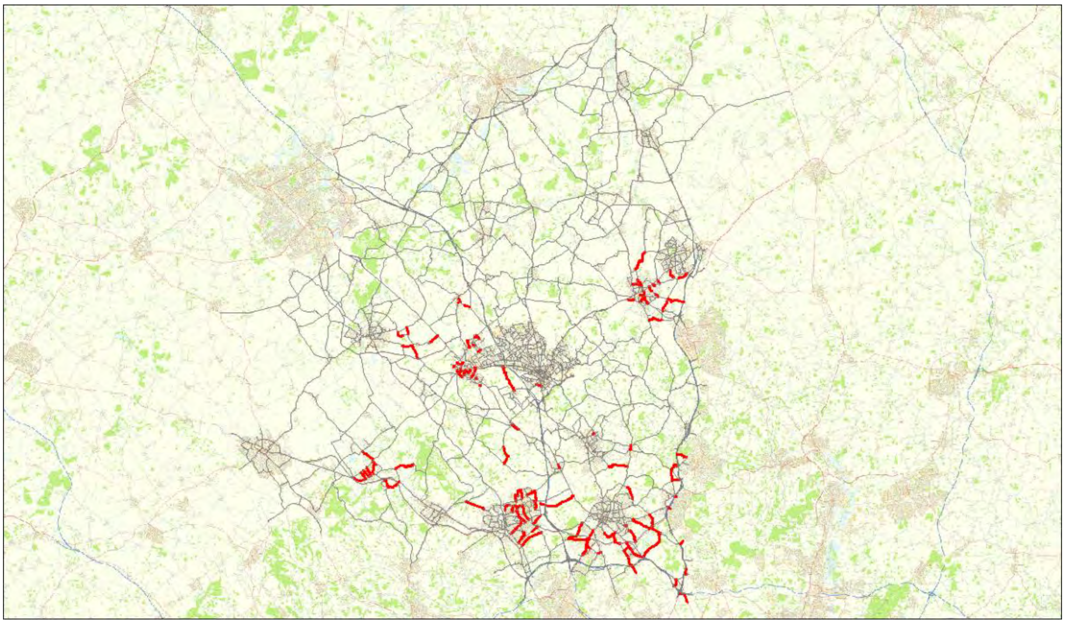


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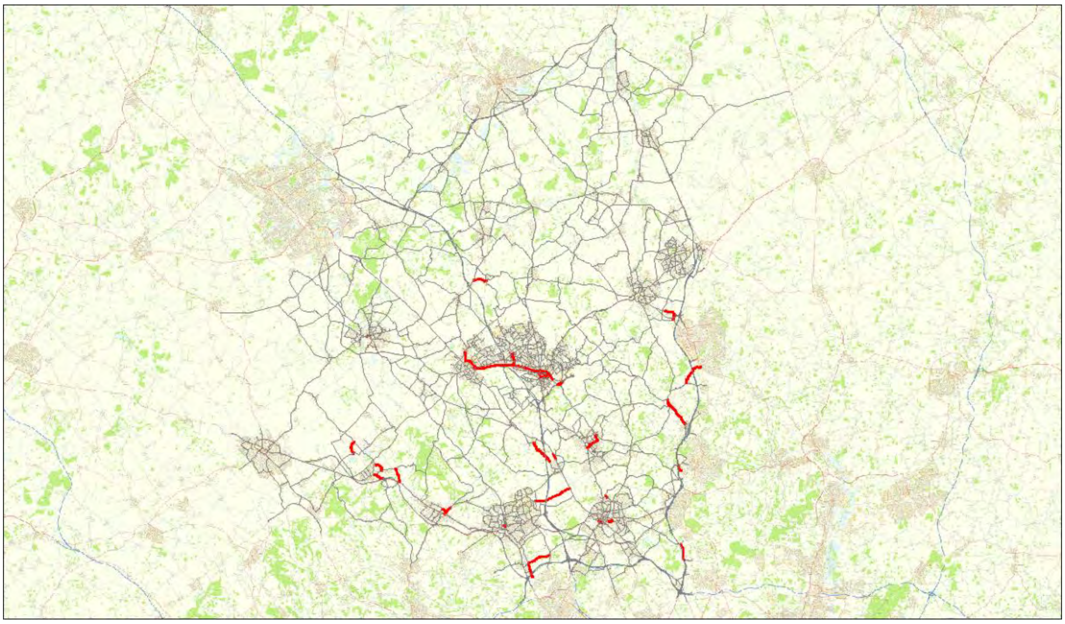
Figure 9.2 Location of HGV Bans (red) in CBLTM-LTN Highway Network



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9.3 Route Choice Validation

9.3.1 WebTAG Unit M3.1 §7.3.1 notes that it is not possible to inspect all origin-destination routeing within the highway assignment, especially in a large model such as CBLTM-LTN.

Therefore a selection of key traffic movements should be assessed and focus on important centres of population and employment or key intersections. Routes should be chosen so that they:

- relate to significant numbers of trips;
- are of significant length or cost (e.g. greater than 20 minutes);
- pass through areas of interest (e.g. scheme impacted areas);
- include both directions of travel (to sense check differences);
- link different compass areas (e.g. north to south, east to west, etc.); and
- coincide with journey time routes as appropriate.

9.3.2 WebTAG recommends that routes modelled for each user class should be examined separately and the number of zones that should be examined and displayed based on the following rule of thumb:

$$OD\ Pair = (number\ of\ zones)^{0.25} * (number\ of\ user\ classes)$$

9.3.3 To validate the route choice within the model, 28 key origin-destination movements were analysed. These routes capture key inter-urban movements across the modelled area. Figure 9.3 and Figure 9.4 show the location of the zones identified for this purpose.

Figure 9.3 Zones Identified for Route Choice Validation

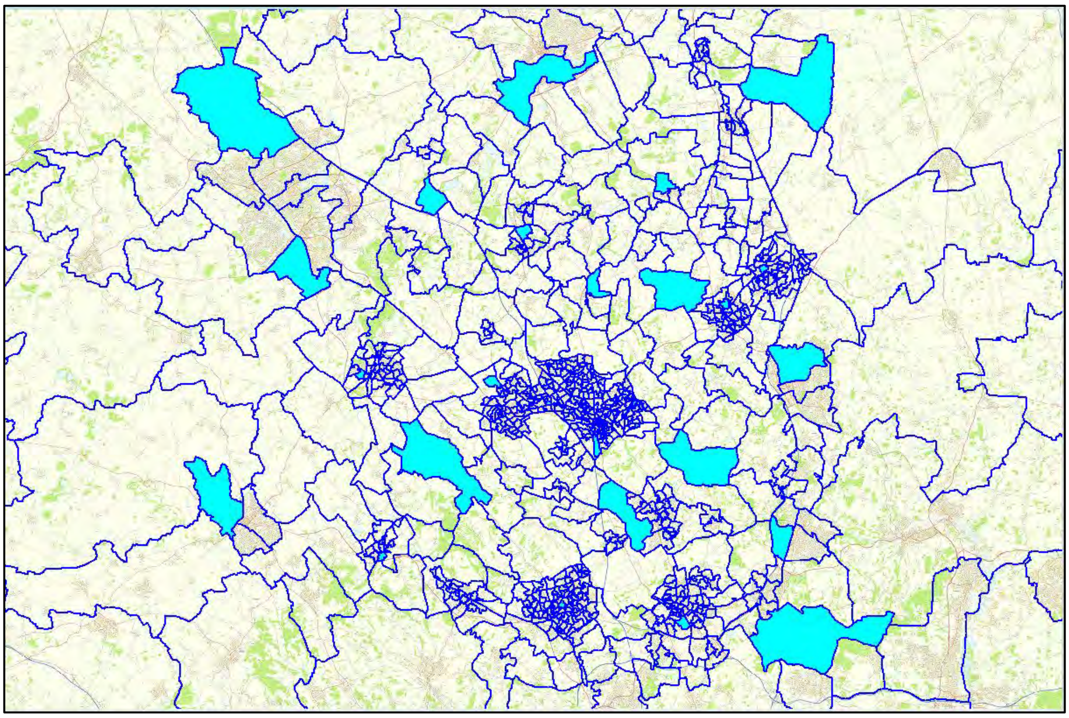

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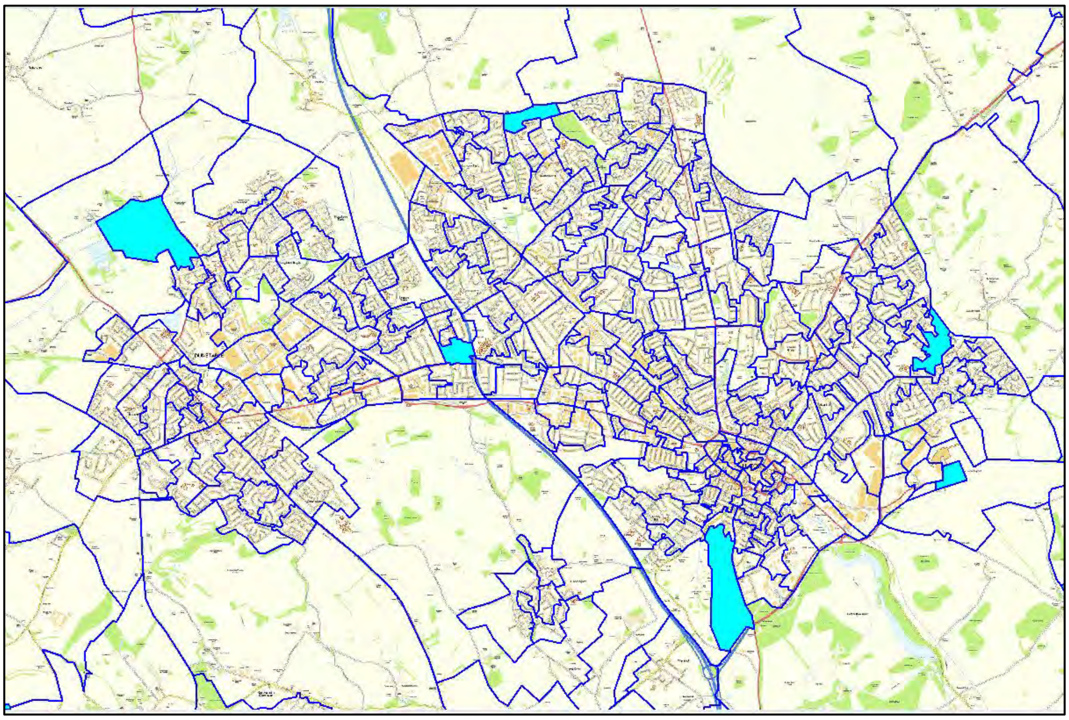
Figure 9.4 Zones Identified for Route Choice Validation: Luton



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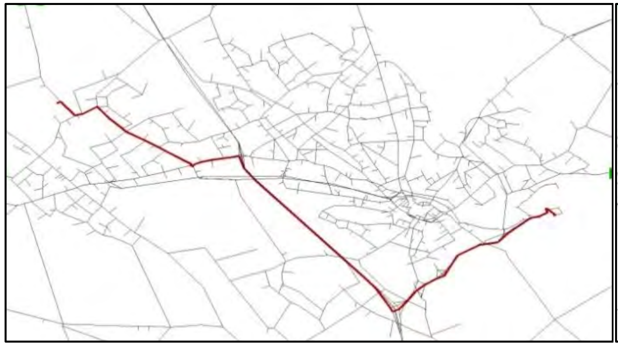
9.3.4 A selection of the routes assessed for car ‘commute’ trips in the AM Peak hour is shown in Figure 9.5 and Figure 9.6. Figure 9.5 shows a selection of routes to / from Luton Airport, with Figure 9.6 showing the same analysis but for longer distance routes. Additional route choice figures are provided in Appendix E.

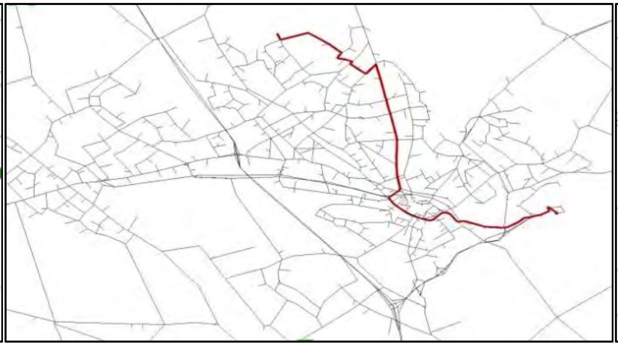
9.3.5 It should be noted that all three time periods have been individually reviewed, based on local knowledge and the directions provided by Google Maps, and indicate logical route choices across all time periods.

Figure 9.5 Selected AM Peak Routeing Validation (Car Commute) – To/From Luton Airport

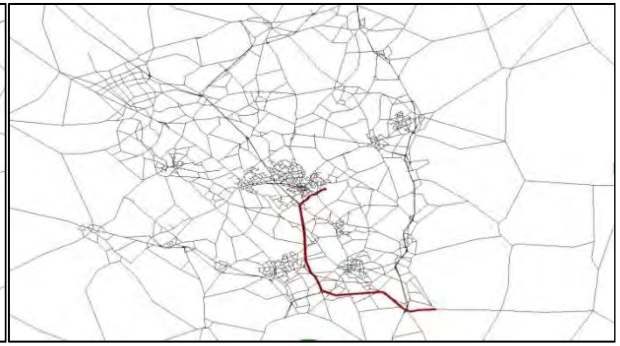
Luton Airport to Luton West



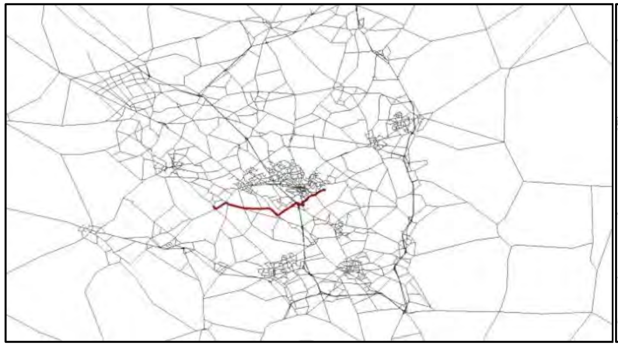
Luton Airport to Luton North



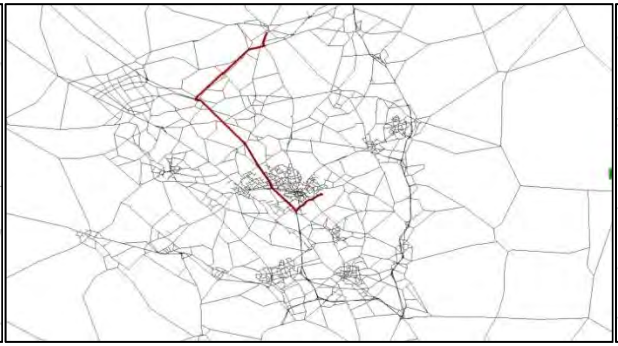
Luton Airport to South East



Luton Airport to Edlesborough



Luton Airport to Bedford



Luton Airport to Letchworth Garden City

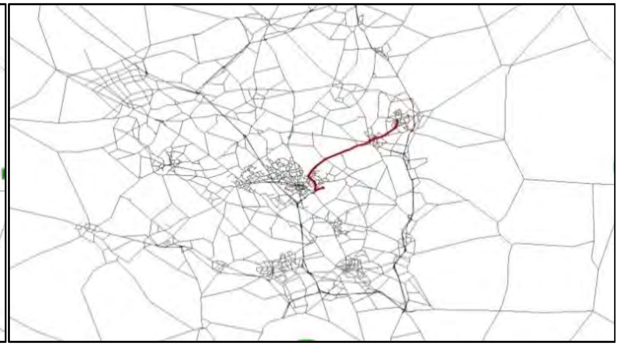
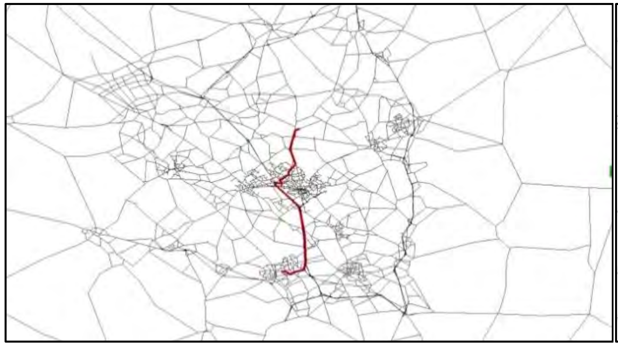
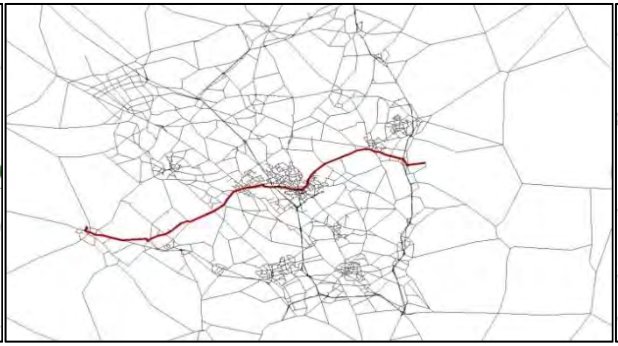


Figure 9.6 Selected AM Peak Routeing Validation (Car Commute) - Long Distance

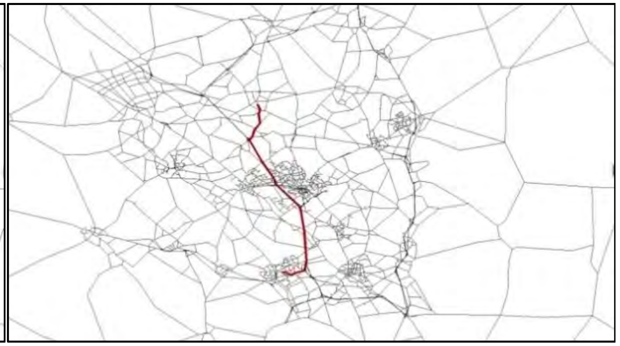
Barton-le-Clay to Hemel Hempstead



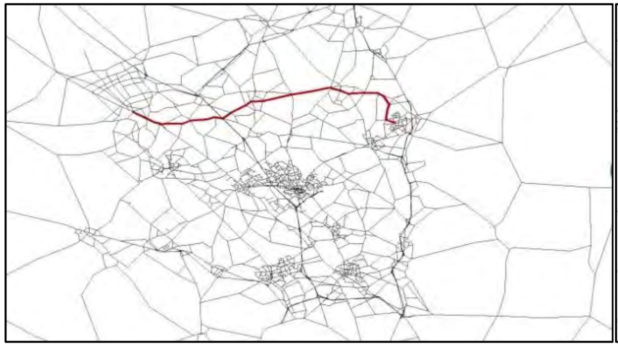
External East to External South West



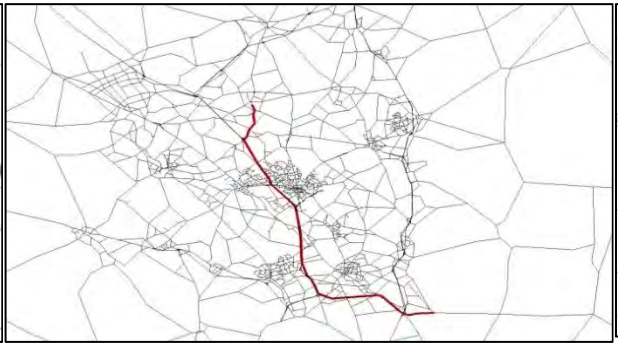
Hemel Hempstead to External North



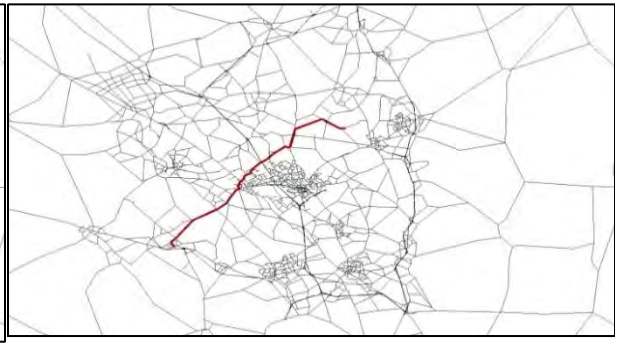
Letchworth GC to Milton Keynes



External North to External South East



Tring to Pirton



10 PRIOR MATRIX ASSIGNMENT RESULTS

10.1 Introduction

10.1.1 This section looks at the performance of the assignment using the prior matrices and the process and impact upon the matrices of matrix estimation. The prior matrices used within this analysis are those derived from the application of sector-based updates, as described in Section 7.8.

10.1.2 Whilst this section does include some comparisons of assigned flows against observed counts for the prior matrix, discussion on the performance of the final calibrated base year model against observed flows and journey times is contained within Section 11.4.

10.2 Trip Matrix Validation

10.2.1 Section 3.1 introduced the WebTAG acceptability guidelines for model performance for the base year model. Table 3.2 lists the set of criteria that were used to test the prior matrices against the observed data.

10.2.2 The proportion of defined screenlines meeting WebTAG criteria using the prior matrix are presented in Table 10.1 for the three modelled periods. Comparing solely total screenline flows removes any potential issues with localised routeing from the assessment of the prior matrices.

10.2.3 This shows that 79%, 76% and 79% of screenlines in the AM Peak, interpeak and PM Peak hours respectively meet WebTAG criteria (the sum of the modelled flows being within 5% of the sum of the counts).

Table 10.1: Screenline Performance (Prior Matrix)

	AM Peak Hour	Interpeak Hour	PM Peak Hour
% Screenline Passes	79%	76%	79%

10.2.4 It is not possible to directly compare the performance of the existing CBLTM highway prior matrices with those developed for the CBLTM-LTN due to difference screenlines being defined in the two models. However, the prior matrix performance shown in Table 10.1 is an improvement on the corresponding performance in the existing CBLTM, where between 40% and 55% of screenlines meet WebTAG criteria in the three modelled hours.

10.2.5 Individual link performance for all observed counts by vehicle type is shown in Table 10.2 for the assignment of the prior matrices. This shows that 63%, 77% and 68% of links meet WebTAG criteria in the AM Peak, interpeak and PM Peak hours respectively.

Table 10.2: Individual Link Performance by Vehicle Type (prior matrix)

Vehicle Type	AM Peak Hour	Interpeak Hour	PM Peak Hour
HGV	99%	99%	99%
LGV	99%	100%	99%
Car	66%	80%	70%
Total	**63%**	**77%**	**68%**

10.2.6 The performance of the prior matrix assignment is below WebTAG acceptability criteria, and as a result matrix estimation has been used to further refine the trip matrices.

10.3 Matrix Estimation Parameters

10.3.1 Matrix estimation has been performed by vehicle type (for cars, LGVs and HGVs separately) by adjusting modelled flows in response to the observed count data.

10.3.2 Calibration screenlines were sub-divided into short-screenlines for this process. As discussed in WebTAG Unit M3.1 §8.3.5 count sites have been grouped and applied at a short-screenline level in order to reduce the chance that large changes between single O-D pairs are made to account for differences between modelled and observed flows that may not be related to deficiencies in the trip matrices (such as errors in modelled routeing).

10.3.3 In terms of the process of matrix estimation, five loops of matrix estimation have been run within the SATURN matrix estimation process. Limiting the number of iterations within matrix estimation is desirable to minimise the possibility of excessive changes to the prior matrices.

10.3.4 In addition to this, the XAMAX parameter within SATURN's matrix estimation process also helps to limit the potential change to the prior matrices. This parameter is the maximum factor that a zone-to-zone movement can be multiplied or divided by during matrix estimation.

10.3.5 In SATURN, the SATPIJA and SATME2 processes were used to estimate the demand matrices. SATPIJA analyses the assignment to calculate factors which feed into SATME2. SATME2 then seeks to improve the fit between observed and modelled flows by factoring individual cells in the prior matrix.

10.3.6 Matrix estimation is an iterative process, whereby new SATPIJA factors are calculated during each assignment to feed back into SATME2, with the updated matrix used in successive iterations. This process of reassignment and adjusting the trip matrix is continued for five iterations.

10.3.7 Table 10.3 presents the key parameters and values applied during matrix estimation. These values are identical for all vehicle classes and time periods.

Table 10.3: Matrix Estimation Parameters (all User Classes, all Time Periods)

Parameter	Definition	Default Value	Actual Value
EPSILN	This value sets the threshold for convergence i.e. the ME run ceases if all observed and estimated flows are within EPSILN (in %) of one another.	0.01	0.01
ITERMX	This value caps the number of iterations within each ME run.	30	30
XAMAX	This factor constrains the balancing factor associated to each count to lie within the range of [1/XAMAX, XAMAX]. This feature is in place to limit the distortion from the ME process.	5.0	3.5

10.3.8 Airport demand to and from Luton Airport has been calculated separately from the rest of the travel demand, and is based on observed data. Therefore, trips with an origin or destination at Luton Airport were “frozen” within matrix estimation, i.e. they were not changed in response to the performance against count data.

10.4 Trip Matrix Estimation: Matrix Changes

10.4.1 WebTAG Unit M3.1 gives four measures against which the changes applied to the prior matrices due to matrix estimation are measures. These were given in Table 3.3 and consider the matrix cell value changes, the matrix trip-end changes, the matrix trip-length changes, and changes to the matrices at a sector level.

10.4.2 WebTAG Unit M3.1 §8.3.15 states that any exceedance of the criteria should be assessed, and if the measure is statistically significant that the use of the prior trip matrix should be reconsidered.

Matrix Cell Changes

10.4.3 Table 10.4 states the regression statistics between the prior and post-matrix estimation matrices for the three modelled hours and by vehicle type for all matrix movements. This table shows that all vehicles pass the significance criteria set out in Table 3.2 for all three time periods.

Table 10.4: Regression Statistics for Matrix Zonal Changes: Whole Matrix

Time Period	Vehicle Type	Slope	R^2
AM Peak	Car	1.00	1.00
	LGV	1.00	1.00
	HGV	1.00	1.00
Interpeak	Car	1.00	1.00
	LGV	1.00	1.00
	HGV	1.00	1.00
PM Peak	Car	1.00	1.00
	LGV	1.00	1.00
	HGV	1.00	1.00

10.4.4 The zonal cells analysis for the ‘whole matrix’ was repeated to only include those movements with an origin within the ‘internal area’. The ‘internal area’ defined for this analysis is that broadly covering the simulation network coding, and this roughly equates to Luton Borough, Central Bedfordshire, North Hertfordshire, St Albans District and Dacorum.

10.4.5 Note that in assessing the ‘internal area’, and not assessing the entire model area, this analysis exceeds WebTAG requirements; however, however this analysis highlights the changes to the matrices within the area of interest. Table 10.5 shows the regression statistics for trips with an origin in the ‘internal area’ between the prior and post-matrix estimation matrices for the three modelled hours and by vehicle type.

Table 10.5: Regression Statistics for Matrix Zonal Changes: Internal Origins

Time Period	Vehicle Type	Slope	R^2
AM Peak	Car	1.00	0.99
	LGV	1.00	0.97
	HGV	1.00	0.74
Interpeak	Car	1.00	1.00
	LGV	1.00	0.99
	HGV	1.05	0.63
PM Peak	Car	1.00	0.99
	LGV	1.01	0.96
	HGV	1.12	0.62

10.4.6 Table 10.5 shows that cars and LGVs meet the WebTAG significance criteria set out in Table 3.2 for all three time periods within the 'internal area'. The HGV matrices exceed the R^2 criteria measures in all three time periods and the slope criteria in the interpeak and PM Peak hours. As stated previously, there is additional uncertainty in HGV movements within the highway matrices due to the underlying data sources, and this analysis shows that matrix estimation is making larger changes to this vehicle class compared with other vehicle classes.

10.4.7 Section A1 of Appendix A provide the matrix scatterplots comparing the prior and post-matrix estimation matrices for trips with an origin in the 'internal area' in the AM Peak, interpeak and PM Peak hours for each vehicle type.

Matrix Trip-End Changes

10.4.8 The second of these matrix change criteria is to consider the change in the matrix trip-ends from the prior matrices to the matrices resulting from matrix estimation. For this comparison the regression slope of best fit should be between 0.99 and 1.01, with an intercept near 0 and an R^2 value in excess of 0.98.

10.4.9 Table 3.2 shows the significance criteria for matrix zonal trip ends as set out in WebTAG Unit M3.1 §8.3. It can be seen from Table 10.6 that the R^2 significance criteria measure was met for all time periods and for all vehicle types when considering the whole matrix.

Table 10.6: Regression Statistics for Matrix Zonal Changes: Whole Matrix

		Origin Trip-ends		Destination Trip-ends	
Time Period	Vehicle Type	Slope	R^2	Slope	R^2
AM Peak	Car	1.00	1.00	1.00	1.00
	LGV	1.00	1.00	1.00	1.00
	HGV	1.00	1.00	1.00	1.00
Interpeak	Car	1.00	1.00	1.00	1.00
	LGV	1.00	1.00	1.00	1.00
	HGV	1.00	1.00	1.00	1.00
PM Peak	Car	1.00	1.00	1.00	1.00
	LGV	1.00	1.00	1.00	1.00
	HGV	1.00	1.00	1.00	1.00

10.4.10 Analogous to the analysis of matrix cell changes, this analysis was additionally performed on the ‘internal area’, which is beyond WebTAG requirements, with the results of this analysis shown in Table 10.7.

Table 10.7: Regression Statistics for Matrix Zonal Changes: Internal Area

		Origin Trip-ends		Destination Trip-ends	
Time Period	Vehicle Type	Slope	R^2	Slope	R^2
AM Peak	Car	1.00	0.97	1.02	0.95
	LGV	0.99	0.96	1.00	0.97
	HGV	0.97	0.86	1.00	0.89
Interpeak	Car	1.00	0.98	1.00	0.98
	LGV	1.01	0.98	1.01	0.98
	HGV	1.07	0.71	1.08	0.77
PM Peak	Car	1.02	0.97	1.00	0.98
	LGV	1.04	0.94	1.01	0.96
	HGV	1.07	0.71	1.06	0.85

10.4.11 Assessing the changes in trip-ends within the ‘internal area’ only, it can be seen from Table 10.7 that both the R^2 and slope criteria measures were close to or marginally outside the WebTAG criteria for cars and LGVs, but were generally outside the criteria for HGVs. As stated previously, there is less confidence on the demand data for HGV traffic, and therefore we expect to see larger changes to the HGV matrices through matrix estimation.

10.4.12 Section A2 of Appendix A provides scatterplots of trip-end changes by time period and vehicle class for the ‘internal area’.

Trip Length Distribution

10.4.13 The third assessment of the impact of matrix estimation on the prior matrices relates to changes in the trip-length profile before and after matrix estimation. The criterion for this measure is that the mean trip-length and standard deviation about this mean should not change by more than 5% due to matrix estimation.

10.4.14 Table 10.8 shows the mean trip-lengths and standard deviations in trip length by vehicle type and by time period for the prior matrices and the matrices resulting from matrix estimation for trips with an origin in the ‘internal area’.

10.4.15 Mean trip-lengths change by more than 5% between the prior and post-matrix estimation matrices for HGVs in both the interpeak and PM Peak hours. The standard deviation also exceeds 5% for HGVs in the PM Peak hour. This marginally exceeds WebTAG guidance; however, as stated previously, this is expected given the relative confidence in the HGV demand data.

10.4.16 It is worth noting that in general the average trip-length is reducing through the application of matrix estimation. This is the expected result as the matrix estimation process tends to add shorter trips in order to satisfy the count constraints. The prior and post matrix estimated matrices therefore share good consistency with observed trip-length patterns from NTS and the Mobile Network Data within the ‘internal area’.

Table 10.8: Changes in Matrix Trip-length Averages and Standard Deviations

Modelled Hour	Vehicle Type	Measure	Prior	Post-ME	% Diff
AM Peak	Car	Mean	15.1	15.2	0.5%
		St Dev	23.5	23.6	0.5%
	LGV	Mean	22.5	22.4	-0.4%
		St Dev	29.5	29.4	-0.3%
	HGV	Mean	50.5	50.5	-0.1%
		St Dev	59.1	58.1	-1.6%
	All	**Mean**	**16.2**	**16.3**	**0.7%**
		St Dev	**25.4**	**25.6**	**0.6%**
Interpeak	Car	Mean	14.2	14.0	-1.2%
		St Dev	30.5	29.8	-2.1%
	LGV	Mean	20.8	20.3	-2.3%
		St Dev	31.8	31.1	-2.1%
	HGV	Mean	52.4	48.5	-7.4%
		St Dev	65.7	62.8	-4.5%
	All	**Mean**	**16.0**	**15.7**	**-1.8%**
		St Dev	**32.7**	**31.9**	**-2.5%**
PM Peak	Car	Mean	16.0	16.0	-0.1%
		St Dev	32.4	31.7	-2.0%
	LGV	Mean	21.3	20.7	-2.6%
		St Dev	31.1	30.5	-2.0%
	HGV	Mean	53.2	48.7	-8.5%
		St Dev	66.7	61.8	-7.4%
	All	**Mean**	**16.8**	**16.7**	**-0.6%**
		St Dev	**33.0**	**32.3**	**-2.4%**

10.4.17 Figures showing the trip-length profiles for ‘internal area’ origins by time period and vehicle class are included in Section A3 of Appendix A.

Sector to Sector Level Matrices

10.4.18 This final piece of matrix analysis is to consider the changes matrix estimation makes to prior matrix at a sector level. WebTAG Unit M3.1 states that the changes in sector-to-sector demand totals should be less than 5% although it does not give guidance as to how to define your sector system. The results of this analysis can be sensitive to the definition of the sector system: the more detailed the sector system the more likely it is that sector-to-sector movements change by more than 5%.

10.4.19 The CBLTM-LTN zones were disaggregated into 20 sectors for the purposes of matrix adjustment, with the defined sectors listed in Table 10.9.

Table 10.9: CBLTM-LTN, Matrix Estimation Sectors

Luton Borough	Surrounding Areas	External
Luton East	Dunstable and South C.Beds.	Rest of Hertfordshire
Luton North-west	Leighton Buzzard and West C.Beds.	Rest of East Anglia
Luton South	Ampthill-Flitwick and Central C.Cbeds.	Bucks Oxfordshire Northants
Luton Airport (fixed)	Sandy-Biggleswade and East C.Beds.	London
	Bedford	External North
	Milton Keynes	External South
	Dacorum	External West
	St Albans	
	North Hertfordshire	

10.4.20 In analysing these results it was found that a significant proportion of sector-to-sector movements changed by more than 5%, but the absolute change in those movements were relatively small. With the 20 sector system there remain a number of sector-to-sector movements that have little demand within the matrices and therefore a relatively modest change in the demand for these movements can result in a large percentage change, particularly for LGV and HGV matrices that contain a smaller number of trips than the car matrices.

10.4.21 In order to address this, the WebTAG criterion was adjusted to identify those sector movements which change by more than 5% and 100 vehicles. Table 10.10 shows the sector-to-sector movements meeting these criteria in the AM Peak, interpeak and PM Peak hours for each time period, along with percentage of sector-sector movements meeting these criteria for all three vehicle classes combined.

Table 10.10: Sector-to-Sector Movement Pass Rate by Vehicle Class

Vehicle Class	AM Peak	Interpeak	PM Peak
Car (400 movements)	97.8%	99.0%	95.0%
LGV (400 movements)	100%	100%	100%
HGV (400 movements)	100%	100%	100%
All Vehicles Classes (1,200 movements)	**99.3%**	**99.7%**	**98.3%**

Using adjusted WebTAG Criterion

10.4.22 Tables showing the change in the demand matrices at a sector-level are shown in Section A4 of Appendix A. Table A.1, Table A.2 and Table A.3, which report on the car matrices, show that the majority of sector-to-sector movements do not have changes in demand of more than 5% and 100 vehicles due to matrix estimation. Where failures do occur, most failures are less than ±25% and mainly in the AM Peak and PM Peak hours.

10.4.23 Table A.4, Table A.5 and Table A.6 (for LGV) and Table A.7, Table A.8, and Table A.9 (for HGV) show that no sector-to-sector movements have demand changes by more than 5% and 100 vehicles due to matrix estimation, reflecting the relative sparsity of the freight matrices when compared with car. In considering the greater uncertainty in the freight matrices (an issue common with most, if not all UK transport models), the scale of change is reassuring, often less than 15%.

11 ASSIGNMENT CALIBRATION AND VALIDATION

11.1 Introduction

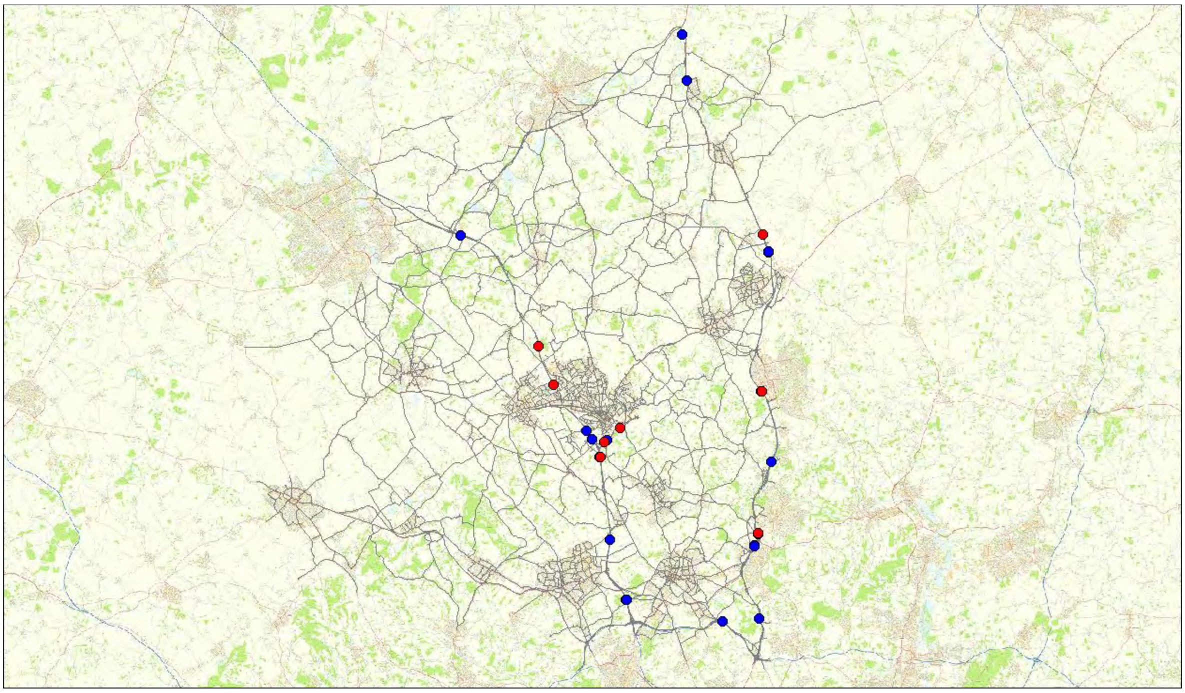
11.1.1 This section details the post-matrix estimation performance of the model compared with screenlines / cordons, individual link counts and journey time calibration data.

11.1.2 As mentioned in Section 10, the prior matrix performance does not meet WebTAG guidance levels, as specified in Table 3.1. Therefore, matrix estimation was undertaken in order to further refine the trip matrices and improve model performance compared against the observed data.

11.1.3 19 bi-directional screenlines and cordons have been defined in the CBLTM-LTN base year model as shown in Figure 5.3 and Figure 5.4. Screenlines and cordons were classified as either calibration or validation, as set out in WebTAG Unit M3.1.

11.1.4 A number of individual calibration and validation counts, not included as part of a screenline / cordon, were selected on the SRN. These counts included counts on the M1, A1 (M) and the M25. Figure 11.1 shows the location of counts on the SRN, with blue counts showing where locations were selected for calibration and red counts those chosen as validation.

Figure 11.1 SRN Count Locations (Calibration=blue | Validation=Red)



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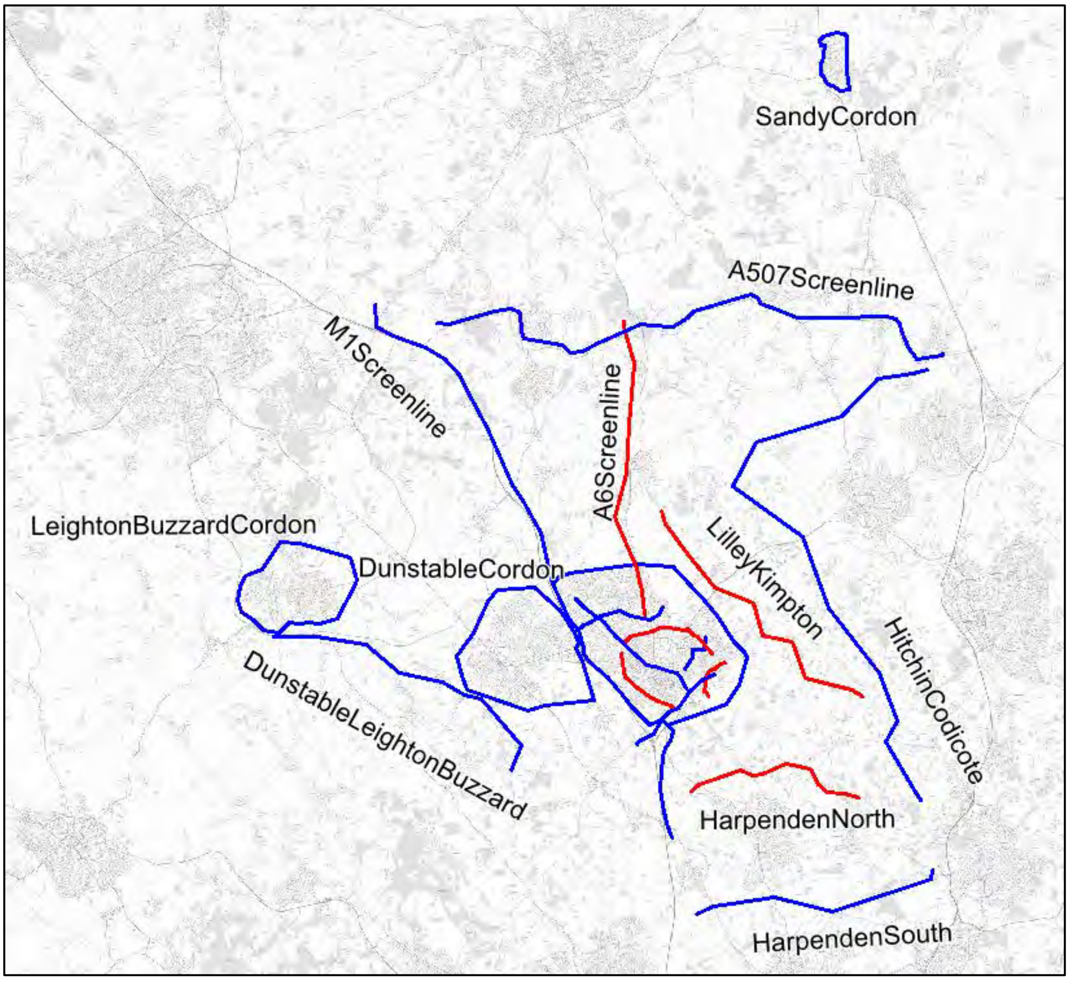
11.2 Model Assignment Tests

11.2.1 Two matrix estimation assignments were performed:

- an 'Initial Assignment Calibration'; and
- a 'Final Assignment Calibration'.

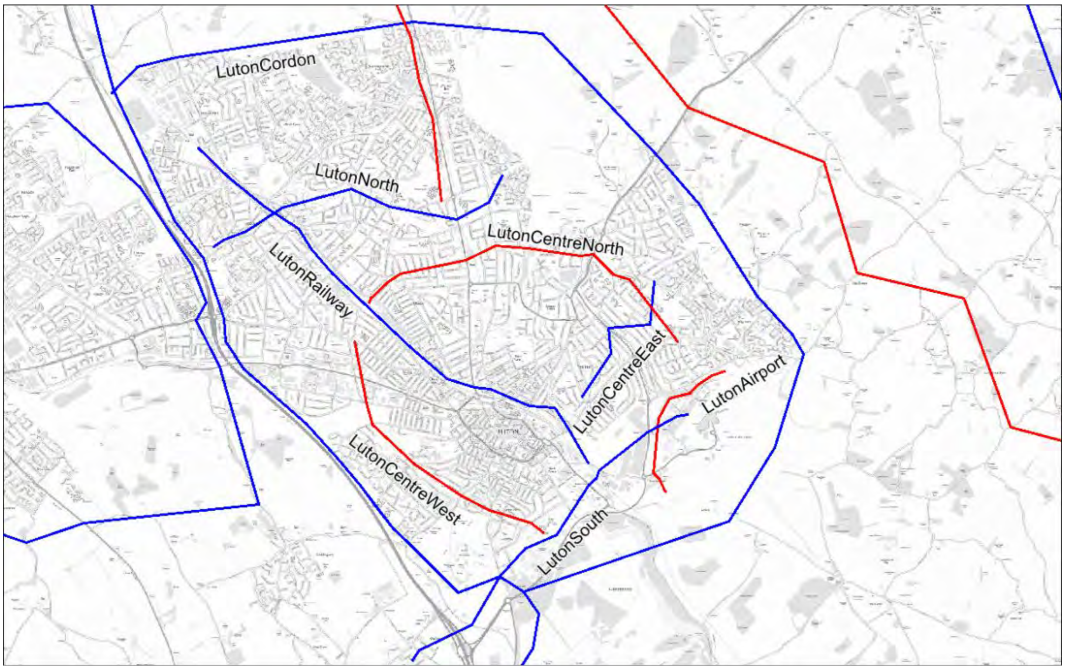
11.2.2 The 'Initial Assignment Calibration' assignment identified and set aside six screenlines for validation, roughly a third of the total number of screenlines defined. The remaining 13 screenlines were used as calibration screenlines and were included in the matrix estimation process, following WebTAG guidance. These screenlines and their classification as calibration or validation is shown in Figure 11.2 and Figure 11.3.

Figure 11.2 'Initial Assignment Calibration' Screenline Classification (Calibration=blue | Validation=Red) – Overview



Map contains Ordnance Survey data © Crown copyright and database right 2020

Figure 11.3 'Initial Assignment Calibration' Screenline Classification (Calibration=blue | Validation=Red) – Luton



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11.2.3 Section 11.3 provides the model performance by screenline, individual link count and journey time route for this 'Initial Assignment Calibration'.

11.2.4 The 'Final Assignment Calibration' included all screenlines as calibration screenlines, except for the 'Luton Airport Screenline', with no change to the classification of counts on the SRN. The performance of the model against observed count and journey time data, and the changes in the assignment matrices by including the majority of screenlines within the calibration process was compared and analysed, and is shown in Sections 11.3 and 11.4.

11.2.5 This analysis showed that by including the majority of screenlines as calibration the matrix estimation process, this primarily adjusted the matrices for movements within Luton Borough. Trips within Luton Borough, due to their short trip-length, are likely to be based on the synthetic matrices rather than the observed MND. It was therefore concluded that this process did not significantly distort the assignment matrices and provided a more robust CBLTM-LTN base year highway model.

11.2.6 The 'Luton Airport Screenline' was not included as a calibration screenline in either assignment test as trips to and from Luton Airport were calculated independently and 'frozen' during the matrix estimation process to ensure that the original volumes and distributions were retained. Section 7.3 details the derivation of Luton Airport Demand in more detail.

11.2.7 All counts used within matrix estimation were combined into short-screenline constraints rather than using individual counts as constraints (as discussed in Section 10.3).

11.3 Initial Assignment Calibration

11.3.1 This section considers the performance against traffic flow and journey time data after matrix estimation for the three modelled hours. Within this analysis, of the 19 screenlines and cordons defined, 13 were identified as calibration screenlines in the matrix estimation process with six screenlines set aside for validation.

Screenline Performance

11.3.2 Table 11.1 displays the post-matrix estimation screenline model performance by modelled hour. For each modelled hour two statistics are given: firstly the aggregate difference between observed and modelled flows across all screenlines; and secondly the percentage of screenlines that pass the criteria set out in Table 3.1. This analysis is based on total vehicle flows.

Table 11.1: Screenline Calibration and Validation Performance (Total Vehicle Flows)

	AM Peak Hour		Interpeak Hour		PM Peak Hour	
	Agg. Flows	ScnLine passes	Agg. Flows	ScnLine passes	Agg. Flows	ScnLine passes
Calibration	-0.6%	96%	-0.2%	100%	-0.4%	89%
Validation	-0.5%	58%	-1.5%	67%	-0.9%	58%
Total	**-0.7%**	**84%**	**-0.5%**	**90%**	**-0.5%**	**79%**

11.3.3 Table 11.1 shows that across the CBLTM-LTN network 84%, 90% and 79% of screenlines meet the specified criteria set out in Table 3.1 for the AM Peak, interpeak and PM Peak hours respectively. This table also shows that, in aggregate terms, there is around -0.5% less traffic in the model than observed at count data locations.

11.3.4 WebTAG states that the screenline criterion should be met for “all or nearly all screenlines”, and whilst not putting a numeric value on this criterion, a pass rate of 90% or more is considered a reasonable target given the methodologies used to develop models of this type and scale. Based on this the model meets this target in the interpeak hour and falls short in the AM Peak and PM Peak hours.

11.3.5 As expected, the calibration screenlines, included in the matrix estimation process, perform better than the validation counts that were not included in the matrix estimation process.

Link Flow Performance

11.3.6 Table 11.2 shows the percentages of links that pass the 'flow' or 'GEH' criteria defined within WebTAG (see Table 3.1) within the CBLTM-LTN base year highway model in the three modelled hours, based on total vehicle flows.

Table 11.2: Link Flow Performance (Total Vehicle Flow)

		AM Peak Hour	Interpeak Hour	PM Peak Hour
	No. of Links	% passes	% passes	% passes
Calibration	253	85%	96%	87%
Validation	98	63%	77%	71%
Total	**351**	**79%**	**91%**	**83%**

11.3.7 WebTAG guidelines are that 85% or more of individual counts meet the 'flow' or 'GEH' criteria within the model. From Table 11.2, 79%, 91% and 83% of individual counts meet the 'flow' criteria in the AM Peak, interpeak and PM Peak hours respectively.

11.3.8 As required within WebTAG, the link flow performance for car-only traffic, excluding LGV and HGV demand, has also been reported. These results are given in Table 11.3 and show that there is little difference between the link performance with all vehicle types and considering car traffic only in terms of overall performance.

Table 11.3: Link Flow Performance (Car Traffic Only)

		AM Peak Hour	Interpeak Hour	PM Peak Hour
	No. of Links	% passes	% passes	% passes
Calibration	253	88%	96%	89%
Validation	98	64%	79%	70%
Total	**351**	**81%**	**91%**	**84%**

11.3.9 For completeness, the same link flow performance data are provided for LGV and HGV traffic in Table 11.4 and Table 11.5. These statistics reflect the WebTAG flow criteria set out in Table 3.1, and therefore the criterion often applied is that the modelled flows are within 100 vehicles of the observed data, as HGV and LGV flows tend to be low relative to car. As such the reported statistics are consequently higher than those in Table 11.2 and Table 11.3.

Table 11.4: Link Flow Performance (LGV Traffic Only)

		AM Peak Hour	Interpeak Hour	PM Peak Hour
	No. of Links	% passes	% passes	% passes
Calibration	253	100%	100%	100%
Validation	98	98%	100%	98%
Total	**351**	99%	100%	99%

Table 11.5: Link Flow Performance (HGV Traffic Only)

		AM Peak Hour	Interpeak Hour	PM Peak Hour
	No. of Links	% passes	% passes	% passes
Calibration	253	100%	100%	100%
Validation	98	98%	99%	98%
Total	**351**	99%	100%	99%

Journey Time Validation

11.3.10 The final measure against which to assess the assignment performance is the journey time validation. The WebTAG guidelines for comparing modelled journey times with observed data are detailed in Table 3.1, but in summary, the modelled times are required to be within 15% of the observed journey times. Table 11.6 gives the performance of the highway assignment in the three modelled hours broken down by journey times on the Strategic Road Network (SRN), and routes within Central Bedfordshire, Luton Borough and Hertfordshire.

11.3.11 Journey time data were not collected for the interpeak hour for Luton Borough. Further details on the observed journey time data can be found in Section 5.4.

11.3.12 Table 11.6 shows that taking all journey time routes defined in the model, 88%, 92% and 85% of these routes meet WebTAG criteria in the AM Peak, interpeak and PM Peak hours respectively. These are at or above the 85% of journey time routes set out in WebTAG Unit M3.1 and therefore demonstrate that the model performs well against observed journey time data.

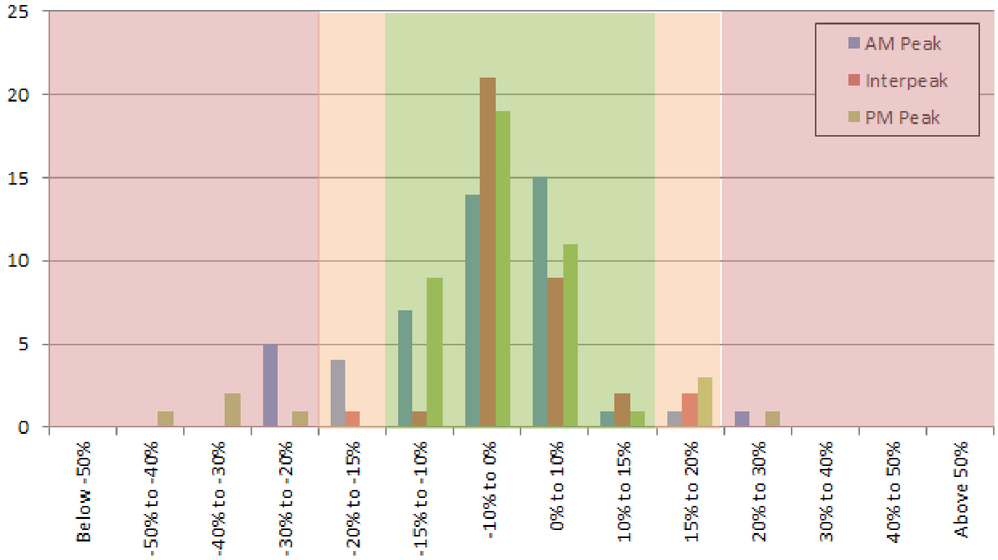
Table 11.6: Journey Time Validation Summary

	AM Peak Hour		Interpeak Hour		PM Peak Hour	
	Routes	%Pass	Routes	%Pass	Routes	%Pass
SRN	10	80%	10	90%	10	70%
Central Beds	18	83%	18	89%	18	94%
Luton	12	100%	0	-	12	83%
Hertfordshire	8	88%	8	100%	8	88%
Total	**48**	**88%**	**36**	**92%**	**48**	**85%**

11.3.13 In order to assess if there is any bias in the modelled journey times in comparison with the observed data, for example that the model is generally slower or faster than the observed data, Figure 11.4 shows the distribution of journey time validation results in the three modelled hours. The performance of the interpeak model implies that the fixed speeds and speed flow curves used in the model are broadly unbiased.

11.3.14 In this figure the area shaded green represents those journey times that fall within WebTAG criteria of ±15%, the orange area shows those that marginally fail to meet this criterion but are within ±20%, with the red shaded areas being those journey time routes outside ±20% of the observed data.

Figure 11.4 Journey Time Distribution by Percentage Difference (Modelled vs. Observed)



11.3.15 From Figure 11.4 it can be seen that the majority of journey time routes fall within the green shaded area, as reported in Table 11.6, with a limited number of routes outside of ±20% of the observed data. This figure also shows that the journey time validation results are broadly evenly distributed about the centre value of matching the observed journey time data.

11.3.16 This shows that there is not a significant bias in the modelled journey times towards being too fast or too slow compared with the observed data. If there is a small bias then it is that the model is slightly faster than observed.

11.3.17 In addition to the journey time validation, "reasonableness" checks on the locations of delays within the highway assignments were undertaken as part of the model calibration process. This process highlighted excessive delays in the model, but was also an important tool for improving the performance of the modelled flows and journey times against observed data.

11.4 Final Assignment Calibration

11.4.1 This section considers the screenline performance after matrix estimation for the three modelled hours. Of the 19 screenlines and cordons, 18 were used as calibration screenlines in the matrix estimation process with 'Luton Airport Screenline' the only screenline not included in the calibration. The classifications of calibration and validation counts on the

Strategic Road Network are unchanged from those assumed within the 'Initial Assignment Calibration'.

Screenline Performance

11.4.2 Table 11.7 displays the post matrix estimation screenline performance by modelled hour for the 'Final Assignment Calibration' test. As described in Section 11.3, for each modelled hour two statistics are given: firstly the aggregate difference between observed and modelled flows across all screenlines; and secondly the percentage of screenlines that pass the criteria set out in Table 3.1. This analysis is based on total vehicle flows.

Table 11.7: Screenline Calibration and Validation Performance (Total Vehicle Flows)

	AM Peak Hour		Interpeak Hour		PM Peak Hour	
	Agg. Flows	ScnLine passes	Agg. Flows	Agg. Flows	ScnLine passes	Agg. Flows
Calibration	-0.6%	97%	-0.4%	94%	-0.6%	89%
Validation	2.7%	50%	1.2%	100%	1.9%	50%
Total	**-0.2%**	**95%**	**0.0%**	**95%**	**-0.1%**	**87%**

11.4.3 Table 11.7 shows that across the CBLTM-LTN network 95%, 95% and 87% of screenlines meet the specified criteria set out in Table 3.1 for the AM Peak, interpeak and PM Peak hours respectively. These results equate to two failures in both the AM Peak and interpeak models, and five in the PM Peak hour out of a total of 38 screenlines. This table also suggest that in aggregate terms there is around -0.1% less traffic in the model than observed at count data locations, and that no systematic bias was identifiable at this level.

11.4.4 WebTAG states that the screenline criterion should be met for "all or nearly all screenlines", and as in Section 11.3 a pass rate of 90% or more considered a reasonable target. Based on this, the model meets this target in the AM Peak and interpeak hours and is marginally below this target in the PM Peak hour.

11.4.5 In terms of individual screenline performance Table 11.8 provides the performance of individual screenlines by direction and time period, and specifies the number of individual counts forming each screenline and the proportion of those links which meet WebTAG criteria. Further details on the performance of the model at a screenline level can be found in Appendix B.

11.4.6 The 'Luton Airport Screenline', which was retained as validation screenline (and highlighted orange), fails in one direction in both the AM Peak hour (where modelled flows are 6.3% below observed in the inbound direction) and PM Peak hour (where modelled flows are 11.4% below observed in the outbound direction).

Table 11.8: Individual Screenline Performance by Direction

Screenline	Direction	Counts	AM Peak Hour		Interpeak Hour		PM Peak Hour	
			Screenline	%Links	Screenline	% Links	Screenline	% Links
M1 Screenline	Eastbound	20	✓	75%	✓	85%	✓	70%
excluding SRN flows		19	✓	74%	✓	84%	✓	68%
M1 Screenline	Westbound	20	✓	80%	✓	90%	✓	85%
excluding SRN flows		19	✓	79%	✓	89%	✓	84%
A6 Screenline	Eastbound	9	✓	67%	✓	100%	✓	56%
A6 Screenline	Westbound	9	✓	56%	✓	78%	✓	67%
A507 Screenline	Northbound	14	✓	100%	✓	100%	✓	86%
A507 Screenline	Southbound	14	✓	71%	✓	100%	✓	100%
Luton Cordon	Inbound	13	✓	69%	✓	77%	✓	69%
Luton Cordon	Outbound	13	✓	77%	✓	85%	✓	85%
Luton Centre West	Eastbound	9	✓	89%	✓	100%	✓	78%
Luton Centre West	Westbound	9	✓	89%	✓	100%	✓	89%
Luton Railway	Eastbound	11	✓	82%	✓	73%	×	45%
Luton Railway	Westbound	12	✓	83%	✓	100%	✓	92%
Luton Centre East	Northbound	5	✓	100%	✓	100%	✓	100%
Luton Centre East	Southbound	5	×	60%	✓	100%	✓	80%
Luton South	Northbound	7	✓	43%	✓	71%	✓	100%
Luton South	Southbound	7	✓	100%	✓	100%	✓	100%
Luton Centre North	Northbound	9	✓	78%	✓	89%	✓	89%
Luton Centre North	Southbound	9	✓	67%	✓	100%	✓	100%
Luton North	Northbound	8	✓	75%	✓	75%	×	63%
Luton North	Southbound	8	✓	75%	✓	100%	✓	100%
Luton Airport	Inbound	3	×	67%	✓	67%	✓	67%
Luton Airport	Outbound	3	✓	100%	✓	100%	×	67%

Screenline	Direction	Counts	AM Peak Hour		Interpeak Hour		PM Peak Hour	
			Screenline	%Links	Screenline	% Links	Screenline	% Links
Dunstable Cordon	Inbound	12	✓	92%	✓	92%	✓	75%
excluding SRN flows		10	✓	90%	✓	90%	×	70%
Dunstable Cordon	Outbound	12	✓	83%	✓	92%	✓	83%
excluding SRN flows		10	✓	80%	✓	90%	✓	80%
Lilley / Kimpton	Eastbound	7	✓	100%	✓	100%	✓	100%
Lilley / Kimpton	Westbound	7	✓	100%	✓	100%	✓	100%
Hitchin / Codicote	Eastbound	11	✓	64%	✓	100%	✓	100%
Hitchin / Codicote	Westbound	11	✓	100%	✓	100%	✓	73%
Harpenden North	Northbound	5	✓	100%	×	100%	×	100%
Harpenden North	Southbound	5	✓	100%	×	80%	✓	100%
Harpenden South	Northbound	4	✓	100%	✓	100%	×	75%
Harpenden South	Southbound	4	✓	100%	✓	100%	✓	100%
Leighton Buzzard Cordon	Inbound	10	✓	90%	✓	100%	✓	80%
Leighton Buzzard Cordon	Outbound	10	✓	60%	✓	100%	✓	70%
Dunstable / Leighton Buzzard	Northbound	9	✓	100%	✓	100%	✓	78%
Dunstable / Leighton Buzzard	Southbound	9	✓	89%	✓	100%	✓	100%
Sandy Cordon	Inbound	5	✓	100%	✓	100%	✓	100%
Sandy Cordon	Outbound	5	✓	100%	✓	100%	✓	100%
Total		**343**	**95%**	**85%**	**95%**	**95%**	**87%**	**86%**

Link Flow Performance

11.4.7 There were 379 individual link counts identified as part of the calibration and validation of the CBLTM-LTN base year highway model. Table 11.9 shows the percentages of links that pass the 'flow' or 'GEH' criteria defined within WebTAG (see Table 3.1) within the CBLTM-LTN base year model in the three modelled hours, based on total vehicle flows. These results show a marked improvement in the model performance compared with the 'Initial Assignment Calibration' test.

Table 11.9: Link Flow Performance (Total Vehicle Flow)

		AM Peak Hour	Interpeak Hour	PM Peak Hour
	No. of Links	% passes	% passes	% passes
Calibration	331	85%	95%	87%
Validation	20	85%	85%	80%
Total	**351**	**85%**	**95%**	**86%**

11.4.8 WebTAG guidelines are that 85% or more of individual counts meet the 'flow' or 'GEH' criteria. From Table 11.9, 85%, 95% and 86% of individual counts meet at least one of these criteria in the AM Peak, interpeak and PM Peak hours respectively, and this either meets or exceeds WebTAG guidelines.

11.4.9 The link flow performance for car-only traffic, excluding LGV and HGV demand, has also been reported. These results are given in Table 11.10 and show, analogous to the 'Initial Assignment Calibration' test, that there is little difference between the link performance with all vehicle types and considering car traffic only both in terms of overall performance.

Table 11.10: Link Flow Performance (Car Traffic Only)

		AM Peak Hour	Interpeak Hour	PM Peak Hour
	No. of Links	% passes	% passes	% passes
Calibration	331	88%	96%	89%
Validation	20	65%	65%	70%
Total	**351**	**86%**	**94%**	**87%**

11.4.10 Again, for completeness, the same link flow performance data are provided for LGV and HGV in Table 11.11 and Table 11.12. As stated previously, as the observed flows for HGV and LGV traffic are generally lower than those observed for car traffic, in the majority of cases the WebTAG criterion applied is that the modelled flow is within 100 vehicles of the observed data.

Table 11.11: Link Flow Performance (LGV Traffic Only)

		AM Peak Hour	Interpeak Hour	PM Peak Hour
	No. of Links	% passes	% passes	% passes
Calibration	331	100%	100%	100%
Validation	20	90%	100%	90%
Total	**351**	**99%**	**100%**	**99%**

Table 11.12: Link Flow Performance (HGV Traffic Only)

		AM Peak Hour	Interpeak Hour	PM Peak Hour
	No. of Links	% passes	% passes	% passes
Calibration	331	100%	100%	100%
Validation	20	90%	95%	90%
Total	**351**	**99%**	**100%**	**99%**

11.4.11 Table 11.13 displays the individual link performance for those counts not included in one of the defined screenlines for total traffic flows. Table 11.3, Table 11.4 and Table 11.5 show the corresponding results for car, LGV and HGV traffic individually. These counts were located on the SRN and have been defined as either calibration or validation counts.

Table 11.13: Individual Link Performance by Direction on SRN (Total Vehicles)

Count Location (Calibration or Validation)	Direction	Counts	AM Peak Hour	Interpeak Hour	PM Peak Hour
M1 Calibration	Northbound	4	100%	100%	100%
M1 Calibration	Southbound	4	100%	100%	100%
M1 Validation	Northbound	2	100%	100%	50%
M1 Validation	Southbound	2	100%	100%	100%
A1081 Calibration	Eastbound	1	100%	100%	100%
A1081 Calibration	Westbound	1	100%	100%	100%
A1081 Validation	Eastbound	2	100%	50%	50%
A1081 Validation	Westbound	2	50%	50%	100%
A1(M)/A1 Calibration	Northbound	5	100%	100%	100%
A1(M)/A1 Calibration	Southbound	5	100%	100%	100%
A1(M)/A1 Validation	Northbound	3	67%	100%	100%
A1(M)/A1 Validation	Southbound	3	100%	100%	100%
M25 Calibration	Eastbound	1	100%	100%	100%
M25 Calibration	Westbound	1	100%	100%	100%
Total		**36**	**94%**	**94%**	**94%**

Table 11.14: Individual Link Performance by Direction on SRN (Car Traffic)

Count Location (Calibration or Validation)	Direction	Counts	AM Peak Hour	Interpeak Hour	PM Peak Hour
M1 Calibration	Northbound	4	100%	100%	100%
M1 Calibration	Southbound	4	100%	100%	100%
M1 Validation	Northbound	2	100%	100%	100%
M1 Validation	Southbound	2	50%	100%	100%
A1081 Calibration	Eastbound	1	100%	100%	100%
A1081 Calibration	Westbound	1	100%	100%	100%
A1081 Validation	Eastbound	2	50%	0%	0%
A1081 Validation	Westbound	2	0%	0%	50%
A1(M)/A1 Calibration	Northbound	5	100%	100%	100%
A1(M)/A1 Calibration	Southbound	5	100%	100%	100%
A1(M)/A1 Validation	Northbound	3	67%	100%	100%
A1(M)/A1 Validation	Southbound	3	100%	100%	100%
M25 Calibration	Eastbound	1	100%	100%	100%
M25 Calibration	Westbound	1	100%	100%	100%
Total		**36**	**86%**	**89%**	**92%**

Table 11.15: Individual Link Performance by Direction on SRN (LGV Traffic)

Count Location (Calibration or Validation)	Direction	Counts	AM Peak Hour	Interpeak Hour	PM Peak Hour
M1 Calibration	Northbound	4	100%	100%	100%
M1 Calibration	Southbound	4	100%	100%	100%
M1 Validation	Northbound	2	100%	100%	50%
M1 Validation	Southbound	2	50%	100%	50%
A1081 Calibration	Eastbound	1	0%	100%	100%
A1081 Calibration	Westbound	1	100%	100%	100%
A1081 Validation	Eastbound	2	100%	100%	100%
A1081 Validation	Westbound	2	50%	100%	100%
A1(M)/A1 Calibration	Northbound	5	100%	100%	100%
A1(M)/A1 Calibration	Southbound	5	100%	100%	100%
A1(M)/A1 Validation	Northbound	3	100%	100%	100%
A1(M)/A1 Validation	Southbound	3	100%	100%	100%
M25 Calibration	Eastbound	1	100%	100%	100%
M25 Calibration	Westbound	1	100%	100%	100%
Total		**36**	**92%**	**100%**	**94%**

Table 11.16: Individual Link Performance by Direction on SRN (HGV Traffic)

Count Location (Calibration or Validation)	Direction	Counts	AM Peak Hour	Interpeak Hour	PM Peak Hour
M1 Calibration	Northbound	4	100%	100%	100%
M1 Calibration	Southbound	4	100%	100%	100%
M1 Validation	Northbound	2	100%	100%	50%
M1 Validation	Southbound	2	100%	100%	100%
A1081 Calibration	Eastbound	1	100%	100%	100%
A1081 Calibration	Westbound	1	100%	100%	100%
A1081 Validation	Eastbound	2	50%	100%	100%
A1081 Validation	Westbound	2	100%	100%	100%
A1(M)/A1 Calibration	Northbound	5	100%	100%	80%
A1(M)/A1 Calibration	Southbound	5	100%	100%	100%
A1(M)/A1 Validation	Northbound	3	100%	100%	67%
A1(M)/A1 Validation	Southbound	3	67%	67%	100%
M25 Calibration	Eastbound	1	100%	100%	100%
M25 Calibration	Westbound	1	100%	100%	100%
Total		**36**	**94%**	**94%**	**92%**

11.4.12 Table 11.13 shows that modelled flows on individual links perform well compared with observed counts on the SRN when considering total vehicle flows. Of the 36 counts, only two counts failed in to meet WebTAG criteria in all three time periods.

11.4.13 Considering LGV and HGV traffic, more than 90% of locations across the SRN meet the defined WebTAG criteria in each time period. For car traffic, Table 11.14 shows that the proportion of locations meeting WebTAG criteria in each time period is above the 85% of locations suggested within WebTAG.

11.4.14 In addition to the tables contained within the section, Appendix C contains figures showing the performance of the base year highway model against individual link counts by time period and vehicle type.

Journey Time Validation

11.4.15 As previously mentioned in Section 11.3, the final measure against which to assess the assignment performance is the journey time validation. The WebTAG guidelines for comparing modelled journey times with observed data are detailed in Table 3.1. Table 11.17 provides the performance of the highway assignment in the three modelled hours broken down by location of journey times on the SRN, and routes within Central Bedfordshire, Luton Borough and Hertfordshire.

Table 11.17: Journey Time Validation Summary

	AM Peak Hour		Interpeak Hour		PM Peak Hour	
	Routes	%Pass	Routes	%Pass	Routes	%Pass
SRN	10	80%	10	90%	10	70%
Central Beds	18	89%	18	94%	18	94%
Luton	12	92%	0	-	12	83%
Hertfordshire	8	75%	8	100%	8	88%
Total	**48**	**85%**	**36**	**94%**	**48**	**85%**

11.4.16 Journey time validation performance is similar to that shown in Table 11.6 for the ‘Initial Assignment Calibration’ test. Table 11.17 shows that taking all journey time routes defined in the model, 85%, 94% and 85% of these routes meet WebTAG criteria in the AM Peak, interpeak and PM Peak hours respectively, and therefore demonstrates that the model performs well against observed journey time data.

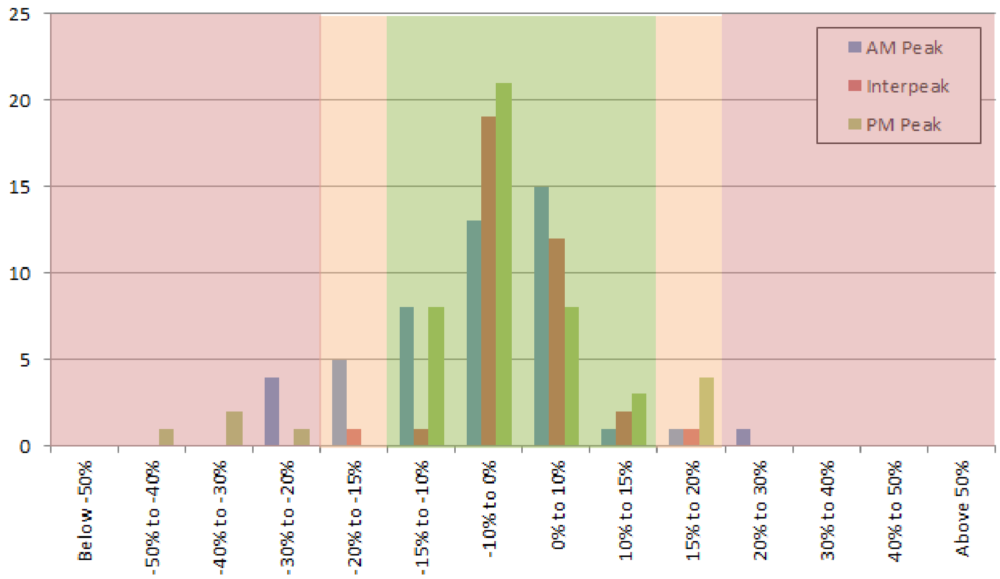
11.4.17 In order to assess if there is any bias in the modelled journey times in comparison with the observed data, for example that the model is generally slower or faster than the observed data, Figure 11.5 shows the distribution of journey time validation results in the three modelled hours.

11.4.18 As previously, in this figure the area shaded green represents those journey times that fall within WebTAG criteria of ±15%, the orange area shows those that marginally fail to meet this criterion but are within ±20%, with the red shaded areas being those journey time routes outside ±20% of the observed data

11.4.19 From Figure 11.5 it can be seen that the majority of journey time routes fall within the green shaded area, as reported in Table 11.17 with a limited number of routes outside of ±20% of the observed data. This figure also shows that the journey time validation results are broadly evenly distributed about the centre value of matching the observed journey time data.

11.4.20 This shows that there is not a significant bias in the modelled journey times towards being too fast or too slow compared with the observed data. If there is a small bias then it is that the model is slightly faster than observed.

Figure 11.5 Journey Time Distribution by Percentage Difference (Modelled vs. Observed)



11.4.21 The results of the journey time validation for these routes are reported in greater detail in Table 11.18. Investigation of the routes that failed showed that, generally on the SRN these failures were due to underrepresentation of travel time compared with the observed data. However, the M1 performs well in all three time periods with no journey time routes failing to meet WebTAG criteria.

11.4.22 Journey time graphs for each route in the AM Peak, interpeak and PM Peak hours can be found in Appendix D.

Table 11.18: Journey Time Validation by Route

Location	Route	AM Peak Hour			Interpeak Hour			PM Peak Hour		
		Abs.	%	WebTAG	Abs.	%	WebTAG	Abs.	%	WebTAG
SRN	M1 Junction 9 to 12 NB	-00:32	-4%	✓	-00:49	-6%	✓	-01:08	-7%	✓
SRN	M1 Junction 9 to 12 SB	01:16	10%	✓	-01:00	-9%	✓	-00:54	-7%	✓
SRN	M1 Junction 6 to 9 NB	00:28	7%	✓	-00:44	-10%	✓	-00:13	-2%	✓
SRN	M1 Junction 6 to 9 SB	00:12	3%	✓	00:02	0%	✓	00:16	4%	✓
SRN	A1 (Stotfold to A421) NB	-02:23	-14%	✓	-02:44	-16%	×	-07:42	-34%	×
SRN	A1 (Stotfold to A421) SB	04:16	26%	×	-00:12	-1%	✓	-00:48	-5%	✓
SRN	A1(M) Junction 7 to 10 NB	00:19	4%	✓	00:20	4%	✓	01:15	15%	×
SRN	A1(M) Junction 7 to 10 SB	-03:40	-29%	×	00:08	2%	✓	00:17	4%	✓
SRN	A1(M) Junction 4 to 7 NB	00:42	9%	✓	-00:36	-8%	✓	-04:46	-35%	×
SRN	A1(M) Junction 4 to 7 SB	00:33	6%	✓	-00:03	-1%	✓	00:19	4%	✓
Central Beds.	A6 (Luton Centre to Barton-le-Clay) NB	-02:14	-13%	✓	01:17	10%	✓	-00:20	-2%	✓
Central Beds.	A6 (Luton Centre to Barton-le-Clay) SB	-00:13	-1%	✓	-01:07	-8%	✓	-00:09	-1%	✓
Central Beds.	A6 (Barton-le-Clay to Chapel End) NB	-01:49	-15%	✓	01:08	12%	✓	-00:29	-4%	✓
Central Beds.	A6 (Barton-le-Clay to Chapel End) SB	-01:32	-12%	✓	01:22	15%	×	01:20	14%	✓
Central Beds.	A5 (Markyate to Hockliffe) SB	-05:43	-17%	×	-00:47	-3%	✓	-02:38	-9%	✓
Central Beds.	A5 (Markyate to Hockliffe) NB	-04:05	-15%	✓	00:26	2%	✓	-01:55	-7%	✓
Central Beds.	B5120 (A5 to Barton-le-Clay) EB	01:02	6%	✓	00:29	3%	✓	01:18	8%	✓
Central Beds.	B5120 (A5 to Barton-le-Clay) WB	00:08	1%	✓	00:34	4%	✓	-00:23	-2%	✓
Central Beds.	Sundon Road (A5 to A6) EB	-01:31	-9%	✓	01:00	7%	✓	-02:03	-11%	✓
Central Beds.	Sundon Road (A5 to A6) WB	-05:02	-22%	×	-00:12	-1%	✓	-02:21	-12%	✓

Location	Route	AM Peak Hour			Interpeak Hour			PM Peak Hour		
		Abs.	%	WebTAG	Abs.	%	WebTAG	Abs.	%	WebTAG
Central Beds.	A505 / A4146 (Leighton Buzzard to A5) EB	-00:21	-4%	✓	-00:21	-4%	✓	-00:02	0%	✓
Central Beds.	A505 / A4146 (Leighton Buzzard to A5) WB	-00:32	-6%	✓	-00:26	-5%	✓	-00:16	-3%	✓
Central Beds.	A507 (A421 to A6) EB	-00:25	-3%	✓	00:04	1%	✓	-00:35	-4%	✓
Central Beds.	A507 (A421 to A6) WB	00:16	2%	✓	-00:16	-2%	✓	-01:13	-8%	✓
Central Beds.	A507 (A6 to A1(M)) EB	01:12	7%	✓	-00:28	-3%	✓	01:45	11%	✓
Central Beds.	A507 (A6 to A1(M)) WB	-00:26	-2%	✓	00:04	0%	✓	01:05	7%	✓
Central Beds.	A421 (Milton Keynes to Bedford) NB	-00:04	-1%	✓	-00:48	-9%	✓	01:55	19%	×
Central Beds.	A421 (Milton Keynes to Bedford) SB	00:32	6%	✓	00:45	12%	✓	00:02	1%	✓
Luton	A1081 (M1 to LTN) NB	00:06	2%	✓				-00:18	-6%	✓
Luton	A1081 (M1 to LTN) SB	00:43	18%	✓				00:41	17%	✓
Luton	Kimpton Road (A505 to LTN) EB	-01:03	-23%	×				-00:30	-13%	✓
Luton	Kimpton Road (A505 to LTN) WB	00:14	7%	✓				-00:27	-12%	✓
Luton	Vauxhall Way (A1081 to Ashcroft Road) NB	00:48	14%	✓				00:20	5%	✓
Luton	Vauxhall Way (A1081 to Ashcroft Road) SB	-00:28	-6%	✓				01:12	20%	×
Luton	Wigmore Lane (A505 to Eaton Green Road) NB	-00:20	-7%	✓				-00:24	-8%	✓
Luton	Wigmore Lane (A505 to Eaton Green Road) SB	00:00	0%	✓				-00:07	-3%	✓
Luton	Eaton Gn Road (Wigmore Ln - Frank Lester Way) EB	-00:10	-12%	✓				-00:02	-2%	✓
Luton	Eaton Gn Road (Wigmore Ln - Frank Lester Way) WB	-00:22	-21%	✓				-00:01	-1%	✓
Luton	Percival Way (A1081 to Eaton Green Road) NB	-00:28	-20%	✓				-01:24	-42%	×
Luton	Percival Way (A1081 to Eaton Green Road) SB	-00:23	-16%	✓				-00:18	-14%	✓
Herts.	A505 (Vauxhall Way to Hitchin) EB	-01:37	-14%	✓	-00:10	-2%	✓	-03:15	-25%	×

Location	Route	AM Peak Hour			Interpeak Hour			PM Peak Hour		
		Abs.	%	WebTAG	Abs.	%	WebTAG	Abs.	%	WebTAG
Herts.	A505 (Vauxhall Way to Hitchin) WB	-00:36	-6%	✓	00:15	3%	✓	00:21	4%	✓
Herts.	A1081 (Walkers Road to West Hyde Road) NB	00:10	2%	✓	-00:41	-7%	✓	-01:07	-12%	✓
Herts.	A1081 (Walkers Road to West Hyde Road) SB	-01:31	-15%	×	00:17	4%	✓	00:50	11%	✓
Herts.	B653 (Batford to A1081) NB	-00:21	-5%	✓	-00:33	-7%	✓	-00:43	-9%	✓
Herts.	B653 (Batford to A1081) SB	-01:34	-18%	×	-00:31	-7%	✓	-00:57	-12%	✓
Herts.	B656 (A1(M) to Hitchin) NB	-01:24	-9%	✓	-01:32	-9%	✓	-01:53	-11%	✓
Herts.	B656 (A1(M) to Hitchin) SB	-02:12	-12%	✓	-01:14	-8%	✓	-01:29	-9%	✓

11.5 Sector to Sector Level Matrices between Initial and Final Tests

11.5.1 This section details the matrix differences at a sector level between the 'Initial Assignment Calibration' test and the 'Final Assignment Calibration'. This analysis follows the same principles as adopted for the analysis of the impact of matrix estimation (see Section 11.4).

11.5.2 In analysing these results it was found that a small proportion of sector-to-sector movements changed by more than 5% when including the majority of screenlines within the matrix estimation process, but the absolute changes in those movements were relatively small and generally these movements were internal to Luton Borough. As defined in Section 10, those sector movements which change by more than 5% and 100 vehicles have been identified, and are within Table 11.19 through to Table 11.27.

11.5.3 As displayed in Table 11.19, Table 11.20 and Table 11.21, which report on the car matrices, the sector-to-sector movements highlighted are between the three Luton sectors. These movements are shorter distance trips which are likely to be based on synthetic demand not derived from MND data. The only highlighted movement not wholly contained within Luton was the 'St Albans' to 'Luton South' movement in the AM Peak hour. The changes in the number of trips for the majority of highlighted movements were less than 15% and in the peak hours.

11.5.4 Table 11.22 to Table 11.27 displays the HGV and LGV sector-to-sector movements for the three modelled hours and shows that no sector-to-sector movements have changed by more than 5% and 100 vehicles due to the additional five screenlines being defined as calibration screenlines in the matrix estimation process. The scale of change is reassuring, often less than 15%.

Table 11.19: AM Peak Sectored Demand Changes – Cars

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	**10%**	**-16%**	3%	0%	5%	-6%	-21%	-21%	-12%	9%	6%	5%	0%	13%	1%	1%	9%	6%	14%	7%
Luton North-west	3%	5%	2%	0%	1%	-3%	6%	0%	20%	-1%	2%	-15%	-1%	-3%	3%	0%	1%	11%	1%	1%
Luton South	1%	**10%**	**9%**	0%	13%	6%	-9%	-2%	-27%	10%	17%	-11%	1%	3%	0%	6%	-1%	0%	-2%	4%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-3%	1%	-5%	0%	-1%	0%	5%	8%	5%	1%	0%	-18%	10%	8%	2%	0%	-1%	-2%	0%	-1%
Leighton Buzzard and West C.Beds.	-10%	0%	-4%	0%	1%	0%	-2%	24%	1%	0%	0%	-7%	10%	4%	3%	0%	5%	0%	3%	0%
Ampthill-Flitwick and Central C.Cbeds.	20%	2%	-9%	0%	2%	-4%	1%	3%	2%	1%	1%	-7%	6%	0%	3%	2%	2%	2%	1%	3%
Sandy-Biggleswade and East C.Beds.	7%	-3%	-23%	0%	8%	12%	0%	0%	-2%	4%	16%	9%	0%	0%	0%	4%	0%	-12%	0%	-23%
Bedford	64%	18%	-8%	0%	-3%	-3%	1%	-2%	0%	0%	2%	-5%	-3%	0%	0%	0%	1%	0%	1%	0%
Milton Keynes	-5%	-2%	-6%	0%	-1%	0%	-1%	16%	0%	0%	0%	-8%	16%	-1%	1%	0%	1%	0%	0%	0%
Dacorum	-4%	-1%	1%	0%	-2%	-1%	-2%	-5%	-1%	-1%	0%	0%	-13%	-1%	-2%	0%	0%	-2%	0%	-2%
St Albans	5%	17%	**44%**	0%	47%	6%	-4%	-5%	6%	5%	1%	0%	-17%	-1%	-2%	1%	-1%	2%	-1%	3%
North Hertfordshire	-14%	-8%	-30%	0%	11%	13%	6%	-1%	5%	14%	10%	20%	0%	1%	0%	-4%	-2%	-10%	-3%	-35%
Rest of Hertfordshire	-7%	-1%	-8%	0%	18%	3%	1%	-1%	0%	3%	0%	0%	0%	0%	0%	0%	0%	-3%	0%	-7%
Rest of East Anglia	13%	4%	-19%	0%	10%	-1%	1%	0%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%	-1%
Bucks Oxfordshire Northants	-4%	-3%	-5%	0%	-1%	0%	2%	8%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
London	-2%	-3%	0%	0%	3%	-1%	-1%	0%	0%	-1%	0%	1%	-1%	0%	0%	0%	0%	-1%	0%	-1%
External North	8%	2%	-6%	0%	-6%	-3%	3%	5%	0%	0%	1%	-3%	4%	0%	0%	0%	1%	0%	0%	0%
External South	-3%	-2%	1%	0%	3%	0%	-1%	1%	0%	-1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
External West	-4%	-4%	-8%	0%	-5%	-2%	3%	18%	0%	0%	1%	-1%	25%	-1%	0%	0%	0%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table 11.20: Interpeak Sectored Demand Changes - Cars

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	**11%**	**-13%**	-3%	0%	-11%	-13%	-9%	-2%	20%	8%	1%	17%	2%	6%	3%	8%	7%	12%	6%	11%
Luton North-west	2%	**7%**	-2%	0%	-1%	2%	4%	1%	6%	0%	-5%	7%	-9%	-3%	-3%	-2%	-5%	1%	-4%	0%
Luton South	-1%	8%	3%	0%	-3%	13%	-8%	-5%	-5%	12%	-5%	16%	-4%	5%	0%	8%	4%	6%	4%	9%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-8%	2%	-3%	0%	0%	0%	4%	8%	-3%	0%	-1%	54%	-6%	-2%	-2%	-1%	-1%	-5%	-1%	-3%
Leighton Buzzard and West C.Beds.	-6%	-1%	-4%	0%	0%	0%	-1%	22%	0%	0%	0%	6%	12%	1%	1%	0%	3%	-1%	1%	-1%
Ampthill-Flitwick and Central C.Cbeds.	7%	-1%	-9%	0%	-4%	-2%	0%	3%	-1%	-2%	2%	6%	4%	2%	3%	0%	2%	-2%	1%	-1%
Sandy-Biggleswade and East C.Beds.	0%	-10%	-2%	0%	-8%	21%	3%	0%	-1%	9%	5%	-3%	0%	0%	0%	5%	0%	2%	3%	6%
Bedford	11%	0%	-7%	0%	-4%	-2%	0%	-1%	0%	0%	-1%	2%	0%	1%	0%	0%	0%	0%	0%	0%
Milton Keynes	5%	1%	-7%	0%	0%	0%	-1%	7%	0%	0%	0%	3%	17%	2%	2%	0%	1%	0%	0%	0%
Dacorum	-3%	0%	-1%	0%	-1%	0%	1%	3%	-1%	-1%	0%	0%	-5%	0%	0%	0%	0%	-2%	0%	-1%
St Albans	13%	6%	18%	0%	59%	10%	1%	-6%	3%	4%	0%	0%	-9%	0%	-1%	0%	0%	0%	0%	2%
North Hertfordshire	0%	-11%	-6%	0%	-9%	4%	3%	-1%	-1%	18%	-5%	-5%	0%	-1%	0%	4%	-1%	4%	1%	14%
Rest of Hertfordshire	5%	-4%	4%	0%	11%	1%	-1%	0%	0%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	1%
Rest of East Anglia	2%	-6%	-2%	0%	1%	1%	3%	0%	0%	2%	0%	-1%	0%	0%	0%	0%	0%	0%	0%	0%
Bucks Oxfordshire Northants	2%	0%	-7%	0%	-1%	0%	0%	6%	0%	0%	0%	1%	4%	0%	0%	0%	0%	0%	0%	0%
London	-6%	-3%	-11%	0%	2%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
External North	7%	2%	-9%	0%	-4%	-1%	-1%	3%	0%	0%	0%	1%	4%	1%	0%	0%	1%	0%	0%	0%
External South	-6%	-2%	-11%	0%	-1%	2%	0%	2%	0%	0%	1%	0%	1%	0%	0%	0%	0%	0%	0%	0%
External West	8%	3%	-8%	0%	-3%	-1%	-1%	6%	0%	0%	0%	2%	19%	3%	1%	0%	0%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table 11.21: PM Peak Sectored Demand Changes - Cars

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	**11%**	-2%	1%	0%	-18%	-14%	13%	0%	54%	0%	-13%	22%	1%	-2%	-1%	1%	2%	5%	0%	3%
Luton North-west	**-7%**	**11%**	0%	0%	-1%	2%	8%	8%	8%	1%	-5%	13%	-17%	-3%	-4%	-1%	-1%	-1%	0%	1%
Luton South	1%	**6%**	1%	0%	-9%	1%	-9%	-6%	-19%	1%	-14%	31%	-8%	-1%	-2%	-1%	5%	1%	4%	2%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-15%	1%	3%	0%	0%	1%	5%	20%	1%	-1%	-1%	40%	-1%	13%	3%	0%	-3%	-3%	-2%	-2%
Leighton Buzzard and West C.Beds.	-9%	0%	-3%	0%	0%	0%	-2%	32%	-1%	0%	0%	3%	1%	0%	0%	0%	2%	-1%	1%	0%
Ampthill-Flitwick and Central C.Cbeds.	3%	0%	-4%	0%	-2%	-3%	-1%	6%	-1%	-2%	-2%	4%	4%	-2%	3%	-2%	-3%	-1%	-3%	-1%
Sandy-Biggleswade and East C.Beds.	-1%	-8%	5%	0%	-3%	13%	1%	0%	-2%	6%	4%	-5%	0%	1%	0%	5%	1%	2%	2%	4%
Bedford	7%	6%	0%	0%	-2%	0%	1%	-2%	0%	0%	-1%	2%	-3%	0%	0%	0%	0%	0%	0%	0%
Milton Keynes	3%	1%	-2%	0%	0%	0%	-2%	10%	0%	0%	0%	3%	3%	2%	2%	0%	1%	0%	0%	0%
Dacorum	-6%	-5%	-5%	0%	1%	0%	-1%	2%	-1%	-1%	0%	0%	0%	0%	1%	0%	-1%	-1%	-1%	-1%
St Albans	18%	3%	17%	0%	18%	3%	2%	-6%	3%	1%	0%	0%	-5%	0%	-1%	1%	0%	1%	0%	2%
North Hertfordshire	4%	-1%	0%	0%	-6%	0%	4%	0%	0%	12%	-14%	-37%	0%	0%	0%	2%	-1%	4%	0%	12%
Rest of Hertfordshire	8%	2%	-9%	0%	5%	0%	3%	0%	1%	1%	0%	-1%	0%	0%	0%	0%	0%	0%	0%	1%
Rest of East Anglia	4%	-3%	-4%	0%	-4%	2%	2%	0%	0%	0%	0%	-2%	0%	0%	0%	0%	0%	0%	0%	0%
Bucks Oxfordshire Northants	1%	-2%	-6%	0%	-1%	0%	1%	5%	0%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%
London	1%	-6%	-10%	0%	6%	3%	3%	-1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
External North	4%	6%	-4%	0%	-2%	0%	-4%	-8%	0%	0%	-1%	0%	-7%	1%	0%	0%	0%	0%	0%	0%
External South	1%	-7%	-10%	0%	4%	2%	2%	2%	1%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%
External West	3%	4%	-3%	0%	-1%	0%	-4%	-6%	1%	0%	-1%	1%	-17%	0%	0%	0%	0%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table 11.22: AM Peak Sectored Demand Changes – LGVs

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	12%	-15%	-3%	0%	1%	-9%	24%	25%	30%	24%	-4%	-11%	31%	13%	21%	8%	5%	25%	4%	22%
Luton North-west	0%	11%	8%	0%	5%	2%	11%	-1%	37%	1%	-1%	-16%	-4%	2%	2%	-4%	-4%	12%	-5%	6%
Luton South	1%	7%	3%	0%	5%	4%	-19%	-1%	-20%	-5%	-5%	-16%	11%	0%	2%	-1%	-2%	-5%	-3%	-1%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-7%	10%	1%	0%	-1%	-1%	1%	1%	-1%	-1%	-1%	-4%	7%	-3%	3%	-1%	5%	-5%	5%	-4%
Leighton Buzzard and West C.Beds.	-14%	10%	-13%	0%	-1%	0%	-5%	49%	-3%	0%	-1%	-5%	4%	-2%	-1%	0%	2%	0%	2%	1%
Ampthill-Flitwick and Central C.Cbeds.	7%	2%	-4%	0%	-3%	-3%	5%	13%	2%	-1%	-5%	-19%	15%	-3%	7%	2%	-1%	2%	-3%	1%
Sandy-Biggleswade and East C.Beds.	8%	4%	-13%	0%	2%	30%	13%	-2%	-1%	-1%	-6%	1%	-1%	0%	-1%	12%	0%	-7%	-1%	-19%
Bedford	2%	12%	-3%	0%	-1%	-2%	1%	-4%	0%	0%	1%	-30%	-6%	-1%	0%	0%	1%	0%	1%	0%
Milton Keynes	-12%	3%	-18%	0%	-1%	-1%	-8%	20%	-1%	0%	0%	-1%	33%	7%	2%	0%	2%	0%	0%	0%
Dacorum	6%	1%	7%	0%	-1%	0%	-12%	4%	-5%	-1%	0%	0%	-1%	0%	0%	0%	0%	-3%	0%	-1%
St Albans	34%	3%	67%	0%	17%	5%	-23%	-9%	-16%	-12%	0%	1%	-30%	0%	-3%	-1%	-1%	-9%	-2%	-15%
North Hertfordshire	11%	1%	-16%	0%	-5%	12%	25%	-3%	-3%	8%	-6%	-17%	-1%	-1%	0%	-3%	0%	-6%	-3%	-22%
Rest of Hertfordshire	-10%	-2%	-6%	0%	15%	4%	0%	-1%	0%	3%	1%	1%	0%	0%	0%	0%	0%	2%	0%	0%
Rest of East Anglia	-1%	-1%	-7%	0%	3%	2%	7%	0%	0%	-1%	0%	-2%	0%	0%	0%	0%	0%	0%	0%	0%
Bucks Oxfordshire Northants	-10%	5%	-9%	0%	-2%	-1%	-7%	9%	0%	0%	0%	1%	6%	0%	0%	0%	0%	0%	0%	0%
London	-12%	-3%	-10%	0%	4%	7%	-5%	-1%	1%	3%	0%	0%	-2%	0%	0%	0%	0%	2%	0%	1%
External North	2%	13%	-6%	0%	-2%	-2%	0%	8%	0%	0%	1%	0%	5%	3%	0%	0%	1%	0%	0%	0%
External South	-13%	2%	-11%	0%	4%	6%	-9%	0%	1%	1%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
External West	-5%	11%	-16%	0%	-1%	-1%	-7%	22%	0%	0%	1%	-2%	33%	5%	0%	0%	0%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table 11.23: Interpeak Sectored Demand Changes – LGVs

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	9%	-19%	-11%	0%	-21%	-16%	54%	29%	37%	11%	-8%	9%	43%	10%	10%	1%	-4%	28%	-5%	25%
Luton North-west	9%	13%	-5%	0%	0%	4%	9%	1%	-5%	2%	-4%	4%	10%	0%	-2%	2%	-5%	2%	-3%	-1%
Luton South	1%	6%	4%	0%	-7%	7%	1%	15%	-4%	8%	4%	26%	23%	8%	7%	4%	7%	6%	7%	7%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-5%	6%	-2%	0%	-2%	-1%	5%	6%	0%	-1%	-3%	45%	-3%	8%	-1%	-3%	-2%	-5%	-3%	-4%
Leighton Buzzard and West C.Beds.	-4%	3%	-7%	0%	0%	0%	0%	15%	0%	-1%	0%	5%	6%	1%	1%	-1%	1%	-2%	1%	-1%
Ampthill-Flitwick and Central C.Cbeds.	65%	0%	-10%	0%	-4%	-3%	1%	3%	-1%	-3%	-1%	1%	7%	6%	1%	-3%	-1%	-3%	-1%	-4%
Sandy-Biggleswade and East C.Beds.	38%	-7%	1%	0%	-8%	14%	3%	-1%	-1%	4%	6%	-10%	-2%	0%	0%	3%	1%	2%	3%	3%
Bedford	26%	-6%	-7%	0%	-4%	-1%	0%	-1%	0%	0%	0%	1%	1%	0%	0%	0%	1%	0%	1%	0%
Milton Keynes	5%	5%	-12%	0%	0%	0%	-1%	4%	0%	0%	0%	2%	12%	3%	1%	0%	1%	0%	0%	0%
Dacorum	-5%	-2%	7%	0%	-2%	0%	-1%	8%	-3%	-1%	0%	-1%	0%	0%	0%	0%	0%	-1%	0%	-1%
St Albans	-6%	-7%	18%	0%	58%	6%	-15%	-9%	-12%	0%	0%	0%	-33%	0%	-2%	0%	0%	-1%	0%	-2%
North Hertfordshire	48%	2%	12%	0%	5%	2%	6%	-2%	-1%	12%	2%	-29%	-1%	-1%	0%	8%	-1%	2%	2%	11%
Rest of Hertfordshire	4%	-4%	5%	0%	19%	3%	3%	0%	0%	1%	0%	0%	-2%	0%	0%	0%	0%	0%	0%	1%
Rest of East Anglia	10%	-11%	6%	0%	7%	3%	2%	-1%	0%	1%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%
Bucks Oxfordshire Northants	-8%	0%	-1%	0%	-1%	0%	-1%	3%	0%	0%	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%
London	-11%	-8%	4%	0%	6%	6%	-4%	0%	0%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%
External North	7%	10%	-12%	0%	-2%	-2%	-2%	1%	0%	0%	0%	2%	1%	1%	0%	0%	0%	0%	0%	0%
External South	-11%	-7%	5%	0%	5%	3%	-3%	2%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%
External West	5%	5%	-13%	0%	-2%	-1%	-1%	7%	-1%	0%	0%	0%	14%	2%	1%	0%	0%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table 11.24: PM Peak Sectored Demand Changes - LGVs

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	2%	-7%	-4%	0%	-15%	-19%	7%	11%	14%	-11%	-16%	11%	5%	1%	-15%	0%	-5%	-1%	-10%	-6%
Luton North-west	0%	19%	12%	0%	0%	4%	8%	8%	12%	5%	-6%	12%	-13%	-4%	-9%	-1%	-2%	2%	-4%	2%
Luton South	0%	10%	7%	0%	-5%	2%	-3%	4%	-19%	0%	-12%	21%	-6%	-2%	-5%	6%	1%	-3%	-2%	-1%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-15%	9%	11%	0%	-1%	-1%	-1%	10%	2%	-1%	-2%	39%	-19%	11%	-3%	-3%	-1%	-6%	-3%	-4%
Leighton Buzzard and West C.Beds.	-19%	1%	8%	0%	0%	0%	-5%	29%	-2%	1%	-1%	9%	-2%	1%	1%	0%	4%	-1%	2%	1%
Ampthill-Flitwick and Central C.Cbeds.	34%	1%	-4%	0%	-7%	-2%	2%	6%	-2%	12%	-9%	18%	4%	4%	16%	5%	19%	4%	2%	2%
Sandy-Biggleswade and East C.Beds.	21%	-14%	1%	0%	-5%	84%	21%	-1%	-5%	-18%	3%	-5%	-4%	1%	0%	0%	2%	-11%	-5%	-30%
Bedford	55%	12%	9%	0%	-3%	0%	3%	-4%	0%	0%	-2%	12%	-8%	-1%	0%	0%	-1%	0%	0%	0%
Milton Keynes	6%	-3%	-3%	0%	-1%	-2%	0%	2%	1%	0%	0%	5%	-8%	-7%	0%	0%	-1%	0%	0%	0%
Dacorum	-1%	3%	9%	0%	-1%	0%	-10%	-2%	-7%	1%	0%	-1%	-2%	1%	1%	0%	-1%	-2%	0%	-2%
St Albans	14%	9%	-1%	0%	3%	5%	-3%	-8%	-15%	12%	-1%	-1%	-26%	2%	-1%	3%	0%	13%	0%	29%
North Hertfordshire	49%	-4%	-1%	0%	0%	3%	15%	1%	-3%	-41%	3%	-48%	-1%	0%	0%	-1%	-2%	-6%	0%	-61%
Rest of Hertfordshire	20%	1%	-8%	0%	10%	-1%	-1%	1%	3%	-7%	0%	0%	-1%	0%	0%	0%	0%	-1%	0%	-6%
Rest of East Anglia	38%	-9%	3%	0%	5%	1%	12%	-1%	0%	-3%	1%	-3%	0%	0%	0%	0%	0%	0%	0%	-1%
Bucks Oxfordshire Northants	5%	-10%	0%	0%	-1%	-1%	1%	5%	0%	1%	0%	3%	12%	0%	0%	0%	0%	0%	0%	0%
London	9%	-12%	1%	0%	8%	6%	0%	1%	1%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%
External North	12%	22%	-5%	0%	-6%	-3%	7%	-5%	1%	0%	-1%	-4%	-7%	-2%	0%	0%	-1%	0%	0%	0%
External South	8%	-22%	0%	0%	4%	4%	-1%	4%	0%	0%	0%	1%	3%	0%	0%	0%	0%	0%	0%	0%
External West	7%	-2%	-5%	0%	-4%	-3%	3%	-6%	4%	0%	-1%	3%	0%	-5%	0%	0%	0%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table 11.25: AM Peak Sectored Demand Changes – HGVs

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	101%	-4%	6%	0%	22%	7%	-17%	-21%	-11%	17%	0%	0%	34%	9%	-14%	3%	-4%	14%	-4%	22%
Luton North-west	55%	20%	0%	0%	16%	5%	2%	-17%	65%	8%	-5%	-26%	-6%	-1%	-8%	6%	-9%	20%	-5%	15%
Luton South	21%	16%	-6%	0%	7%	-23%	-10%	-52%	-16%	3%	-1%	-10%	30%	-3%	-8%	-3%	-7%	-1%	-5%	0%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	1%	11%	-13%	0%	2%	-6%	7%	3%	0%	-1%	-2%	-22%	-8%	-10%	-1%	-5%	3%	-4%	-1%	-6%
Leighton Buzzard and West C.Beds.	-10%	9%	-12%	0%	4%	-1%	-1%	104%	3%	-2%	1%	-16%	14%	-1%	1%	-1%	1%	-4%	0%	-2%
Ampthill-Flitwick and Central C.Cbeds.	51%	28%	-5%	0%	30%	15%	6%	5%	11%	10%	-18%	-27%	-3%	-8%	3%	10%	-1%	9%	-5%	5%
Sandy-Biggleswade and East C.Beds.	36%	17%	-14%	0%	51%	65%	28%	-5%	-7%	-6%	-21%	4%	-5%	-1%	0%	0%	-1%	-23%	-3%	-22%
Bedford	37%	14%	0%	0%	1%	-1%	1%	-5%	0%	0%	-9%	-29%	-1%	-16%	2%	0%	-2%	0%	1%	0%
Milton Keynes	-11%	13%	-18%	0%	1%	-2%	19%	27%	0%	0%	3%	-21%	89%	16%	2%	0%	4%	0%	1%	0%
Dacorum	-2%	7%	3%	0%	1%	-5%	-5%	0%	-8%	0%	0%	2%	25%	-1%	-1%	0%	-2%	-1%	-1%	-2%
St Albans	0%	15%	-4%	0%	11%	14%	1%	-22%	-4%	12%	4%	-1%	-45%	-5%	-3%	9%	1%	12%	2%	12%
North Hertfordshire	56%	37%	2%	0%	28%	13%	28%	-3%	-7%	18%	-15%	12%	0%	0%	2%	-13%	0%	-31%	-3%	-39%
Rest of Hertfordshire	6%	19%	3%	0%	6%	0%	1%	0%	-3%	3%	1%	1%	-1%	0%	0%	0%	0%	-1%	0%	-2%
Rest of East Anglia	2%	13%	0%	0%	-4%	7%	11%	-1%	0%	2%	2%	1%	-2%	0%	0%	0%	0%	0%	0%	-1%
Bucks Oxfordshire Northants	-15%	15%	-6%	0%	5%	-2%	6%	2%	0%	0%	1%	-12%	1%	1%	1%	0%	0%	0%	0%	0%
London	-8%	7%	-2%	0%	1%	1%	-1%	0%	-4%	3%	2%	1%	-1%	0%	0%	0%	0%	-1%	0%	-1%
External North	-24%	28%	-4%	0%	-2%	-3%	5%	-14%	0%	0%	7%	-19%	-5%	4%	1%	0%	3%	0%	0%	0%
External South	-10%	8%	-5%	0%	2%	-2%	1%	14%	-2%	0%	1%	1%	12%	0%	0%	0%	0%	0%	0%	0%
External West	-21%	24%	-7%	0%	7%	-2%	10%	3%	0%	0%	4%	-19%	-2%	5%	1%	0%	1%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table 11.26: Interpeak Sectored Demand Changes – HGVs

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	38%	-8%	12%	0%	-17%	-14%	33%	-5%	34%	-6%	3%	9%	14%	10%	10%	-8%	6%	-10%	-5%	-11%
Luton North-west	4%	46%	3%	0%	17%	19%	19%	20%	30%	27%	11%	22%	22%	11%	10%	24%	12%	34%	19%	32%
Luton South	33%	-6%	10%	0%	-12%	-8%	-19%	-7%	-4%	-9%	6%	10%	7%	10%	13%	-5%	11%	-4%	-8%	-5%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-4%	16%	-13%	0%	-4%	-3%	-2%	23%	29%	-2%	-1%	15%	7%	1%	1%	-5%	-1%	-15%	0%	-12%
Leighton Buzzard and West C.Beds.	-6%	10%	-13%	0%	-2%	-1%	4%	83%	11%	4%	-5%	13%	30%	-1%	8%	-2%	-1%	-4%	-2%	-2%
Ampthill-Flitwick and Central C.Cbeds.	41%	25%	-11%	0%	-9%	-21%	3%	15%	0%	16%	-8%	10%	14%	4%	9%	12%	2%	13%	7%	14%
Sandy-Biggleswade and East C.Beds.	3%	-17%	-14%	0%	-4%	80%	12%	-4%	-10%	-15%	-9%	-2%	-3%	-1%	-1%	3%	-1%	-29%	-4%	-27%
Bedford	-3%	3%	-7%	0%	-18%	-2%	-2%	-11%	0%	0%	-16%	-6%	-16%	-1%	0%	0%	-8%	0%	-2%	0%
Milton Keynes	-10%	26%	-11%	0%	-4%	-1%	19%	9%	1%	0%	0%	11%	69%	6%	2%	0%	2%	0%	1%	0%
Dacorum	2%	5%	3%	0%	0%	-2%	-3%	-11%	-1%	0%	0%	0%	-12%	0%	0%	0%	0%	-1%	0%	-1%
St Albans	-3%	13%	4%	0%	19%	16%	6%	1%	1%	14%	0%	1%	3%	1%	0%	10%	0%	16%	2%	15%
North Hertfordshire	30%	22%	16%	0%	7%	6%	13%	1%	-9%	-33%	-3%	-1%	-3%	-1%	-1%	-2%	0%	-15%	-4%	-39%
Rest of Hertfordshire	6%	5%	7%	0%	3%	-3%	2%	-1%	-3%	-3%	0%	0%	0%	0%	0%	0%	0%	-1%	0%	-4%
Rest of East Anglia	2%	0%	-1%	0%	1%	9%	5%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bucks Oxfordshire Northants	-8%	24%	-9%	0%	-4%	0%	7%	-12%	2%	0%	0%	9%	-14%	0%	0%	0%	0%	0%	0%	0%
London	-2%	2%	0%	0%	2%	2%	-1%	0%	-3%	2%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
External North	-8%	34%	-9%	0%	-6%	-1%	9%	-19%	0%	0%	-2%	13%	-3%	-1%	0%	0%	0%	0%	0%	0%
External South	-3%	8%	-10%	0%	2%	0%	0%	0%	0%	1%	0%	-1%	0%	0%	0%	0%	0%	0%	0%	0%
External West	-8%	33%	-9%	0%	-6%	0%	11%	-19%	1%	0%	-1%	13%	-21%	-3%	0%	0%	0%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table 11.27: PM Peak Sectored Demand Changes - HGVs

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	43%	5%	50%	0%	-12%	-1%	7%	-2%	2%	6%	53%	2%	7%	30%	-23%	14%	41%	12%	10%	9%
Luton North-west	11%	38%	5%	0%	12%	18%	27%	26%	51%	15%	11%	13%	17%	6%	9%	21%	10%	36%	12%	30%
Luton South	15%	-2%	3%	0%	-12%	-6%	-4%	-14%	-14%	-7%	2%	5%	2%	3%	8%	-4%	7%	-3%	-12%	-4%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	12%	16%	0%	0%	3%	4%	32%	10%	8%	8%	1%	4%	24%	-3%	1%	9%	-1%	19%	0%	17%
Leighton Buzzard and West C.Beds.	-8%	-4%	-8%	0%	-3%	-1%	11%	79%	1%	0%	-4%	6%	18%	-2%	0%	-2%	0%	0%	-2%	-1%
Ampthill-Flitwick and Central C.Cbeds.	27%	-6%	-5%	0%	-9%	-21%	2%	13%	0%	8%	24%	4%	13%	6%	5%	5%	5%	6%	5%	5%
Sandy-Biggleswade and East C.Beds.	5%	-39%	-28%	0%	-12%	94%	4%	-2%	-5%	-14%	19%	-5%	6%	3%	2%	2%	2%	-21%	0%	-23%
Bedford	11%	-10%	5%	0%	-11%	-1%	4%	-8%	0%	1%	-1%	6%	-14%	-7%	0%	0%	-4%	0%	0%	0%
Milton Keynes	-20%	6%	-5%	0%	1%	-4%	5%	2%	2%	0%	3%	7%	16%	-1%	1%	0%	-1%	0%	1%	0%
Dacorum	34%	3%	-9%	0%	-1%	-9%	-4%	-6%	-7%	-11%	0%	0%	-4%	-1%	-1%	-1%	0%	-6%	0%	-4%
St Albans	73%	2%	5%	0%	0%	0%	-3%	-17%	-5%	-1%	1%	-3%	-31%	0%	0%	2%	0%	1%	5%	1%
North Hertfordshire	17%	-7%	11%	0%	-44%	-31%	-8%	-4%	1%	-45%	9%	-12%	-3%	0%	-1%	-4%	0%	-24%	-3%	-47%
Rest of Hertfordshire	31%	6%	-12%	0%	8%	-9%	-1%	1%	-40%	-12%	0%	-1%	1%	0%	1%	0%	0%	1%	0%	-3%
Rest of East Anglia	12%	-6%	1%	0%	-2%	16%	11%	0%	-1%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	-1%
Bucks Oxfordshire Northants	-16%	5%	-5%	0%	-1%	-4%	10%	-2%	-1%	0%	0%	4%	4%	-1%	-1%	0%	0%	0%	0%	0%
London	33%	0%	-16%	0%	1%	17%	-1%	1%	-7%	4%	0%	-1%	1%	-1%	0%	0%	0%	0%	0%	0%
External North	-22%	6%	-4%	0%	-1%	-4%	15%	-28%	1%	0%	2%	5%	-6%	-3%	0%	0%	0%	0%	0%	0%
External South	22%	3%	-13%	0%	0%	-7%	2%	5%	-4%	-1%	0%	0%	9%	-1%	0%	0%	0%	0%	0%	0%
External West	-22%	8%	-5%	0%	-1%	-3%	11%	-20%	1%	0%	1%	5%	-18%	-5%	-1%	0%	0%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

12 SUMMARY OF MODEL DEVELOPMENT, STANDARDS ACHIEVED, AND FITNESS FOR PURPOSE

12.1 Introduction

12.1.1 The preceding sections of this report detail the development of the CBLTM-LTN highway model, the definition and derivation of the observed data used to assess the model, the calibration process adopted, and the results of this calibration process assessed against standards defined in WebTAG. This section summarises these process and results, and assesses the model performance against WebTAG guidelines in light of the known and expected applications of the model.

12.2 Summary of Model Development

12.2.1 The CBLTM-LTN highway model was developed from the existing CBLTM highway model by expanding, reviewing and updating the network within the Area of Detailed Modelling. The zone system within the Fully Modelled Area was also reviewed and disaggregated, particularly within Luton Borough including at Luton Airport. In addition, the COMET model, which contained more network and zone detail to the east and south of Luton Airport was adopted for western Hertfordshire.

12.2.2 The highway demand matrices were reprocessed and rebuilt using the existing MND data, using current guidance and best practice.

12.2.3 Existing count data from both the CBLTM and COMET were used where available and supplemented with new count data collected in July and September 2018, and data collected as part of the microsimulation model.

12.2.4 A selection of existing journey time routes from CBLTM and COMET were used to calibrate speeds in CBLTM-LTN. In addition, journey times collected as part of the microsimulation modelling collected in the peak hours were also used. These moving car observation journey times were observed in Luton Borough close to Luton Airport.

12.2.5 With the updated demand data, networks and observed count and journey time data sets, matrix estimation was applied using short-screenlines rather than individual counts as constraints. This is in-line with WebTAG Unit M3.1 guidance whereby counts on a given screenline or cordon are grouped based on road type and / or capturing similar movements using a set of links into a single constraint within matrix estimation. This reduces the risk of matrix estimation correcting routeing within the highway assignment, placing emphasis on network calibration to improve the individual link performance rather than using matrix estimation.

12.2.6 Two matrix estimation assignments were explored: an 'Initial Assignment Calibration' defining approximately a third of screenlines as validation; and a second test ('Final Assignment Calibration') that included all screenlines, except for the 'Luton Airport Screenline' as calibration in the matrix estimation process.

12.2.7 After analysing the matrices at sector level between the two tests it was concluded that there was no significant change in the matrices with the 'Final Assignment Calibration' test; however, this version of the base year highway model had a higher level of performance against observed count and journey time data. Therefore, the 'Final Assignment Calibration' test has been adopted as the CBLTM-LTN base year highway model.

12.3 Summary of Standards Achieved

12.3.1 Based on the approach outlined above the resulting highway model can be assessed against the acceptability guidelines detailed in WebTAG Unit M3.1 (and in Table 3.1 and Table 3.2 within this report). These acceptability guidelines can be broken down into two main areas: those that relate to the assignment results in terms of modelled flows and journey times; and those that relate to the changes made to the prior matrices through the process of matrix estimation.

12.3.2 Whether or not these acceptability guidelines are met by a given model does not determine whether a model is fit for purpose. As stated in WebTAG Unit M3.1 §3.4.2:

"The achievement of the validation acceptability guidelines specified in Table 1, Table 2 and Table 3 does not guarantee that a model is 'fit for purpose' and likewise a failure to meet the specified validation standards does not mean that a model is not 'fit for purpose'.

12.3.3 With this in mind Table 12.1 summarises the results of the model calibration against the acceptability guidelines set out in WebTAG Unit M3.1. This details the model assignment performance in terms of flows on screenlines and at individual locations, and the journey time validation. Also included in this table are the changes made to the prior matrices due to matrix estimation.

Table 12.1: Summary of Matrix Performance against WebTAG Guidelines

	Measure		WebTAG	AM Peak	Interpeak	PM Peak
Assignment Performance	Screenline		All or nearly all	95%	95%	87%
	'Flow'		>85%	85%	95%	86%
	Journey Times		>85%	85%	94%	85%
Matrix Changes	Zonal	R^2	>0.95	1.00	1.00	1.00
		Slope	0.98 - 1.02	1.00	1.00	1.00
	Trip-end	R^2	>0.98	1.00	1.00	1.00
		Slope	0.99 - 1.01	1.00	1.00	1.00
	Trip-length	Mean	<5%	0.7%	-1.8%	-0.6%
		St. Dev.	<5%	0.6%	-2.5%	-2.4%
	Sector Movements		<5% (or 100 veh)	99.3%	99.7%	98.3%

12.3.4 The assignment performance results detailed in Table 12.1 show that more than 87% of screenlines meet WebTAG guidelines in each of the three modelled hours, with the individual flow performance at or above the 85% criterion. The percentage of journey times that meet WebTAG guidelines is at or above the 85% criterion in each of the three modelled hours.

12.4 Assessment of Fitness for Purpose

12.4.1 Based on the results detailed above in Table 12.1, the CBLTM-LTN highway model meets and generally exceeds WebTAG acceptability guidelines for all measures.

12.4.2 Given the use of the model, which focus on roads around Luton Airport including the SRN, particularly the M1, it should be recognised that whilst these results show that the model reflects traffic levels and journey times within WebTAG criteria focusing around Luton Airport this level of performance is not necessarily reproduced in all areas of the model.

12.4.3 Given the expected uses of this model as part of the strategic assessment of the proposed expansion of Luton Airport, the model performs well on the key routes to and from Luton Airport and in areas surrounding the airport. If the CBLTM-LTN highway model is used for other purposes than those detailed in Section 2.1, an assessment of the model performance within the area of influence should be undertaken.

12.4.4 The model development and performance detailed in this report demonstrates that the CBLTM-LTN 2016 base year highway model is suitable for assessing the forecast strategic impacts of the proposed expansion of Luton Airport on the road network.

Appendix A – Matrix Changes Following Matrix Estimation

A1 Matrix Cell Changes

Figure A.1 Matrix Cell Changes, AM Peak Hour, Internal Origins, Car

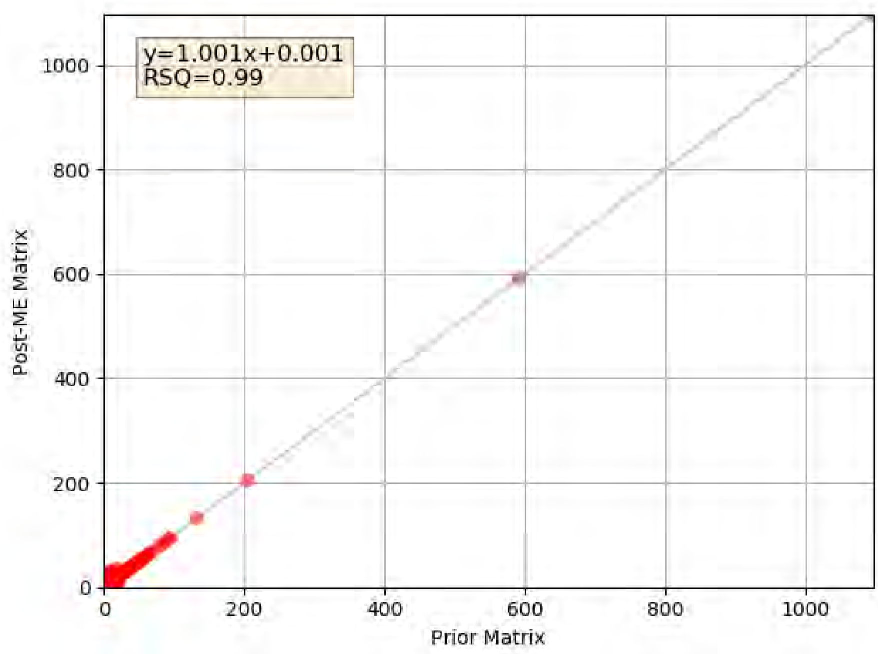


Figure A.2 Matrix Cell Changes, AM Peak Hour, Internal Origins, LGV

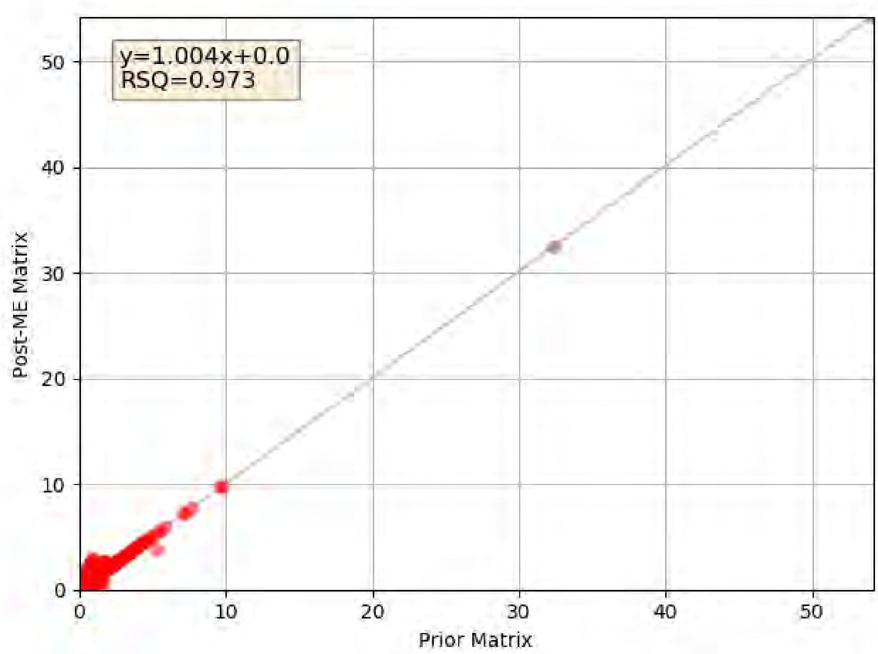


Figure A.3 Matrix Cell Changes, AM Peak Hour, Internal Origins, HGV

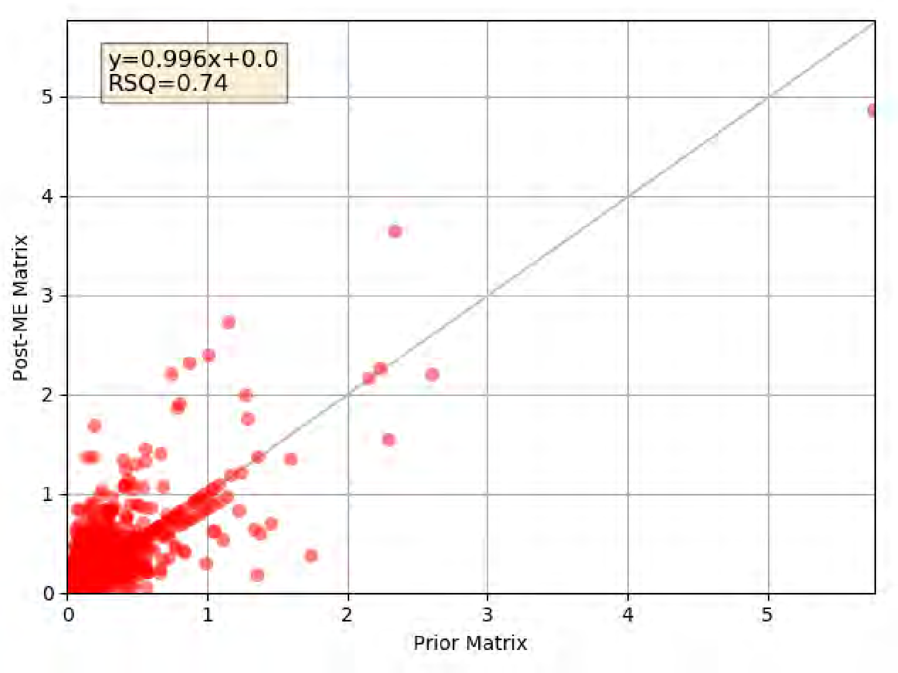


Figure A.4 Matrix Cell Changes, Interpeak Hour, Internal Origins, Car

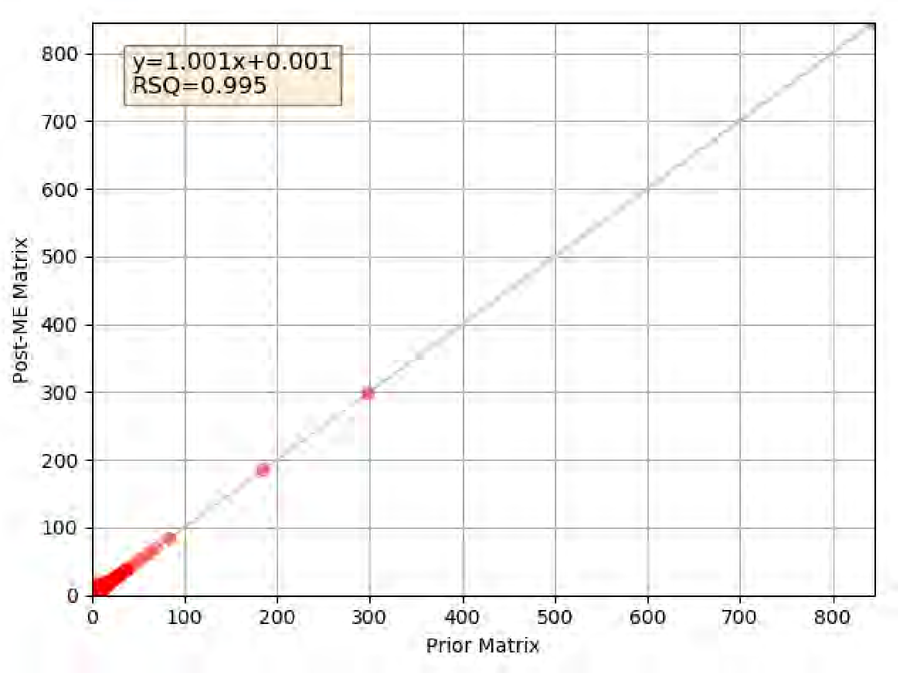


Figure A.5 Matrix Cell Changes, Interpeak Hour, Internal Origins, LGV

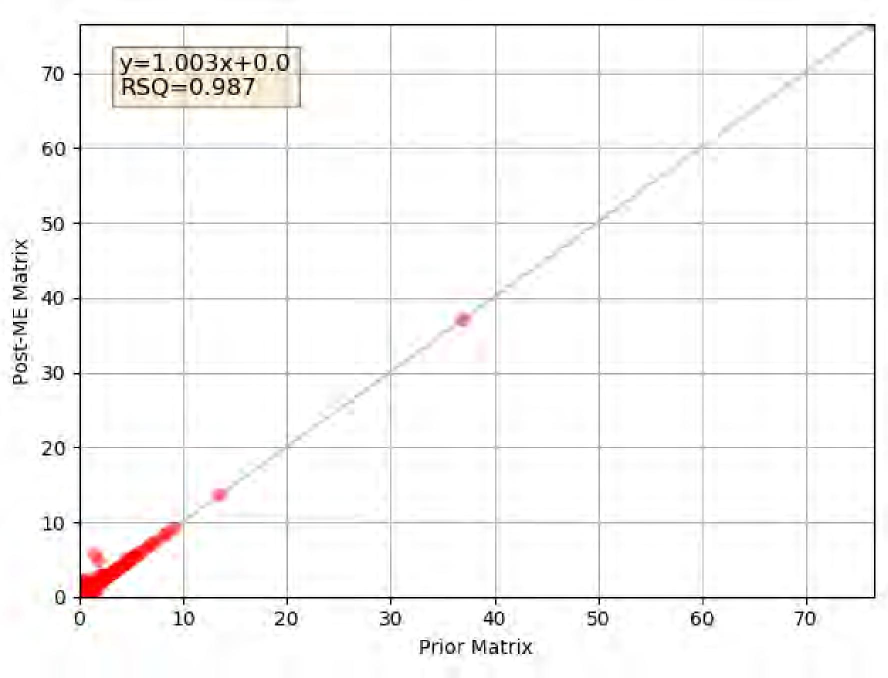


Figure A.6 Matrix Cell Changes, Interpeak Hour, Internal Origins, HGV

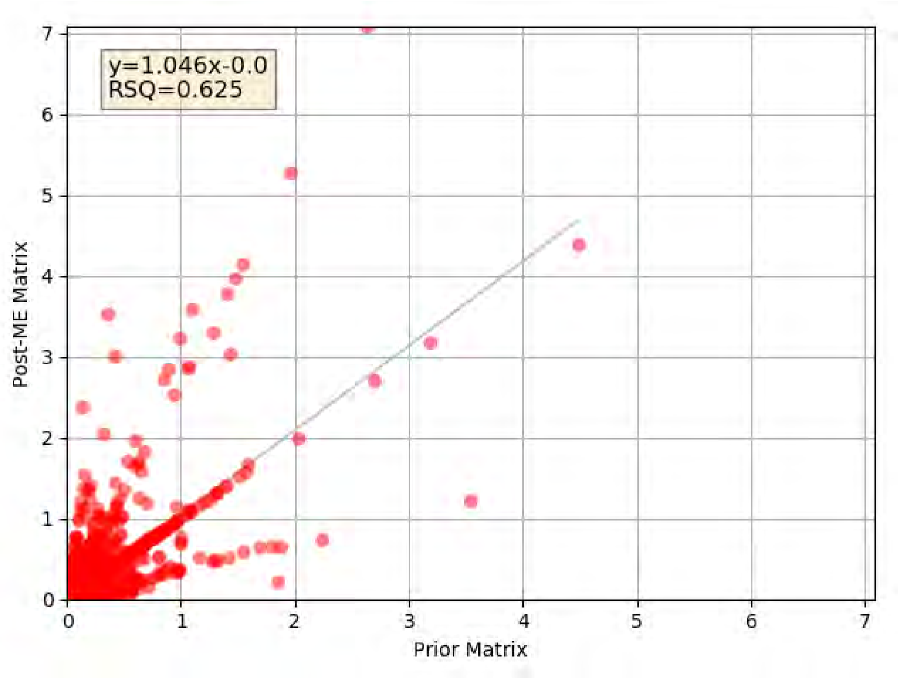


Figure A.7 Matrix Cell Changes, PM Peak Hour, Internal Origins, Car

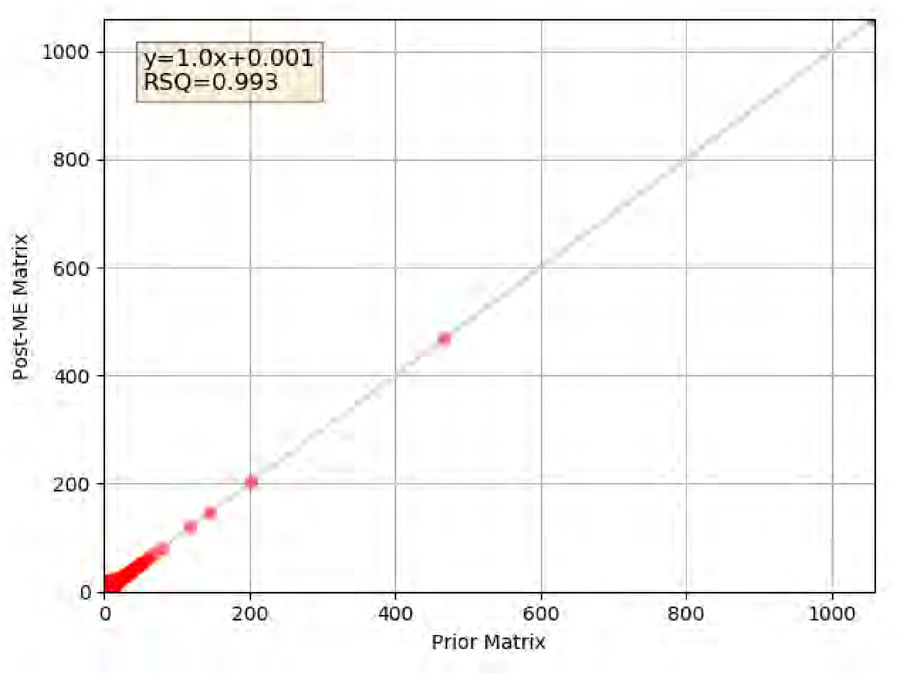


Figure A.8 Matrix Cell Changes, PM Peak Hour, Internal Origins, LGV

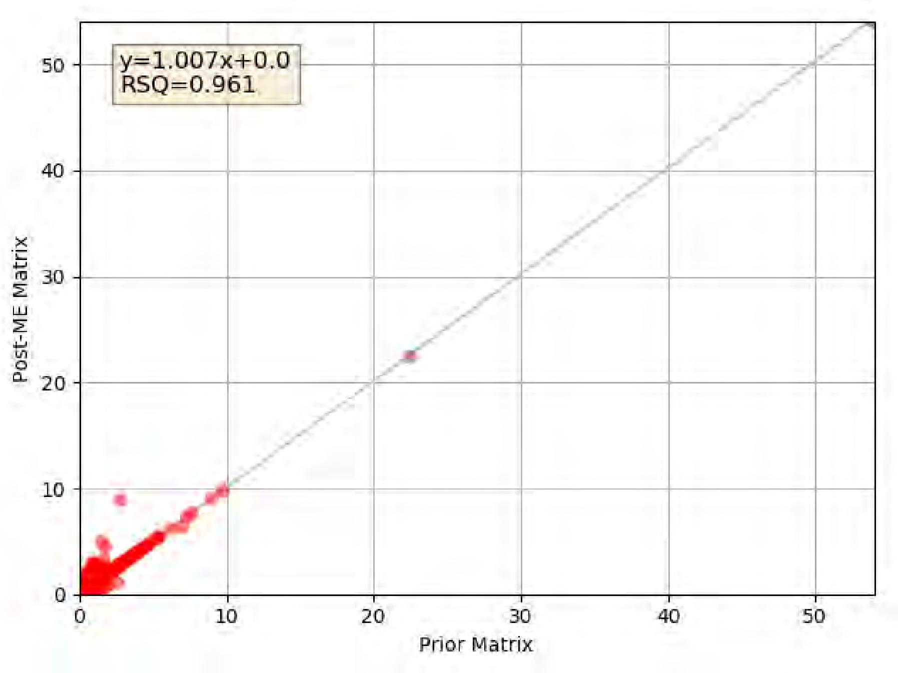
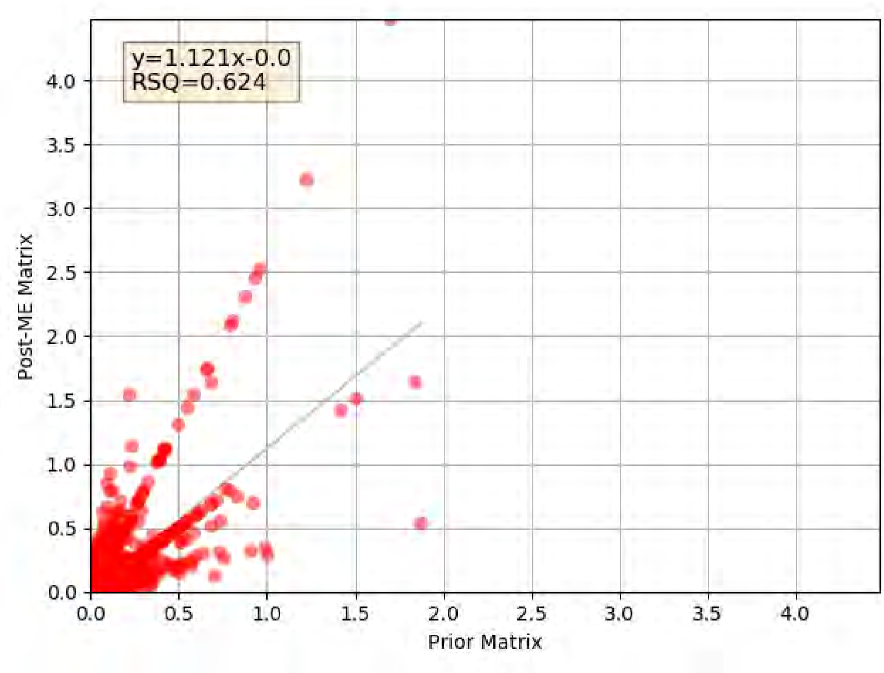


Figure A.9 Matrix Cell Changes, PM Peak Hour, Internal Origins, HGV



A2 Matrix Trip-end Changes

Figure A.10 Matrix Trip-End Changes, AM Peak Hour, Internal Origins, Car

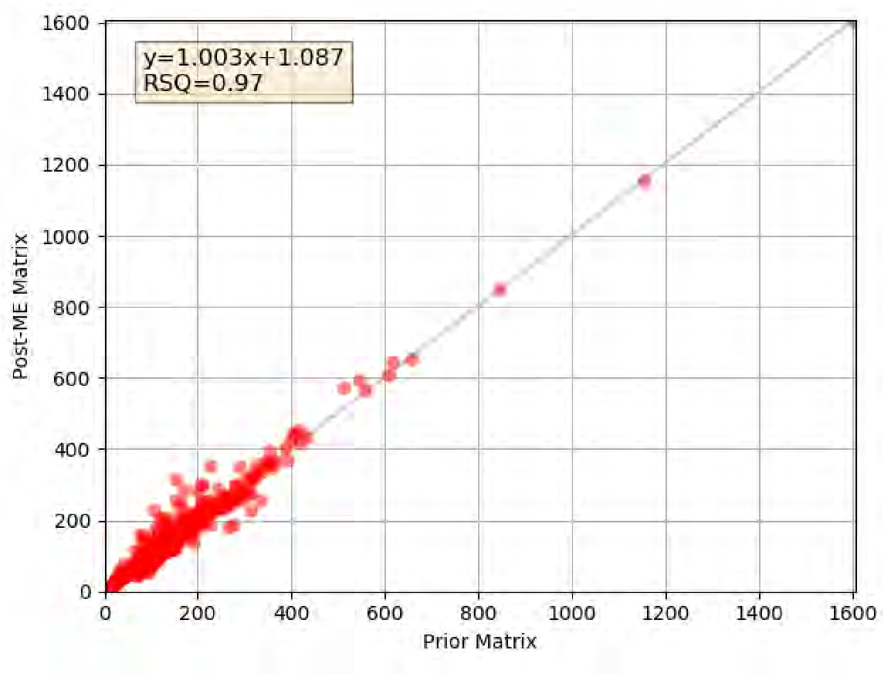


Figure A.11 Matrix Trip-End Changes, AM Peak Hour, Internal Origins, LGV

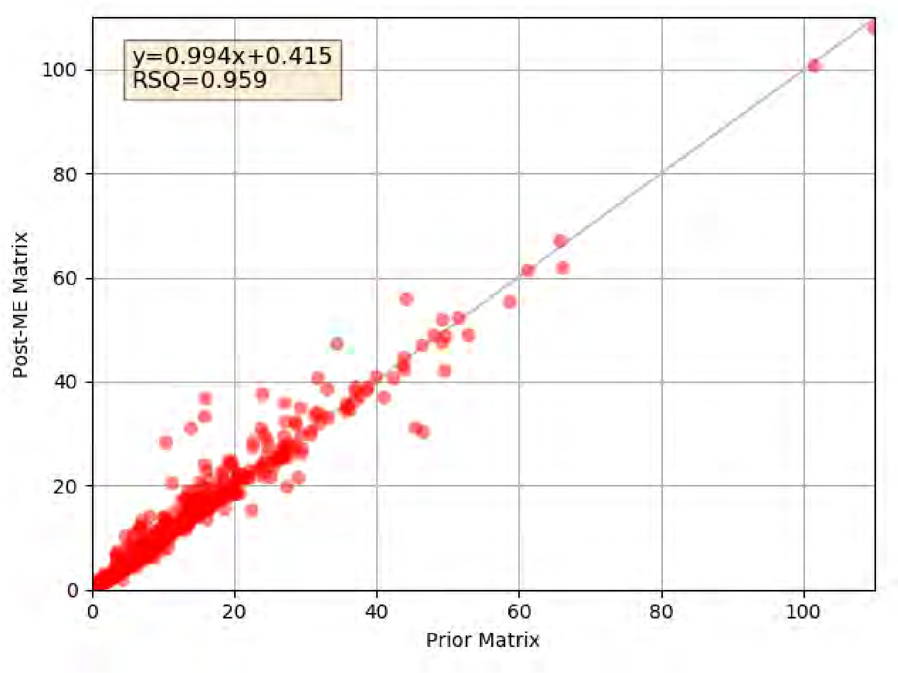


Figure A.12 Matrix Trip-End Changes, AM Peak Hour, Internal Origins, HGV

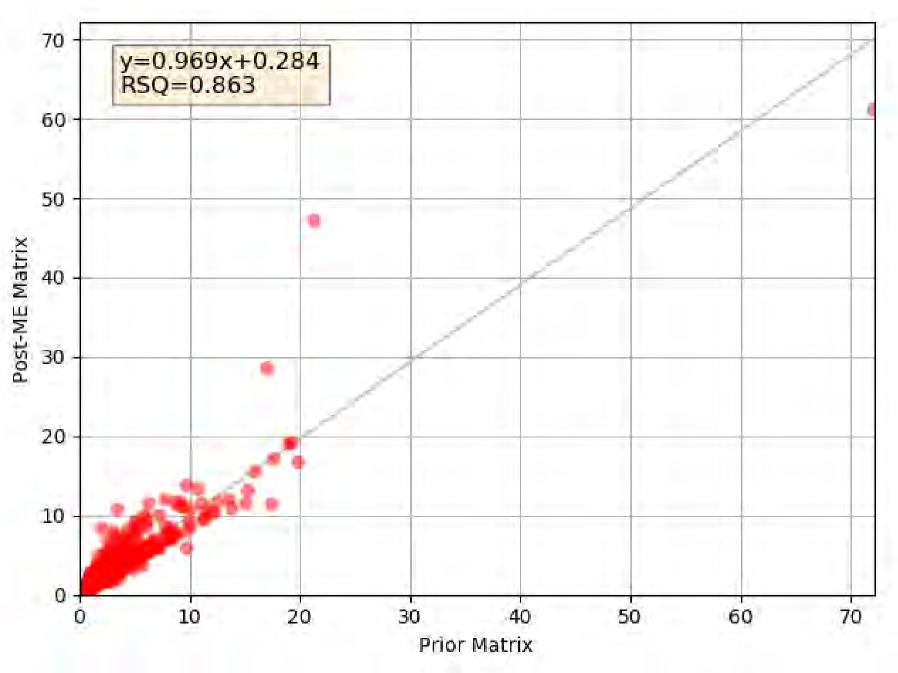


Figure A.13 Matrix Trip-End Changes, Interpeak Hour, Internal Origins, Car

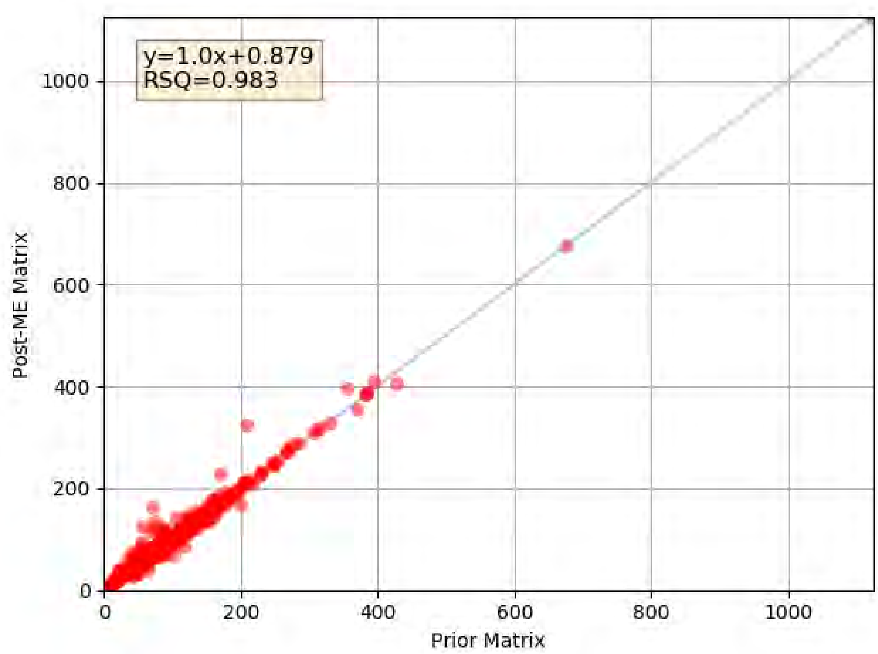


Figure A.14 Matrix Trip-End Changes, Interpeak Hour, Internal Origins, LGV

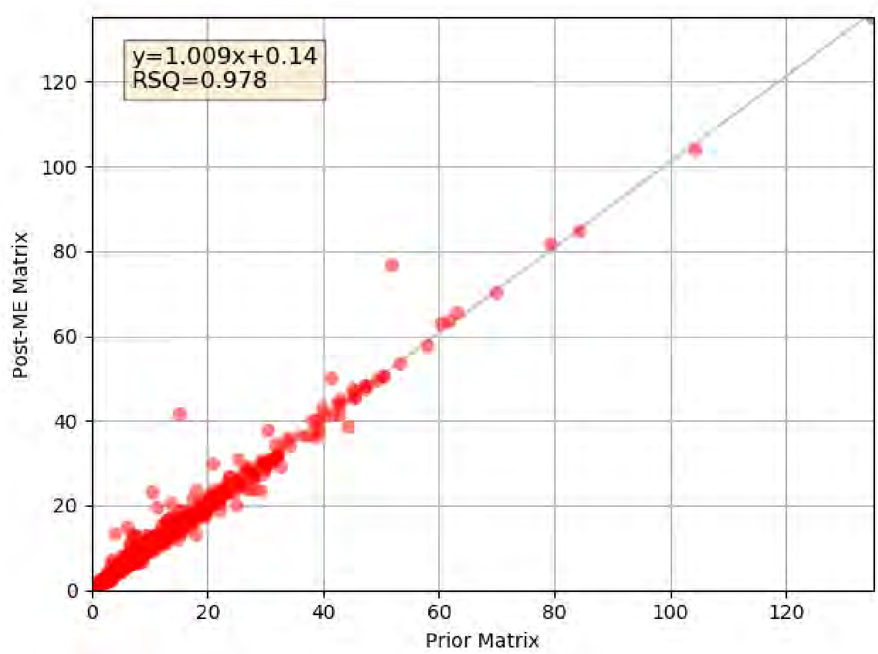


Figure A.15 Matrix Trip-End Changes, Interpeak Hour, Internal Origins, HGV

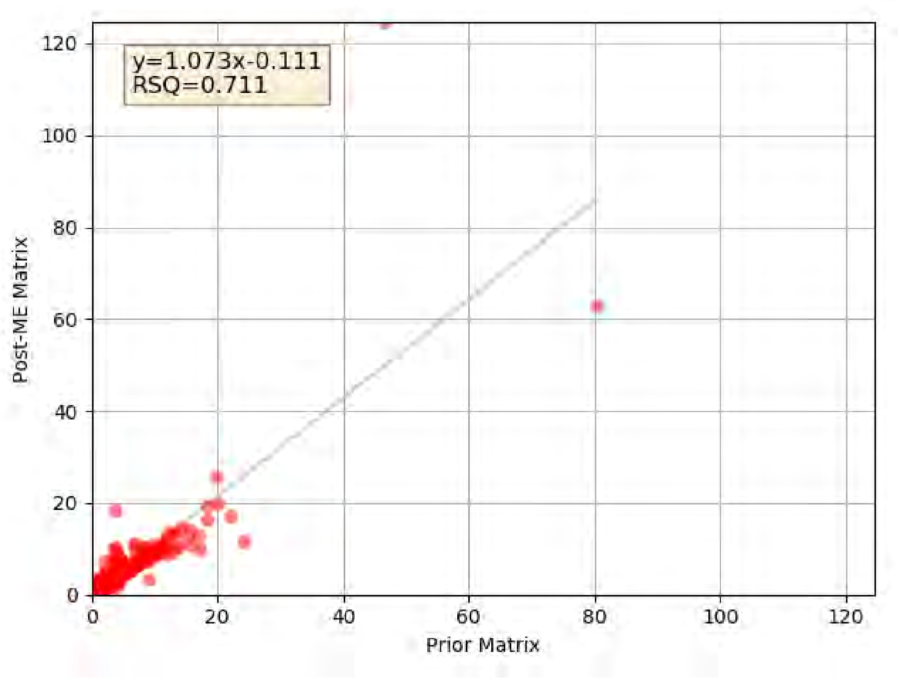


Figure A.16 Matrix Trip-End Changes, PM Peak Hour, Internal Origins, Car

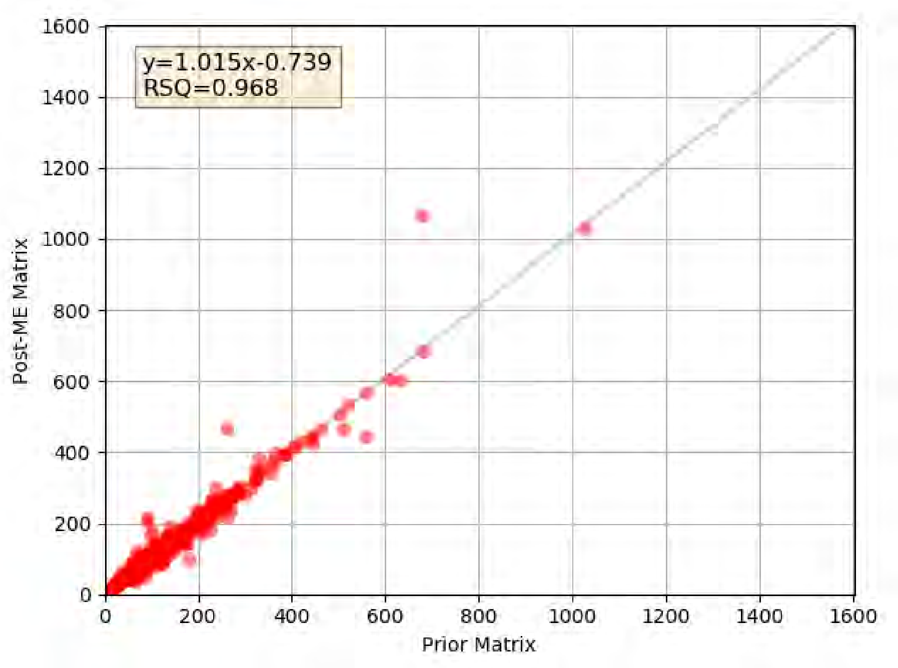


Figure A.17 Matrix Trip-End Changes, PM Peak Hour, Internal Origins, LGV

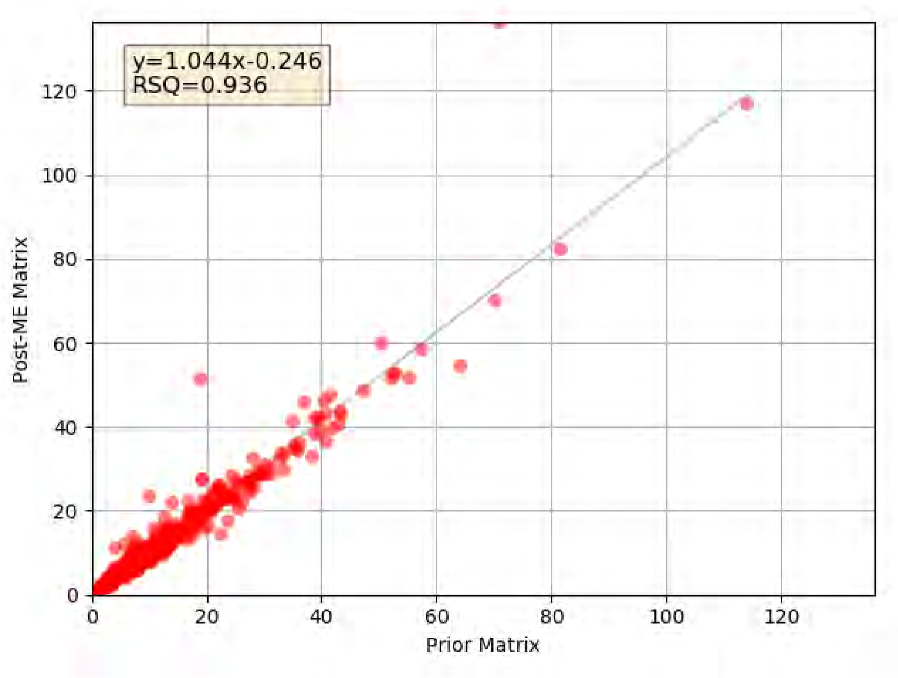
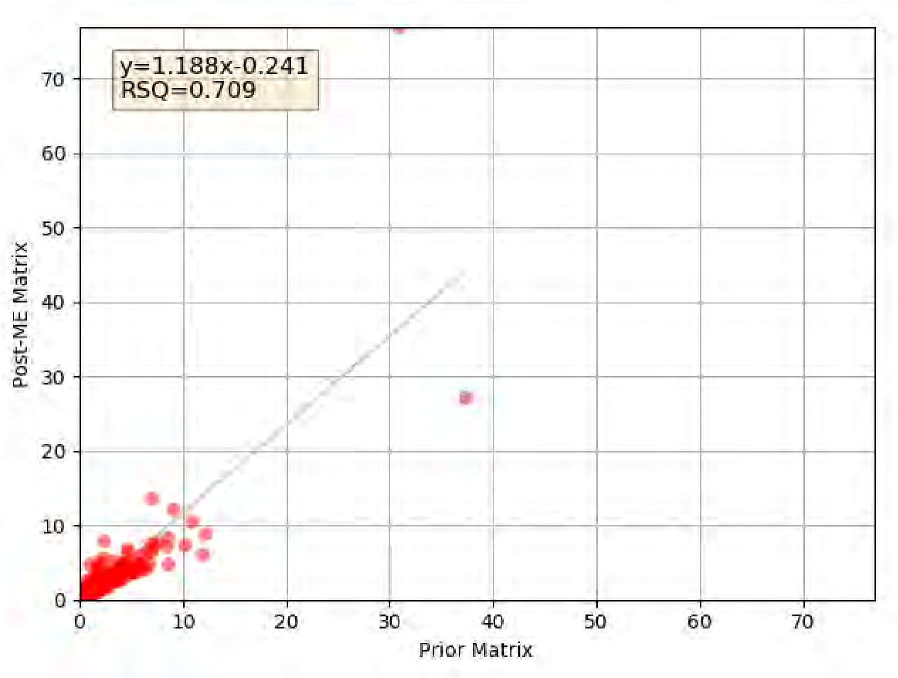


Figure A.18 Matrix Trip-End Changes, PM Peak Hour, Internal Origins, HGV



A3 Trip Length Distribution Plots

Figure A.19 Trip-Length Distributions, AM Peak Hour, Internal Origins: Car

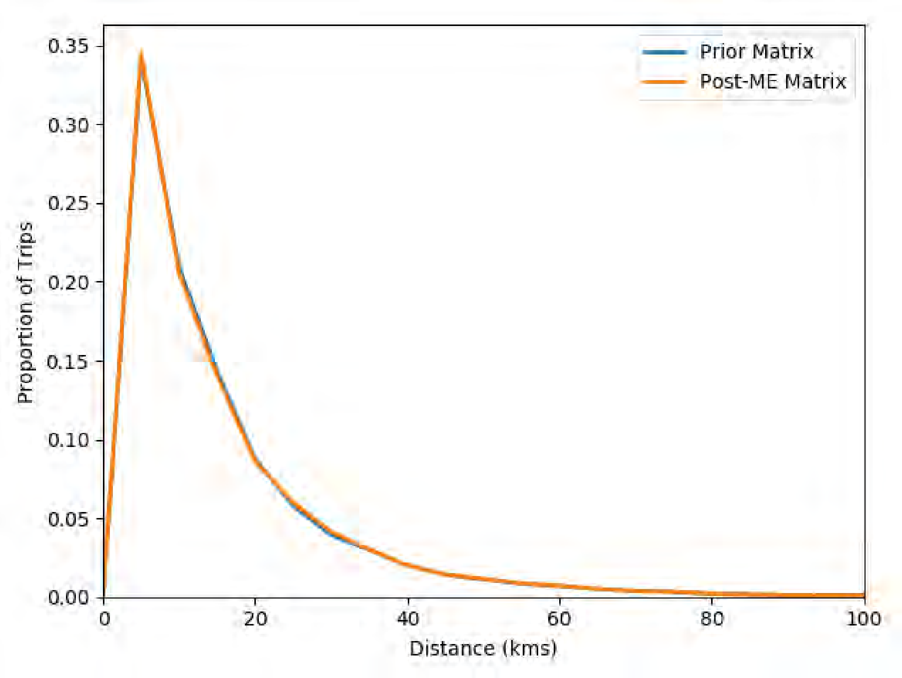


Figure A.20 Trip-Length Distributions, AM Peak Hour, Internal Origins: LGV

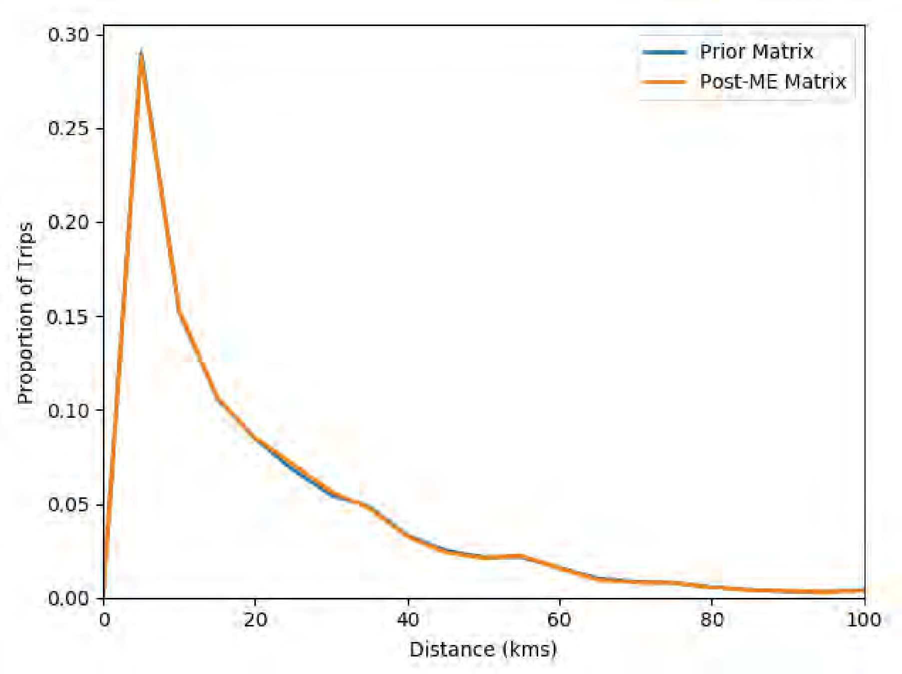


Figure A.21 Trip-Length Distributions, AM Peak Hour, Internal Origins: HGV

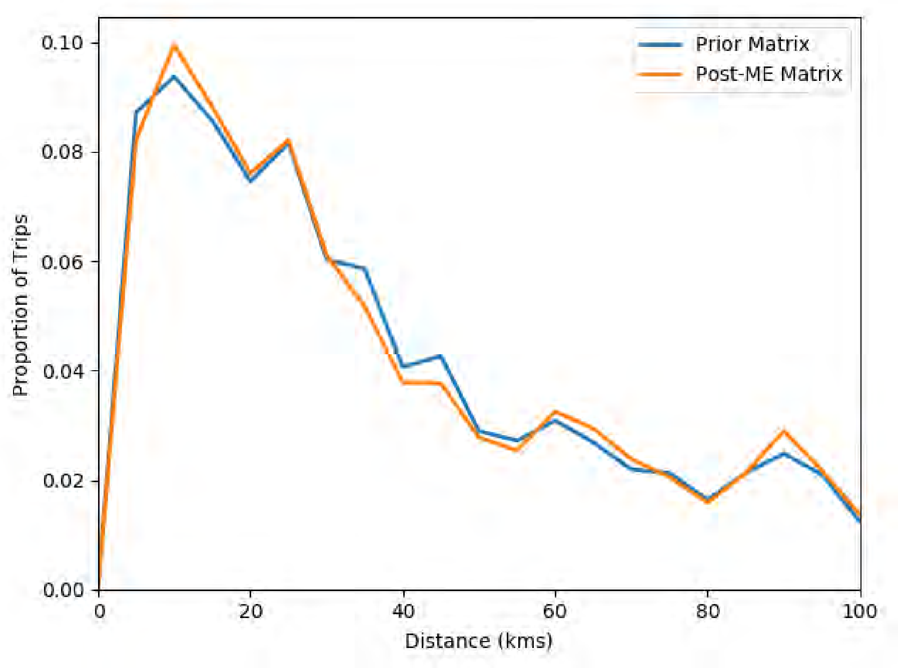


Figure A.22 Trip-Length Distributions, Interpeak Hour, Internal Origins: Car

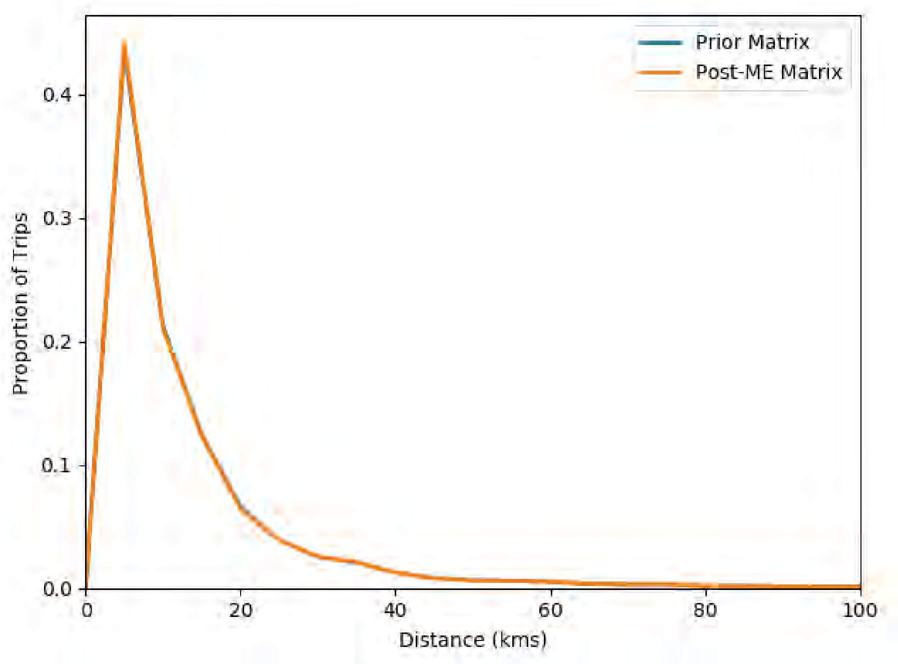


Figure A.23 Trip-Length Distributions, Interpeak Hour, Internal Origins: LGV

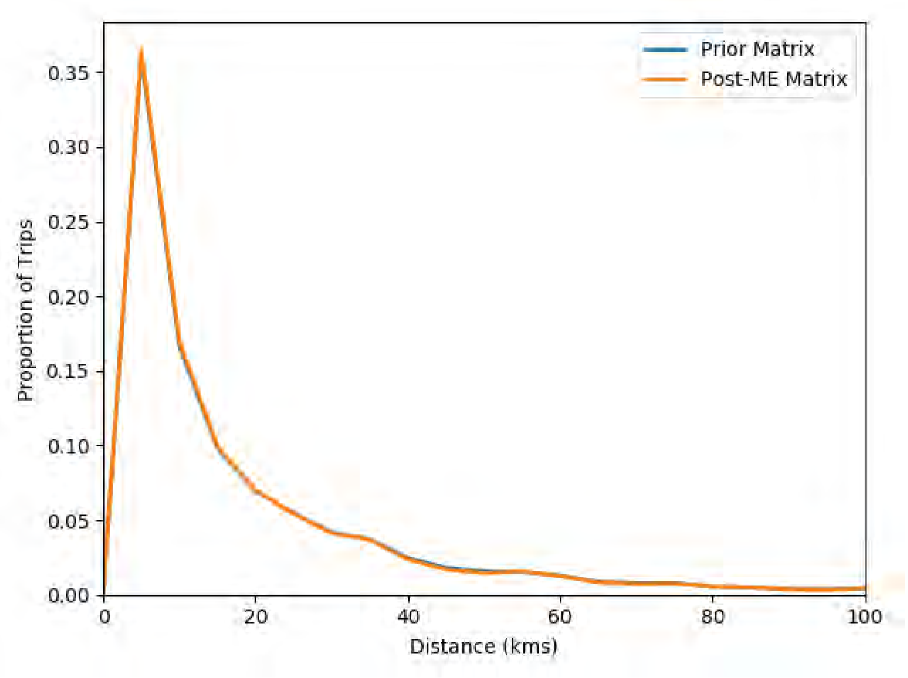


Figure A.24 Trip-Length Distributions, Interpeak Hour, Internal Origins: HGV

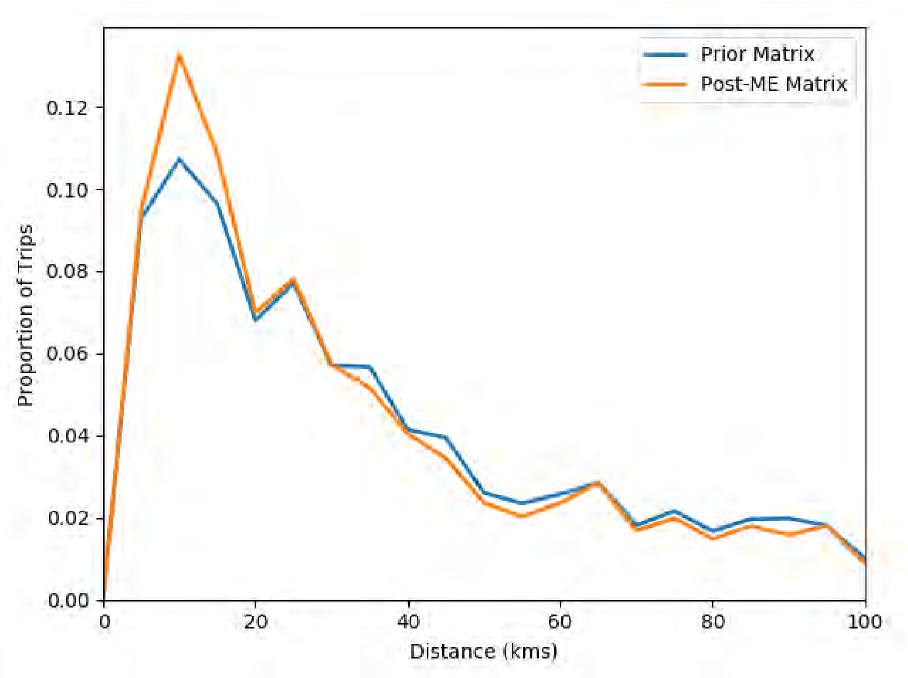


Figure A.25 Trip-Length Distributions, PM Peak Hour, Internal Origins: Car

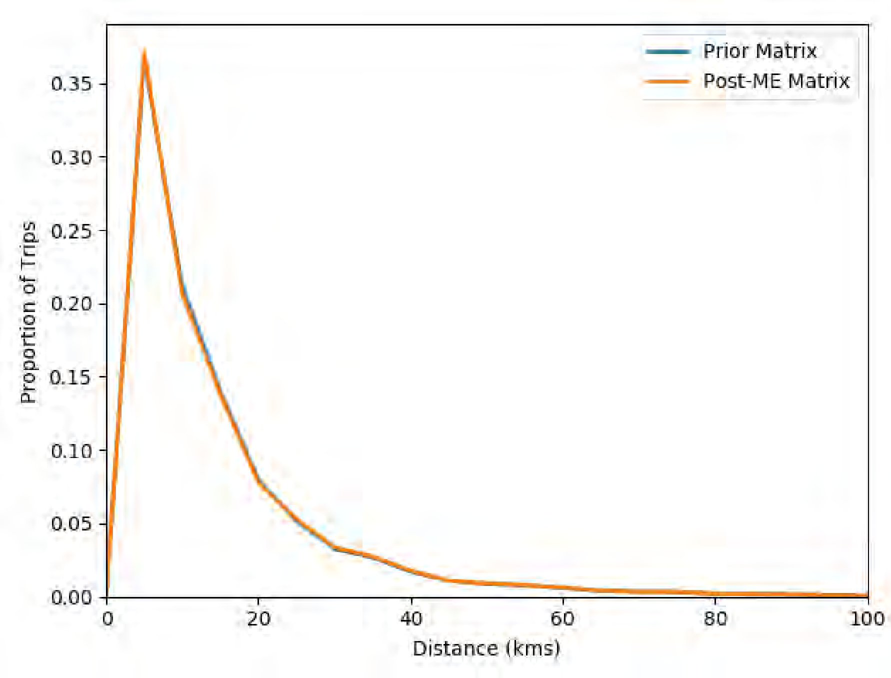


Figure A.26 Trip-Length Distributions, PM Peak Hour, Internal Origins: LGV

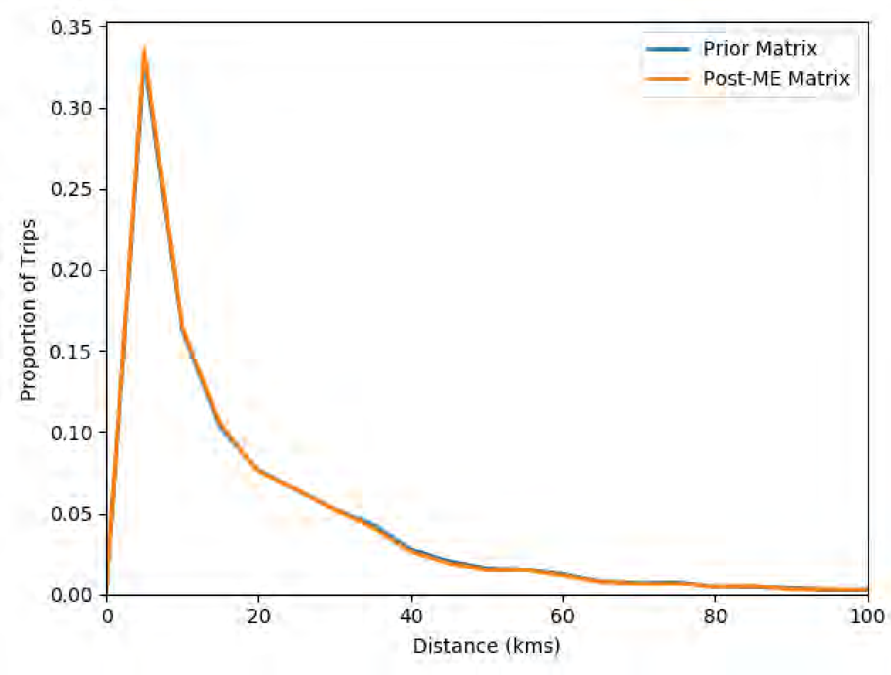
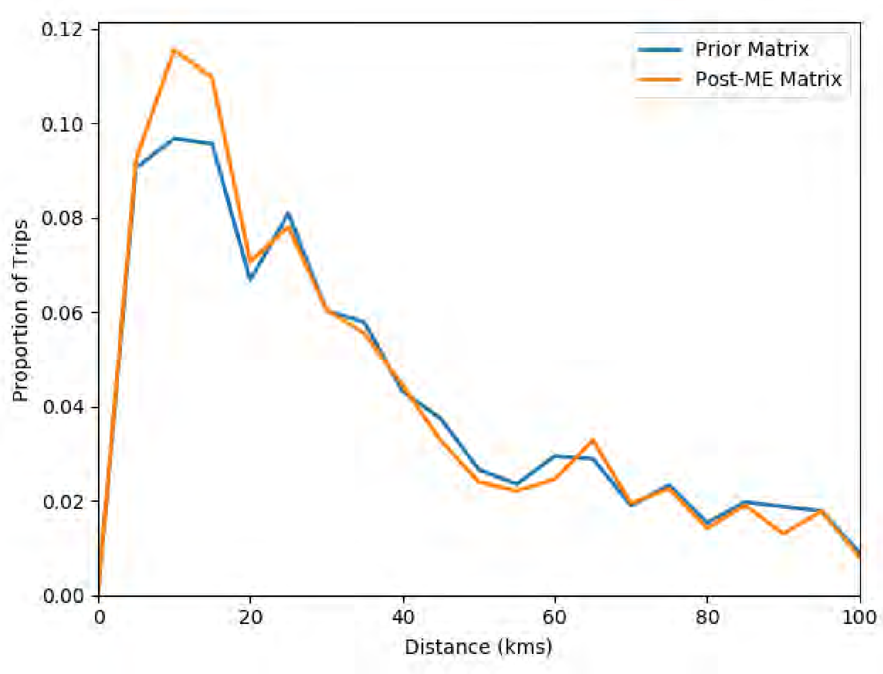


Figure A.27 Trip-Length Distributions, PM Peak Hour, Internal Origins: HGV



A4 Sector to Sector Level Matrices

Table A.1: Sectored Demand Changes, AM Peak Hour, Car

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	**17%**	1%	**32%**	0%	-12%	-8%	3%	21%	-42%	1%	44%	24%	25%	14%	21%	7%	45%	-4%	41%	-2%
Luton North-west	4%	-4%	0%	0%	-3%	8%	2%	6%	-32%	-20%	29%	0%	-23%	-2%	-19%	-5%	-7%	-27%	-5%	-23%
Luton South	6%	0%	**16%**	0%	**-26%**	-24%	-25%	-32%	-42%	-11%	-12%	-24%	-22%	7%	-27%	-9%	22%	-11%	21%	-10%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	4%	3%	9%	0%	2%	20%	5%	25%	2%	31%	5%	**-28%**	-28%	6%	-1%	11%	18%	-7%	13%	1%
Leighton Buzzard and West C.Beds.	5%	-9%	-13%	0%	-4%	**5%**	-4%	-1%	23%	-4%	18%	-16%	-32%	7%	11%	0%	5%	-1%	8%	-3%
Ampthill-Flitwick and Central C.Cbeds.	27%	-4%	-5%	0%	-1%	-5%	-2%	6%	-2%	3%	26%	-16%	-3%	-9%	-3%	-5%	-14%	5%	-14%	0%
Sandy-Biggleswade and East C.Beds.	21%	9%	17%	0%	49%	-10%	5%	2%	2%	7%	15%	12%	-6%	8%	-6%	-7%	13%	-1%	12%	8%
Bedford	57%	25%	-6%	0%	4%	8%	2%	9%	0%	3%	50%	14%	51%	11%	1%	1%	1%	0%	2%	1%
Milton Keynes	10%	-13%	-25%	0%	10%	-9%	-7%	-4%	6%	0%	-11%	-6%	-44%	-20%	11%	-2%	-15%	0%	-9%	0%
Dacorum	43%	-5%	-1%	0%	-1%	11%	-19%	-1%	18%	0%	0%	2%	-12%	**6%**	-9%	0%	-7%	-10%	0%	-6%
St Albans	42%	15%	-17%	0%	12%	14%	29%	26%	66%	40%	0%	-5%	12%	**9%**	18%	4%	1%	49%	1%	39%
North Hertfordshire	6%	-19%	6%	0%	-21%	-34%	-13%	**-11%**	15%	-6%	0%	-9%	1%	-2%	0%	-8%	1%	-3%	4%	-14%
Rest of Hertfordshire	-2%	-14%	-12%	0%	-9%	-25%	-20%	-4%	12%	-13%	1%	-3%	-3%	0%	0%	0%	0%	-4%	0%	-6%
Rest of East Anglia	18%	-3%	14%	0%	-10%	-8%	-3%	1%	0%	5%	11%	-3%	0%	0%	0%	1%	0%	0%	0%	0%
Bucks Oxfordshire Northants	8%	-17%	-19%	0%	-11%	-7%	-9%	-1%	2%	-1%	0%	-6%	-15%	-1%	1%	0%	-1%	0%	0%	0%
London	58%	1%	-10%	0%	4%	-27%	-17%	3%	16%	-7%	6%	-4%	-1%	-1%	0%	0%	0%	-3%	0%	-2%
External North	11%	-9%	-14%	0%	-9%	-7%	-9%	1%	0%	0%	23%	5%	-10%	-1%	0%	0%	-7%	0%	-2%	0%
External South	58%	-10%	-9%	0%	-4%	-3%	-15%	5%	16%	-2%	3%	-2%	-2%	-1%	0%	0%	0%	0%	0%	0%
External West	17%	-15%	-21%	0%	-14%	-7%	-12%	0%	2%	0%	15%	3%	-38%	-10%	-2%	0%	-5%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table A.2: Sectored Demand Changes, Interpeak Hour, Car

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	12%	8%	22%	0%	-1%	9%	20%	16%	29%	0%	53%	25%	5%	-8%	27%	12%	75%	23%	66%	23%
Luton North-west	7%	1%	1%	0%	2%	3%	-8%	1%	20%	-19%	6%	5%	-11%	-11%	7%	-7%	2%	-19%	5%	-19%
Luton South	19%	7%	7%	0%	-12%	-23%	-24%	-14%	5%	-17%	3%	-25%	-8%	-30%	-2%	-13%	20%	-15%	21%	-15%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	2%	1%	-1%	0%	-2%	22%	-19%	38%	52%	35%	-2%	-27%	-12%	-12%	10%	0%	2%	-17%	3%	-3%
Leighton Buzzard and West C.Beds.	-5%	2%	-25%	0%	11%	5%	-15%	-5%	58%	-11%	14%	-28%	-33%	-13%	15%	3%	-29%	-6%	4%	-8%
Ampthill-Flitwick and Central C.Cbeds.	25%	-1%	-35%	0%	-13%	3%	-3%	8%	6%	-3%	-14%	-15%	0%	-6%	-1%	-5%	-20%	-6%	-20%	-9%
Sandy-Biggleswade and East C.Beds.	9%	5%	-13%	0%	8%	11%	6%	1%	14%	13%	14%	13%	-7%	-3%	-4%	5%	0%	-1%	4%	13%
Bedford	21%	27%	-20%	0%	26%	3%	0%	5%	0%	6%	23%	37%	22%	12%	1%	1%	8%	1%	10%	2%
Milton Keynes	1%	-11%	-2%	0%	41%	-14%	-11%	32%	16%	0%	-8%	19%	-37%	-15%	43%	-1%	-1%	0%	0%	0%
Dacorum	14%	4%	-2%	0%	-9%	23%	-37%	2%	71%	-6%	0%	3%	-6%	0%	7%	0%	-2%	-7%	0%	-6%
St Albans	8%	13%	-9%	0%	-17%	-13%	-30%	15%	84%	-5%	1%	3%	4%	-1%	5%	0%	1%	4%	2%	2%
North Hertfordshire	-3%	-13%	2%	0%	-13%	3%	-4%	-8%	40%	-16%	14%	4%	0%	-1%	0%	-3%	0%	-9%	1%	-23%
Rest of Hertfordshire	-13%	-3%	-19%	0%	0%	7%	-18%	0%	25%	-13%	0%	-2%	-2%	0%	0%	-1%	0%	-7%	0%	-9%
Rest of East Anglia	10%	11%	-3%	0%	15%	2%	-8%	-5%	1%	6%	6%	4%	0%	0%	0%	2%	0%	0%	0%	-1%
Bucks Oxfordshire Northants	-13%	-15%	-18%	0%	-10%	1%	-19%	7%	7%	-1%	0%	0%	-12%	0%	6%	0%	0%	0%	0%	0%
London	46%	12%	22%	0%	16%	-4%	-37%	1%	46%	-12%	1%	1%	-3%	0%	0%	0%	0%	-7%	0%	-5%
External North	10%	-11%	-5%	0%	9%	-7%	-17%	3%	2%	0%	1%	28%	-14%	-3%	0%	0%	-1%	0%	0%	0%
External South	30%	10%	10%	0%	9%	23%	-35%	10%	48%	-4%	2%	2%	0%	2%	1%	0%	0%	-2%	0%	0%
External West	5%	-17%	-1%	0%	8%	-9%	-21%	51%	8%	0%	1%	16%	-32%	-7%	1%	0%	-1%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table A.3: Sectored Demand Changes, PM Peak Hour, Car

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	**14%**	-8%	-8%	0%	-10%	5%	20%	13%	28%	-8%	38%	17%	30%	22%	22%	18%	87%	-12%	58%	-6%
Luton North-west	**10%**	-3%	1%	0%	-1%	6%	-14%	10%	5%	-29%	-4%	11%	11%	-15%	1%	-23%	-13%	-33%	-16%	-35%
Luton South	**19%**	**15%**	**11%**	0%	-1%	-9%	-19%	-37%	23%	-25%	-3%	-18%	-5%	-14%	-15%	-11%	28%	-26%	21%	-22%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-2%	-3%	11%	0%	0%	**24%**	-6%	66%	81%	24%	-3%	6%	-8%	-15%	11%	-5%	1%	13%	-4%	12%
Leighton Buzzard and West C.Beds.	3%	16%	-14%	0%	12%	**6%**	**-33%**	-4%	52%	**-15%**	14%	-13%	-38%	-24%	14%	2%	-42%	-21%	-7%	-16%
Ampthill-Flitwick and Central C.Cbeds.	20%	-5%	-31%	0%	16%	20%	0%	17%	5%	-3%	16%	11%	-5%	-8%	3%	2%	-5%	-5%	-5%	-7%
Sandy-Biggleswade and East C.Beds.	24%	0%	-15%	0%	31%	11%	5%	0%	**16%**	5%	30%	-16%	-6%	-1%	-10%	0%	3%	-18%	5%	8%
Bedford	10%	-1%	-21%	0%	14%	5%	2%	2%	0%	0%	9%	58%	26%	12%	0%	0%	2%	0%	1%	0%
Milton Keynes	-8%	-10%	-4%	0%	**37%**	**-12%**	**-8%**	45%	**13%**	0%	-18%	50%	-41%	-23%	**66%**	-2%	-7%	0%	-4%	0%
Dacorum	17%	16%	3%	0%	-2%	31%	-12%	14%	151%	3%	0%	2%	-9%	3%	15%	0%	0%	2%	-2%	5%
St Albans	-8%	7%	-25%	0%	-28%	-1%	-19%	41%	139%	2%	2%	-3%	17%	0%	3%	-2%	-1%	12%	0%	3%
North Hertfordshire	3%	-15%	-10%	0%	-10%	25%	0%	**-10%**	49%	-10%	41%	-3%	0%	0%	-1%	4%	2%	-13%	15%	-5%
Rest of Hertfordshire	-6%	6%	0%	0%	-14%	6%	-17%	1%	28%	-23%	0%	**7%**	-4%	0%	0%	-2%	0%	-16%	-1%	-12%
Rest of East Anglia	17%	4%	-9%	0%	3%	-8%	-2%	-2%	1%	-4%	7%	4%	0%	0%	0%	0%	0%	0%	0%	-1%
Bucks Oxfordshire Northants	8%	-13%	0%	0%	-4%	-2%	-16%	16%	8%	-2%	0%	1%	-10%	0%	1%	0%	0%	0%	0%	0%
London	34%	6%	27%	0%	5%	-13%	**-26%**	3%	**67%**	-21%	**6%**	-5%	-5%	-1%	0%	-1%	0%	-16%	0%	-7%
External North	-9%	-23%	-5%	0%	7%	-11%	-6%	1%	2%	0%	4%	60%	-12%	-5%	0%	0%	1%	0%	0%	0%
External South	14%	6%	25%	0%	0%	20%	-25%	25%	51%	-11%	4%	0%	13%	1%	0%	0%	0%	-4%	0%	0%
External West	-15%	-24%	0%	0%	0%	-10%	-13%	11%	4%	0%	4%	49%	-28%	-13%	-1%	0%	0%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table A.4: Sectored Demand Changes, AM Peak Hour, LGV

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	26%	9%	8%	0%	16%	-4%	17%	36%	-29%	3%	12%	3%	73%	27%	19%	7%	-1%	-23%	-10%	-27%
Luton North-west	9%	4%	1%	0%	17%	47%	10%	16%	-13%	6%	-1%	-13%	-21%	-6%	-19%	-6%	-18%	12%	-12%	15%
Luton South	-7%	0%	-2%	0%	3%	3%	4%	7%	4%	26%	22%	16%	-23%	25%	8%	6%	17%	9%	19%	6%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-11%	-11%	-3%	0%	4%	32%	17%	-7%	4%	35%	-7%	11%	-34%	32%	-4%	-3%	45%	9%	17%	7%
Leighton Buzzard and West C.Beds.	-36%	-34%	-19%	0%	0%	7%	15%	-20%	29%	7%	21%	-23%	-47%	-4%	-1%	10%	-15%	10%	-10%	11%
Ampthill-Flitwick and Central C.Cbeds.	45%	9%	30%	0%	27%	16%	6%	16%	4%	27%	-8%	-25%	1%	-17%	0%	22%	-14%	48%	-4%	40%
Sandy-Biggleswade and East C.Beds.	32%	-8%	-28%	0%	85%	-14%	19%	5%	7%	-7%	20%	6%	7%	8%	-1%	-3%	10%	-8%	12%	-9%
Bedford	110%	47%	42%	0%	38%	-8%	14%	20%	0%	3%	12%	2%	61%	3%	0%	0%	-9%	1%	-9%	2%
Milton Keynes	-22%	-18%	-20%	0%	37%	-5%	0%	-1%	7%	0%	-9%	-19%	-31%	-24%	8%	-5%	-21%	0%	-9%	0%
Dacorum	-26%	-25%	-7%	0%	-19%	4%	-27%	-44%	8%	-25%	0%	-2%	-42%	0%	-9%	0%	-5%	-16%	-2%	-11%
St Albans	5%	42%	-5%	0%	104%	33%	31%	-7%	59%	67%	1%	0%	10%	3%	4%	4%	3%	40%	3%	78%
North Hertfordshire	31%	-22%	-37%	0%	-16%	-36%	-3%	7%	40%	-31%	1%	-2%	1%	-1%	1%	-4%	0%	-8%	1%	-29%
Rest of Hertfordshire	-4%	-13%	-3%	0%	9%	-21%	-25%	1%	2%	-34%	-1%	-6%	-2%	0%	0%	-2%	0%	-16%	0%	-23%
Rest of East Anglia	15%	-4%	-7%	0%	14%	-22%	0%	6%	0%	-1%	5%	-6%	1%	0%	0%	0%	0%	0%	0%	-2%
Bucks Oxfordshire Northants	-36%	-30%	-27%	0%	-14%	10%	-3%	0%	2%	0%	-1%	-1%	-17%	0%	1%	0%	0%	0%	0%	0%
London	6%	-2%	36%	0%	8%	-18%	-23%	1%	2%	-27%	6%	-3%	-1%	0%	0%	0%	0%	-10%	0%	-4%
External North	4%	23%	6%	0%	39%	-5%	4%	11%	2%	0%	-17%	-13%	-4%	-5%	0%	0%	-10%	0%	-2%	0%
External South	3%	-2%	24%	0%	1%	0%	-21%	-5%	4%	-6%	3%	4%	-3%	1%	1%	0%	0%	-2%	0%	0%
External West	-32%	0%	-14%	0%	20%	0%	0%	-9%	3%	0%	-7%	-15%	-40%	-15%	-2%	0%	-5%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table A.5: Sectored Demand Changes, Interpeak Hour, LGV

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	21%	15%	-9%	0%	-12%	-35%	31%	68%	-2%	-25%	32%	22%	44%	9%	41%	-11%	23%	-28%	25%	-28%
Luton North-west	10%	7%	24%	0%	4%	-5%	-6%	7%	4%	-17%	3%	13%	-5%	-7%	-3%	-13%	-7%	-5%	-7%	-6%
Luton South	-1%	15%	5%	0%	4%	-28%	-21%	-3%	18%	-11%	49%	33%	-9%	2%	26%	4%	86%	-5%	75%	-12%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-7%	4%	1%	0%	-2%	10%	3%	39%	59%	26%	-9%	16%	-13%	-8%	3%	-9%	2%	5%	3%	5%
Leighton Buzzard and West C.Beds.	-22%	-7%	-17%	0%	10%	6%	-9%	7%	26%	-5%	11%	-11%	-14%	-14%	-4%	12%	-20%	-4%	-2%	-6%
Ampthill-Flitwick and Central C.Cbeds.	25%	-1%	-13%	0%	3%	21%	-1%	30%	6%	-11%	-19%	-13%	2%	-16%	1%	-8%	-25%	-16%	-24%	-23%
Sandy-Biggleswade and East C.Beds.	32%	9%	-20%	0%	8%	23%	20%	4%	23%	22%	21%	-15%	5%	1%	-1%	8%	3%	-1%	7%	22%
Bedford	12%	33%	16%	0%	32%	4%	3%	15%	0%	11%	22%	21%	16%	9%	1%	3%	3%	2%	9%	6%
Milton Keynes	-9%	-7%	18%	0%	30%	-6%	-13%	31%	15%	0%	-8%	16%	-22%	-20%	31%	0%	-11%	0%	-4%	0%
Dacorum	-22%	-18%	4%	0%	-17%	12%	-42%	-15%	17%	-10%	0%	1%	-20%	-3%	-2%	-1%	-4%	-11%	-1%	-8%
St Albans	-13%	17%	52%	0%	37%	-5%	-26%	-14%	15%	-8%	2%	6%	-8%	-5%	-4%	1%	0%	-6%	1%	-6%
North Hertfordshire	30%	-9%	-20%	0%	-28%	5%	-3%	1%	28%	-21%	8%	-3%	1%	-3%	0%	-10%	0%	-8%	-3%	-28%
Rest of Hertfordshire	-10%	-5%	7%	0%	-4%	-2%	-27%	1%	15%	-23%	-1%	-4%	-3%	0%	0%	-2%	0%	-10%	0%	-16%
Rest of East Anglia	12%	4%	7%	0%	11%	5%	-8%	-1%	1%	9%	3%	-1%	0%	0%	0%	1%	0%	0%	0%	-2%
Bucks Oxfordshire Northants	-19%	-10%	7%	0%	-12%	11%	-15%	9%	11%	0%	0%	0%	-10%	-1%	3%	0%	0%	0%	0%	0%
London	-8%	2%	38%	0%	24%	8%	-36%	1%	27%	-14%	1%	0%	-2%	0%	0%	0%	0%	-9%	0%	-4%
External North	-17%	15%	21%	0%	23%	0%	-17%	-5%	-1%	0%	3%	21%	-6%	-6%	0%	0%	-6%	0%	-1%	0%
External South	-7%	-2%	33%	0%	3%	15%	-34%	5%	26%	-5%	1%	2%	-4%	0%	1%	0%	0%	-2%	0%	0%
External West	-15%	1%	19%	0%	19%	0%	-23%	6%	1%	0%	1%	27%	-28%	-13%	-1%	0%	-3%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table A.6: Sectored Demand Changes, PM Peak Hour, LGV

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	27%	2%	-9%	0%	-11%	-23%	44%	34%	68%	-21%	4%	-4%	48%	13%	-9%	-27%	5%	-14%	38%	-26%
Luton North-west	6%	4%	22%	0%	-7%	-9%	-11%	13%	20%	-36%	-8%	38%	-10%	-16%	-2%	-36%	-28%	-27%	-16%	-27%
Luton South	-4%	29%	29%	0%	28%	9%	10%	-31%	57%	-1%	16%	23%	-21%	13%	35%	-21%	76%	6%	56%	3%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-15%	3%	10%	0%	2%	22%	7%	43%	51%	20%	-8%	59%	-24%	-5%	4%	-7%	6%	6%	-9%	6%
Leighton Buzzard and West C.Beds.	-16%	38%	-7%	0%	29%	7%	-28%	11%	12%	-9%	17%	29%	-53%	-21%	-7%	3%	-44%	-10%	-9%	-3%
Ampthill-Flitwick and Central C.Cbeds.	6%	-8%	-17%	0%	12%	28%	1%	39%	8%	-7%	-28%	18%	4%	-25%	0%	-2%	-24%	-4%	-19%	-14%
Sandy-Biggleswade and East C.Beds.	45%	0%	-46%	0%	12%	10%	17%	5%	34%	6%	45%	3%	16%	7%	-4%	5%	13%	-7%	9%	2%
Bedford	-1%	3%	-11%	0%	43%	25%	3%	19%	0%	1%	17%	22%	51%	-4%	0%	-1%	-6%	0%	-3%	0%
Milton Keynes	-23%	-3%	22%	0%	66%	2%	6%	45%	24%	0%	-15%	97%	-34%	-38%	60%	-1%	-21%	0%	-5%	0%
Dacorum	-19%	3%	-13%	0%	-19%	10%	-11%	-16%	38%	-9%	0%	0%	-21%	-3%	3%	0%	-2%	1%	0%	6%
St Albans	-44%	-18%	-25%	0%	29%	-12%	-32%	-4%	6%	-16%	3%	4%	-10%	-5%	-11%	-1%	-6%	-6%	-1%	-15%
North Hertfordshire	11%	-4%	-36%	0%	-17%	12%	5%	-4%	37%	-13%	33%	27%	1%	1%	-1%	-5%	-1%	-7%	12%	-9%
Rest of Hertfordshire	-7%	35%	56%	0%	11%	7%	-27%	3%	4%	-20%	0%	8%	-3%	0%	0%	-2%	1%	-15%	0%	-13%
Rest of East Anglia	6%	3%	0%	0%	6%	8%	3%	3%	1%	-2%	2%	5%	0%	0%	0%	0%	0%	0%	0%	-1%
Bucks Oxfordshire Northants	-12%	-19%	6%	0%	-13%	-2%	-1%	8%	10%	-3%	1%	9%	-14%	1%	5%	0%	0%	0%	0%	0%
London	11%	5%	28%	0%	14%	-20%	-24%	-1%	15%	-16%	13%	1%	2%	0%	0%	0%	0%	-8%	0%	-2%
External North	-11%	-8%	25%	0%	36%	5%	22%	8%	2%	0%	19%	108%	-9%	-14%	0%	0%	-4%	0%	-2%	0%
External South	13%	13%	22%	0%	-10%	15%	-20%	13%	8%	-7%	3%	-1%	-1%	1%	2%	0%	0%	-2%	0%	0%
External West	-19%	-1%	33%	0%	46%	4%	6%	5%	10%	0%	9%	102%	-35%	-20%	-1%	0%	-3%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table A.7: Sectored Demand Changes, AM Peak Hour, HGV

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	12%	-1%	-19%	0%	-12%	-4%	27%	29%	134%	-12%	-12%	-23%	61%	8%	8%	-14%	-21%	-23%	-20%	-36%
Luton North-west	-27%	-1%	60%	0%	-12%	114%	37%	73%	105%	-5%	30%	40%	-24%	12%	40%	-8%	50%	-20%	-11%	-26%
Luton South	-24%	86%	3%	0%	118%	162%	44%	31%	32%	86%	42%	7%	-62%	26%	17%	45%	38%	44%	42%	48%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	37%	7%	116%	0%	22%	51%	-22%	-15%	-63%	35%	-14%	24%	-17%	34%	4%	-17%	-6%	-41%	13%	-24%
Leighton Buzzard and West C.Beds.	12%	18%	88%	0%	-2%	17%	54%	-26%	-42%	17%	39%	87%	-29%	32%	3%	29%	25%	7%	40%	35%
Ampthill-Flitwick and Central C.Cbeds.	61%	-17%	59%	0%	-36%	4%	3%	77%	7%	16%	21%	40%	63%	29%	27%	28%	58%	50%	29%	51%
Sandy-Biggleswade and East C.Beds.	55%	-53%	-47%	0%	-59%	-37%	-13%	3%	30%	15%	-11%	52%	39%	69%	88%	16%	71%	-3%	64%	25%
Bedford	395%	18%	122%	0%	-75%	-50%	17%	55%	0%	28%	-52%	-14%	203%	152%	85%	-7%	-14%	0%	24%	1%
Milton Keynes	-18%	-11%	59%	0%	42%	-11%	-40%	5%	33%	0%	-22%	3%	-61%	-50%	34%	-1%	-17%	0%	-7%	0%
Dacorum	-50%	-22%	-51%	0%	-32%	28%	-34%	-77%	-57%	-42%	0%	-4%	-66%	-1%	-6%	-4%	-1%	-28%	0%	-23%
St Albans	-4%	92%	6%	0%	101%	94%	21%	56%	-29%	57%	19%	0%	32%	2%	-1%	31%	6%	40%	9%	42%
North Hertfordshire	40%	-20%	-60%	0%	-30%	-7%	22%	46%	85%	-18%	-20%	-18%	1%	-7%	0%	-1%	-21%	24%	-12%	50%
Rest of Hertfordshire	-28%	-1%	-40%	0%	4%	-10%	-28%	27%	-49%	-35%	-2%	-7%	-4%	-1%	-1%	-13%	-5%	-24%	-5%	-27%
Rest of East Anglia	-32%	27%	-19%	0%	0%	-29%	-1%	42%	-8%	33%	3%	-10%	-6%	-4%	0%	3%	0%	0%	0%	1%
Bucks Oxfordshire Northants	-35%	-26%	-6%	0%	-33%	22%	-16%	38%	7%	0%	-4%	3%	58%	-5%	2%	0%	-1%	0%	0%	0%
London	-29%	44%	-36%	0%	40%	21%	-19%	45%	-60%	31%	21%	-5%	-12%	-5%	-1%	1%	0%	1%	0%	3%
External North	-36%	-22%	28%	0%	-48%	-19%	-18%	14%	0%	0%	-16%	4%	34%	-12%	-2%	0%	-10%	0%	-2%	0%
External South	-31%	-20%	-31%	0%	0%	31%	-36%	23%	-1%	-1%	10%	-1%	-23%	-1%	2%	0%	0%	0%	0%	0%
External West	-37%	-37%	16%	0%	-13%	8%	-34%	1%	6%	0%	-13%	3%	-39%	-25%	-4%	0%	-7%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table A.8: Sectored Demand Changes, Interpeak Hour, HGV

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	19%	-7%	-9%	0%	35%	12%	-33%	35%	127%	-25%	-29%	-20%	43%	-15%	-15%	-44%	-31%	-48%	-35%	-47%
Luton North-west	-25%	3%	92%	0%	39%	42%	-13%	-6%	96%	27%	-20%	0%	-29%	-18%	-10%	-32%	0%	-36%	-35%	-36%
Luton South	20%	120%	-2%	0%	128%	143%	72%	60%	390%	90%	-18%	-20%	0%	-15%	-48%	32%	-10%	40%	-18%	42%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	6%	-14%	105%	0%	17%	0%	-45%	-43%	-81%	-14%	-42%	19%	-24%	-6%	-24%	-46%	-1%	-44%	-21%	-37%
Leighton Buzzard and West C.Beds.	-12%	31%	73%	0%	9%	13%	-11%	-42%	-51%	10%	39%	12%	-34%	-10%	-27%	35%	-6%	-8%	43%	21%
Ampthill-Flitwick and Central C.Cbeds.	4%	8%	92%	0%	-40%	47%	6%	64%	13%	9%	-17%	-7%	50%	-26%	6%	4%	-17%	12%	-21%	14%
Sandy-Biggleswade and East C.Beds.	42%	5%	10%	0%	-40%	-6%	57%	23%	33%	52%	-32%	40%	77%	47%	53%	19%	53%	15%	54%	60%
Bedford	123%	62%	85%	0%	-72%	-42%	10%	35%	0%	17%	-57%	-44%	91%	40%	33%	6%	-36%	0%	16%	5%
Milton Keynes	0%	-8%	103%	0%	15%	-9%	-35%	56%	37%	0%	-40%	28%	-45%	-38%	59%	-1%	53%	0%	-6%	0%
Dacorum	-43%	-23%	-59%	0%	-18%	41%	-33%	-41%	-70%	-47%	0%	4%	-30%	-3%	-5%	-7%	1%	-39%	1%	-28%
St Albans	-25%	22%	-48%	0%	27%	85%	-8%	95%	-63%	17%	8%	0%	-9%	-4%	-7%	7%	-2%	-1%	26%	5%
North Hertfordshire	24%	-8%	-18%	0%	-20%	48%	58%	78%	73%	19%	-20%	-6%	1%	-5%	-1%	0%	-10%	5%	-5%	28%
Rest of Hertfordshire	-24%	0%	-48%	0%	13%	31%	-26%	88%	-64%	-15%	5%	-2%	-9%	-1%	-4%	-7%	-1%	-13%	0%	-23%
Rest of East Anglia	-18%	13%	-55%	0%	-11%	3%	-1%	117%	-11%	26%	15%	-5%	-2%	-2%	0%	1%	0%	-1%	1%	-2%
Bucks Oxfordshire Northants	-16%	-14%	78%	0%	-25%	35%	-15%	29%	9%	0%	-2%	13%	0%	-9%	4%	0%	0%	0%	0%	0%
London	-26%	31%	-49%	0%	29%	52%	-20%	72%	-68%	51%	19%	-4%	-36%	-11%	-1%	0%	0%	-5%	0%	-2%
External North	-11%	-15%	102%	0%	-44%	-14%	-17%	13%	0%	0%	-8%	11%	-11%	-10%	1%	0%	3%	0%	1%	0%
External South	-27%	-13%	-30%	0%	13%	44%	-31%	89%	-7%	-4%	10%	17%	-26%	-4%	0%	0%	0%	-1%	0%	0%
External West	-11%	-17%	99%	0%	-25%	18%	-22%	30%	8%	0%	-11%	14%	-21%	-23%	3%	0%	2%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Table A.9: Sectored Demand Changes, PM Peak Hour, HGV

	Luton East	Luton North-west	Luton South	Luton Airport (fixed)	Dunstable and South C.Beds.	Leighton Buzzard and West C.Beds.	Ampthill-Flitwick and Central C.Cbeds.	Sandy-Biggleswade and East C.Beds.	Bedford	Milton Keynes	Dacorum	St Albans	North Hertfordshire	Rest of Hertfordshire	Rest of East Anglia	Bucks Oxfordshire Northants	London	External North	External South	External West
Luton East	19%	-38%	-27%	0%	-7%	15%	22%	-15%	401%	-25%	-56%	-50%	50%	-29%	-54%	-23%	-58%	-31%	-62%	-43%
Luton North-west	-30%	-14%	76%	0%	7%	46%	-40%	-42%	30%	-12%	-18%	5%	-26%	-17%	-11%	-48%	4%	-62%	-55%	-64%
Luton South	-8%	68%	-2%	0%	91%	171%	103%	-16%	164%	100%	-48%	-60%	12%	-35%	-61%	43%	-47%	62%	-56%	63%
Luton Airport (fixed)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dunstable and South C.Beds.	-43%	-31%	58%	0%	15%	-3%	-35%	-14%	-77%	-21%	-46%	11%	-28%	-27%	-29%	-54%	-11%	-53%	-34%	-46%
Leighton Buzzard and West C.Beds.	-37%	60%	76%	0%	59%	21%	-26%	-41%	-56%	-14%	42%	52%	-29%	2%	-25%	11%	7%	-46%	45%	-3%
Ampthill-Flitwick and Central C.Cbeds.	11%	-23%	86%	0%	-24%	67%	7%	39%	28%	-19%	-20%	3%	46%	-28%	-2%	-12%	-22%	-9%	-35%	-17%
Sandy-Biggleswade and East C.Beds.	27%	-31%	-38%	0%	-42%	-2%	42%	-3%	68%	31%	-32%	49%	41%	56%	55%	40%	63%	1%	63%	26%
Bedford	166%	42%	50%	0%	-55%	-56%	9%	21%	0%	21%	-42%	-23%	93%	80%	59%	0%	2%	0%	59%	7%
Milton Keynes	-15%	-25%	102%	0%	100%	1%	-19%	91%	103%	0%	-41%	48%	-22%	-30%	135%	-1%	5%	0%	-7%	0%
Dacorum	-76%	-61%	-77%	0%	-13%	35%	-56%	-62%	-79%	-35%	0%	-1%	-64%	0%	-14%	-12%	1%	-52%	0%	-38%
St Albans	-64%	8%	-63%	0%	13%	98%	10%	136%	-29%	21%	13%	-2%	36%	-4%	-9%	0%	-2%	0%	4%	1%
North Hertfordshire	60%	8%	-38%	0%	43%	253%	88%	33%	148%	6%	-17%	-3%	5%	-6%	-1%	40%	-10%	31%	-11%	17%
Rest of Hertfordshire	-25%	34%	-35%	0%	-4%	64%	-5%	80%	-12%	18%	12%	-2%	-11%	-1%	-5%	-12%	0%	-29%	0%	-30%
Rest of East Anglia	-21%	-1%	-8%	0%	-17%	-1%	20%	118%	-3%	31%	43%	-4%	-2%	-3%	0%	1%	-1%	-2%	1%	-3%
Bucks Oxfordshire Northants	-9%	-23%	99%	0%	10%	24%	8%	32%	-5%	0%	2%	22%	-6%	-5%	4%	0%	0%	0%	0%	0%
London	-41%	2%	-46%	0%	3%	72%	-8%	69%	-55%	33%	82%	-4%	-33%	-8%	-1%	-1%	0%	-8%	0%	-3%
External North	-2%	-27%	126%	0%	-38%	1%	4%	4%	1%	0%	-5%	28%	1%	-13%	1%	0%	1%	0%	0%	0%
External South	-41%	-13%	-39%	0%	13%	50%	-14%	97%	-27%	-1%	37%	9%	-22%	-1%	0%	0%	0%	-2%	0%	0%
External West	-5%	-33%	121%	0%	-7%	15%	4%	34%	2%	0%	-7%	28%	2%	-18%	3%	0%	2%	0%	0%	0%

Highlighted cells change by more than 5% and by more than 100 vehicles

Appendix B – Detailed Screenline Performance

Table B.1: Individual Screenline Performance by Direction (Total Vehicle Flows)

Screenline	Direction	Counts	AM Peak Hour				Interpeak Hour				PM Peak Hour			
			Observed	Modelled	% Difference	WebTAG	Observed	Modelled	% Difference	WebTAG	Observed	Modelled	% Difference	WebTAG
M1 Screenline	Eastbound	20	13,681	13,354	-2.4%	✓	9,082	9,094	0.1%	✓	14,429	14,503	0.5%	✓
excluding SRN flows		19	11,802	11,478	-2.7%	✓	7,501	7,514	0.2%	✓	11,673	11,846	1.5%	✓
M1 Screenline	Westbound	20	14,033	14,194	1.1%	✓	9,309	9,303	-0.1%	✓	13,808	13,572	-1.7%	✓
excluding SRN flows		19	11,766	11,925	1.3%	✓	7,818	7,816	-0.0%	✓	11,985	11,741	-2.0%	✓
A6 Screenline	Eastbound	9	3,388	3,368	-0.6%	✓	2,263	2,244	-0.8%	✓	3,374	3,353	-0.6%	✓
A6 Screenline	Westbound	9	3,163	3,161	-0.1%	✓	1,935	1,923	-0.6%	✓	2,899	2,896	-0.1%	✓
A507 Screenline	Northbound	14	3,815	3,818	0.1%	✓	2,921	2,882	-1.3%	✓	4,869	4,880	0.2%	✓
A507 Screenline	Southbound	14	5,003	5,019	0.3%	✓	2,892	2,859	-1.1%	✓	4,341	4,327	-0.3%	✓
Luton Cordon	Inbound	13	10,961	10,484	-4.3%	✓	6,635	6,648	0.2%	✓	10,168	10,077	-0.9%	✓
Luton Cordon	Outbound	13	9,429	9,362	-0.7%	✓	6,907	6,968	0.9%	✓	10,736	10,633	-1.0%	✓
Luton Centre West	Eastbound	9	3,634	3,585	-1.3%	✓	2,661	2,630	-1.2%	✓	3,313	3,303	-0.3%	✓
Luton Centre West	Westbound	9	3,160	3,019	-4.5%	✓	2,697	2,659	-1.4%	✓	3,485	3,354	-3.8%	✓
Luton Railway	Eastbound	11	4,337	4,293	-1.0%	✓	4,468	4,311	-3.5%	✓	6,422	6,020	-6.3%	×
Luton Railway	Westbound	12	6,319	6,313	-0.1%	✓	4,500	4,487	-0.3%	✓	4,902	4,984	1.7%	✓
Luton Centre East	Northbound	5	1,465	1,461	-0.3%	✓	1,336	1,341	0.4%	✓	2,297	2,307	0.4%	✓
Luton Centre East	Southbound	5	2,175	2,445	12.4%	×	1,296	1,311	1.1%	✓	1,743	1,803	3.4%	✓
Luton South	Northbound	7	3,735	3,589	-3.9%	✓	2,813	2,694	-4.2%	✓	4,918	4,768	-3.1%	✓
Luton South	Southbound	7	4,671	4,749	1.7%	✓	2,723	2,721	-0.1%	✓	3,881	3,939	1.5%	✓
Luton Centre North	Northbound	9	4,233	4,146	-2.0%	✓	3,440	3,427	-0.4%	✓	4,702	4,718	0.3%	✓
Luton Centre North	Southbound	9	4,583	4,735	3.3%	✓	3,290	3,259	-1.0%	✓	4,112	4,103	-0.2%	✓
Luton North	Northbound	8	2,954	2,972	0.6%	✓	2,619	2,601	-0.7%	✓	3,469	3,218	-7.2%	×
Luton North	Southbound	8	4,044	4,047	0.1%	✓	2,662	2,662	-0.0%	✓	3,206	3,216	0.3%	✓
Luton Airport	Inbound	3	2,154	2,018	-6.3%	×	1,198	1,126	-5.9%	✓	1,553	1,498	-3.5%	✓
Luton Airport	Outbound	3	1,483	1,520	2.5%	✓	1,216	1,158	-4.8%	✓	2,287	2,025	-11.4%	×
Dunstable Cordon	Inbound	12	6,752	6,517	-3.5%	✓	4,963	5,139	3.5%	✓	7,344	7,711	5.0%	✓
excluding SRN flows		10	5,701	5,461	-4.2%	✓	3,940	4,126	4.7%	✓	5,681	6,076	7.0%	×

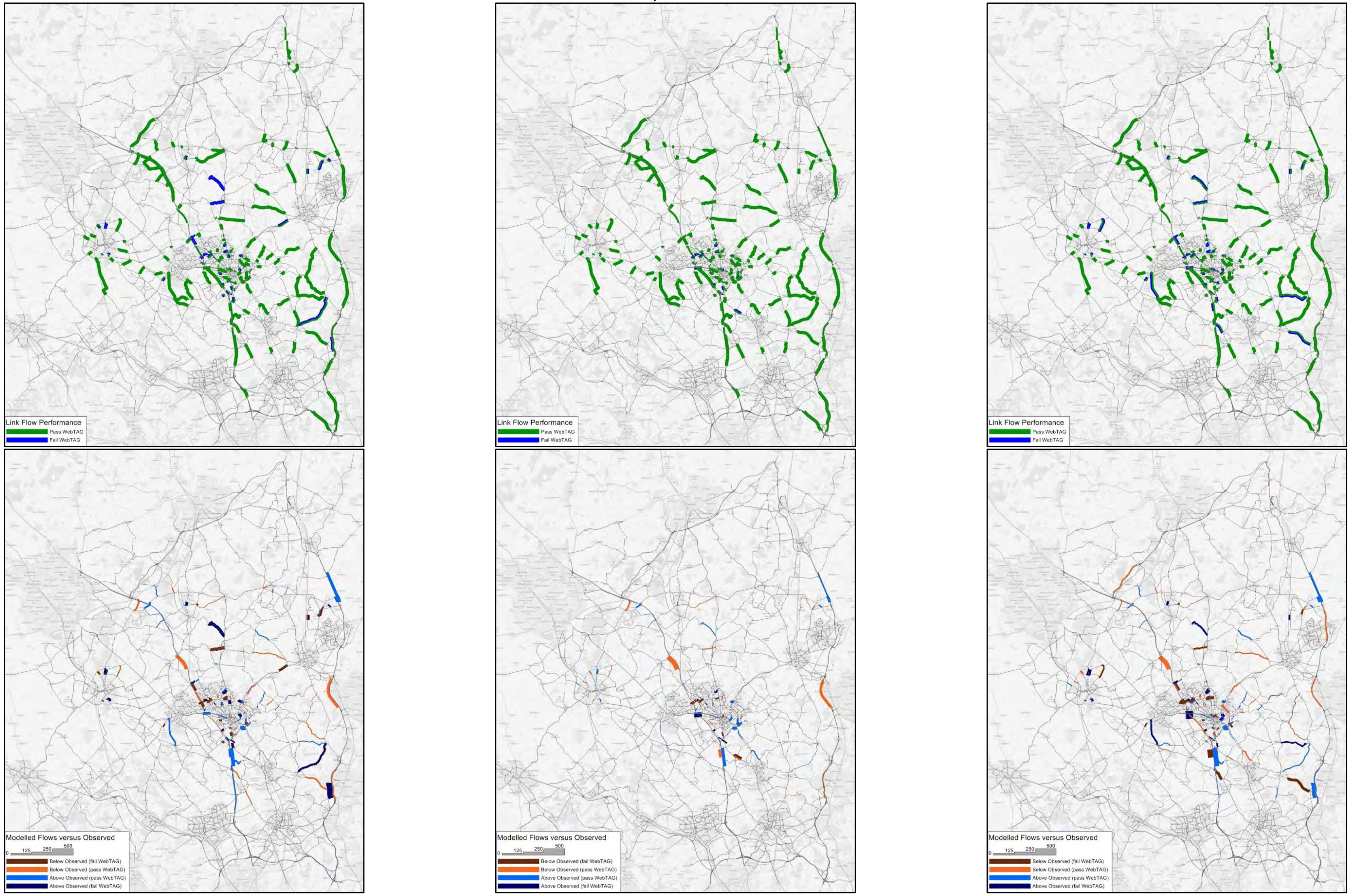
Screenline	Direction	Counts	AM Peak Hour				Interpeak Hour				PM Peak Hour			
			Observed	Modelled	% Difference	WebTAG	Observed	Modelled	% Difference	WebTAG	Observed	Modelled	% Difference	WebTAG
Dunstable Cordon	Outbound	12	6,708	6,668	-0.6%	✓	4,758	4,699	-1.2%	✓	6,227	6,036	-3.1%	✓
excluding SRN flows		10	5,123	5,098	-0.5%	✓	3,769	3,709	-1.6%	✓	5,054	4,874	-3.6%	✓
Lilley / Kimpton	Eastbound	7	1,319	1,362	3.3%	✓	815	835	2.5%	✓	1,697	1,622	-4.4%	✓
Lilley / Kimpton	Westbound	7	1,899	1,842	-3.0%	✓	780	808	3.6%	✓	1,520	1,524	0.3%	✓
Hitchin / Codicote	Eastbound	11	3,653	3,603	-1.4%	✓	1,856	1,853	-0.2%	✓	3,117	3,120	0.1%	✓
Hitchin / Codicote	Westbound	11	2,999	3,010	0.4%	✓	1,876	1,876	0.0%	✓	3,472	3,613	4.1%	✓
Harpenden North	Northbound	5	1,414	1,396	-1.3%	✓	1,143	1,038	-9.2%	×	1,723	1,575	-8.6%	×
Harpenden North	Southbound	5	1,794	1,755	-2.1%	✓	1,154	964	-16.5%	×	1,395	1,349	-3.3%	✓
Harpenden South	Northbound	4	2,943	2,864	-2.7%	✓	1,718	1,701	-1.0%	✓	2,735	2,593	-5.2%	×
Harpenden South	Southbound	4	2,642	2,550	-3.5%	✓	1,695	1,674	-1.2%	✓	2,732	2,718	-0.5%	✓
Leighton Buzzard Cordon	Inbound	10	2,803	2,799	-0.2%	✓	2,184	2,191	0.3%	✓	3,930	3,932	0.0%	✓
Leighton Buzzard Cordon	Outbound	10	3,804	3,803	-0.0%	✓	2,110	2,105	-0.2%	✓	3,142	3,141	-0.0%	✓
Dunstable / Leighton Buzzard	Northbound	9	1,831	1,821	-0.5%	✓	1,389	1,394	0.4%	✓	2,640	2,645	0.2%	✓
Dunstable / Leighton Buzzard	Southbound	9	2,420	2,422	0.1%	✓	1,355	1,359	0.3%	✓	1,912	1,928	0.8%	✓
Sandy Cordon	Inbound	5	1,380	1,392	0.9%	✓	1,065	1,071	0.6%	✓	1,682	1,678	-0.3%	✓
Sandy Cordon	Outbound	5	1,486	1,493	0.5%	✓	1,047	1,046	-0.1%	✓	1,595	1,590	-0.3%	✓

Appendix C – Link Flow Performance Figures

AM Peak Hour | Interpeak Hour | PM Peak Hour

Total Vehicles: WebTAG Pass / Fail (Simulation Network)

Total Vehicles: Modelled vs. Observed Flow Difference (Simulation Network)



AM Peak Hour | Interpeak Hour | PM Peak Hour

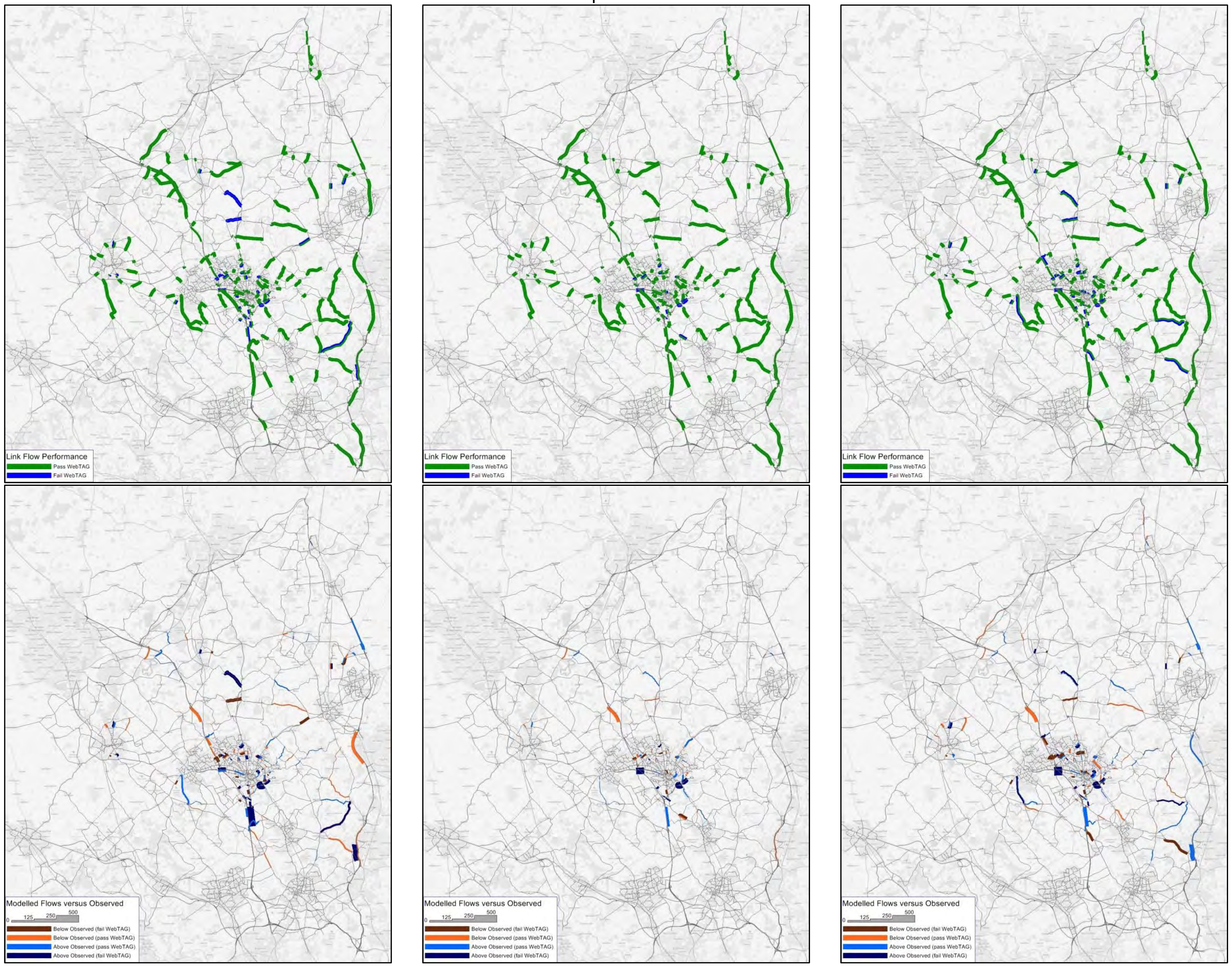
Total Vehicles: WebTAG Pass / Fail (Luton)

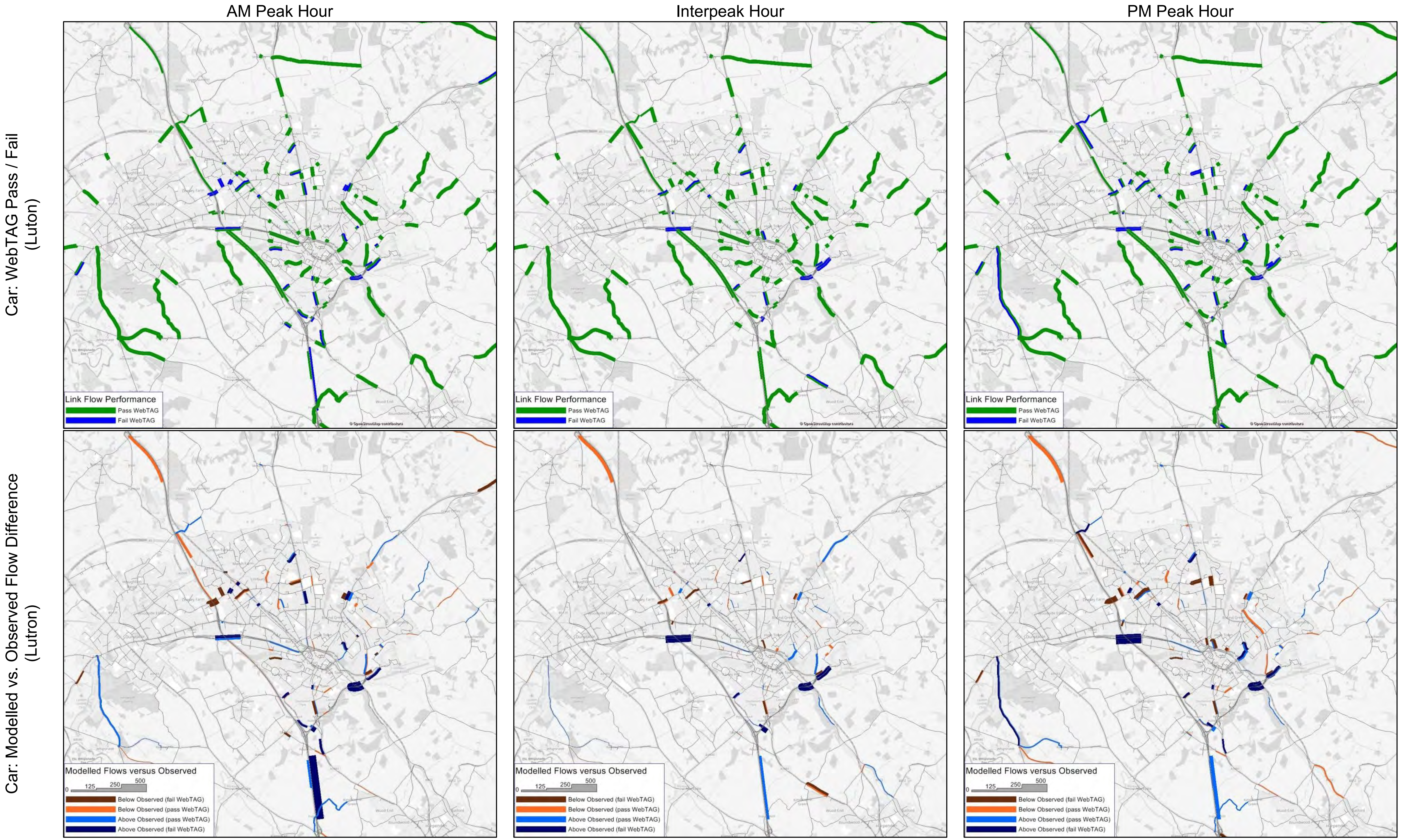
Total Vehicles: Modelled vs. Observed Flow Difference (Lutron)

AM Peak Hour | Interpeak Hour | PM Peak Hour

Car: WebTAG Pass / Fail (Simulation Network)

Car: Modelled vs. Observed Flow Difference (Simulation Network)

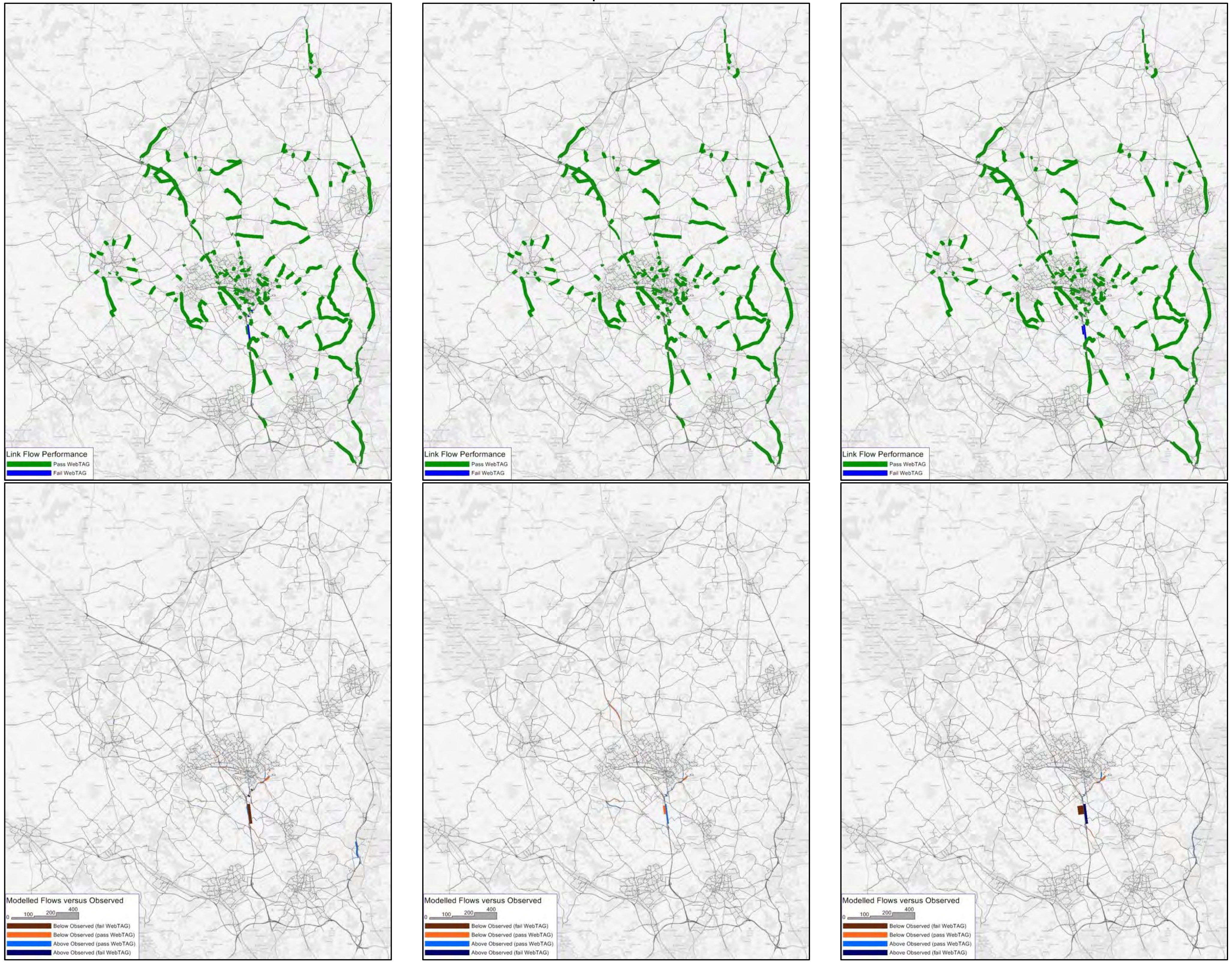


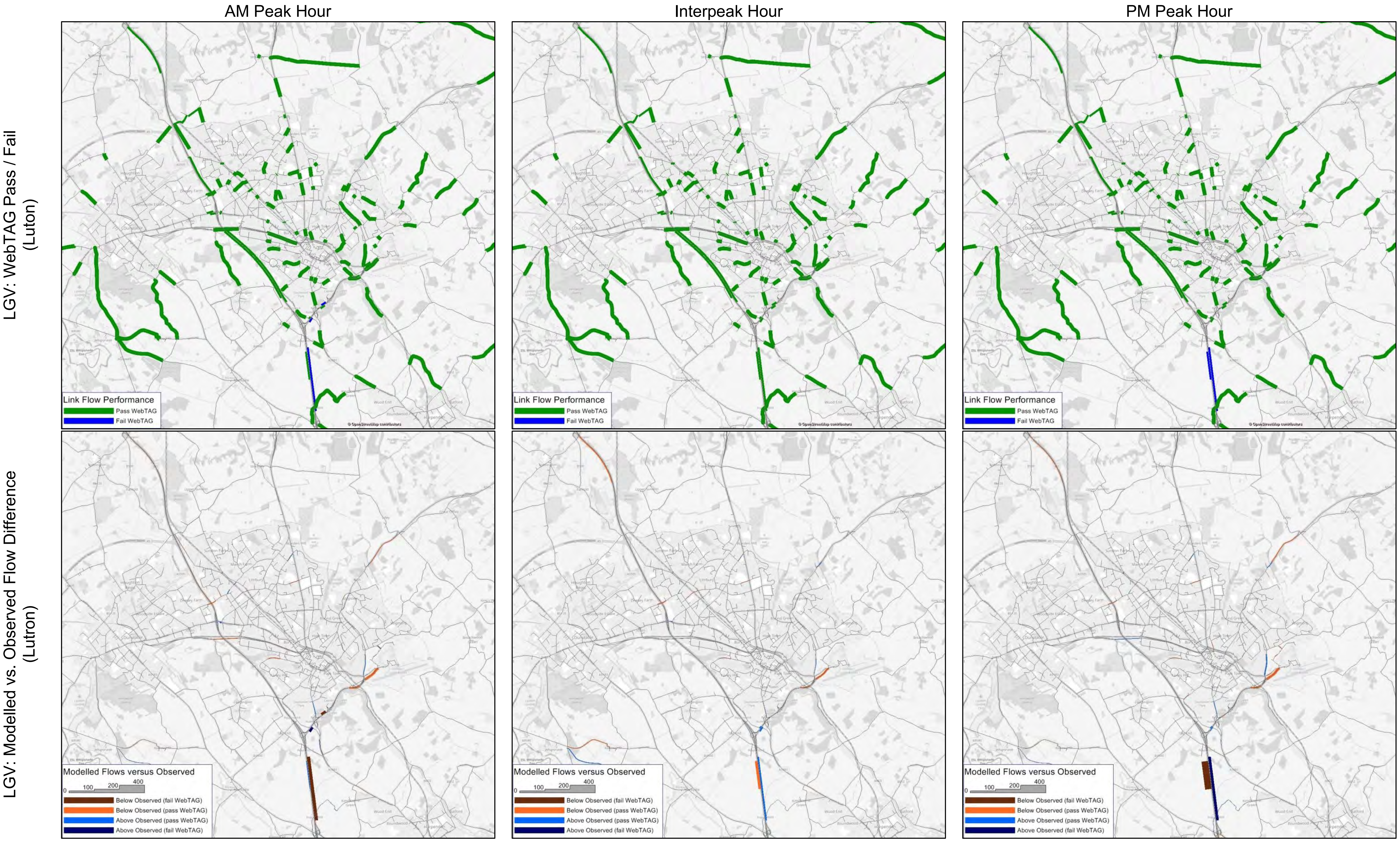

AM Peak Hour
Interpeak Hour
PM Peak Hour
Car: WebTAG Pass / Fail
(Luton)
Car: Modelled vs. Observed Flow Difference
(Lutron)
Link Flow Performance
Pass WebTAG
Fail WebTAG
Modelled Flows versus Observed
0
125
250
500
Below Observed (fail WebTAG)
Below Observed (pass WebTAG)
Above Observed (pass WebTAG)
Above Observed (fail WebTAG)

AM Peak Hour | Interpeak Hour | PM Peak Hour

LGV: WebTAG Pass / Fail (Simulation Network)

LGV: Modelled vs. Observed Flow Difference (Simulation Network)

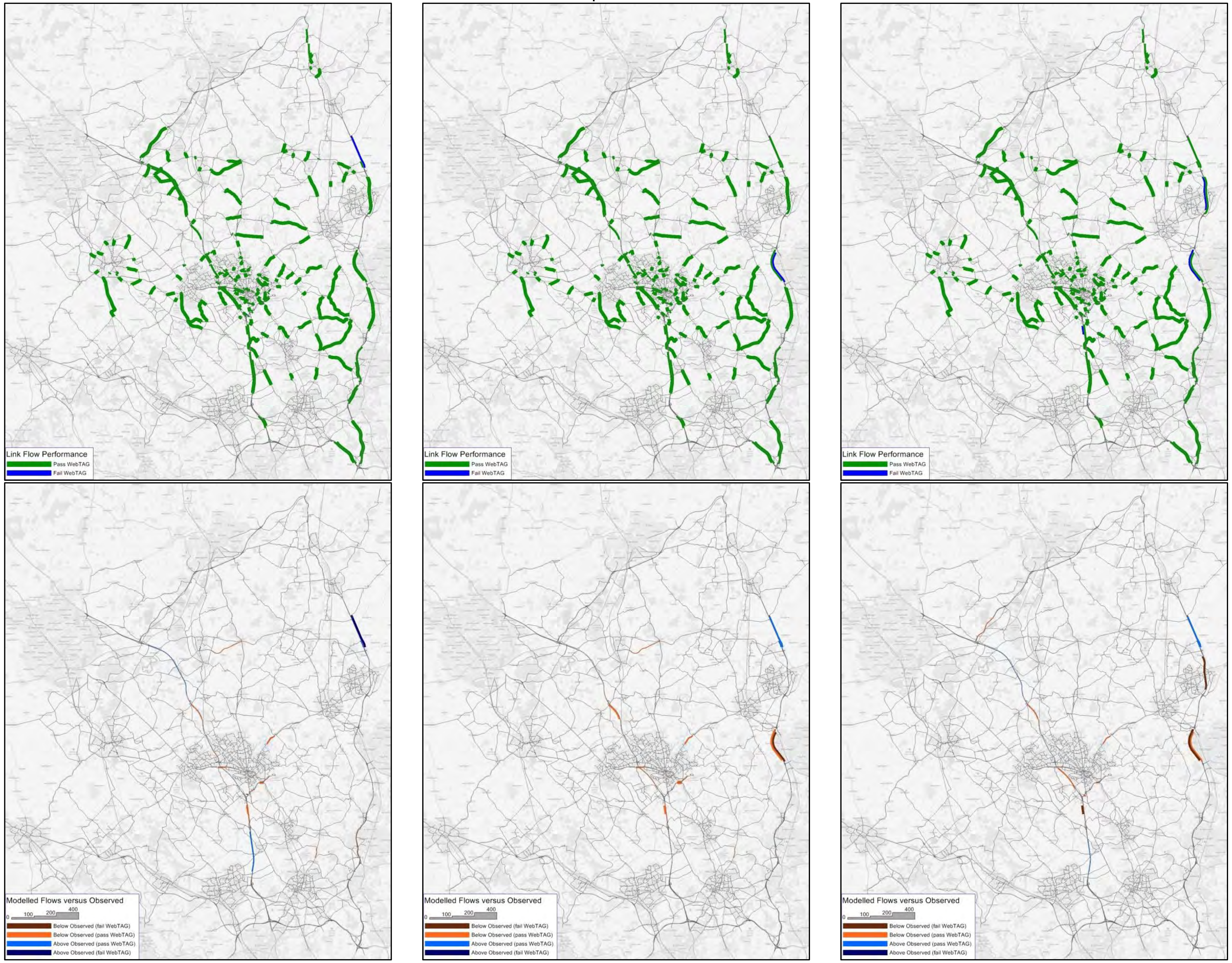



AM Peak Hour
Interpeak Hour
PM Peak Hour
LGV: WebTAG Pass / Fail
(Luton)
LGV: Modelled vs. Observed Flow Difference
(Lutron)
Link Flow Performance
Pass WebTAG
Fail WebTAG
Modelled Flows versus Observed
0
100
200
400
Below Observed (fail WebTAG)
Below Observed (pass WebTAG)
Above Observed (pass WebTAG)
Above Observed (fail WebTAG)

AM Peak Hour | Interpeak Hour | PM Peak Hour

HGV: WebTAG Pass / Fail (Simulation Network)

HGV: Modelled vs. Observed Flow Difference (Simulation Network)

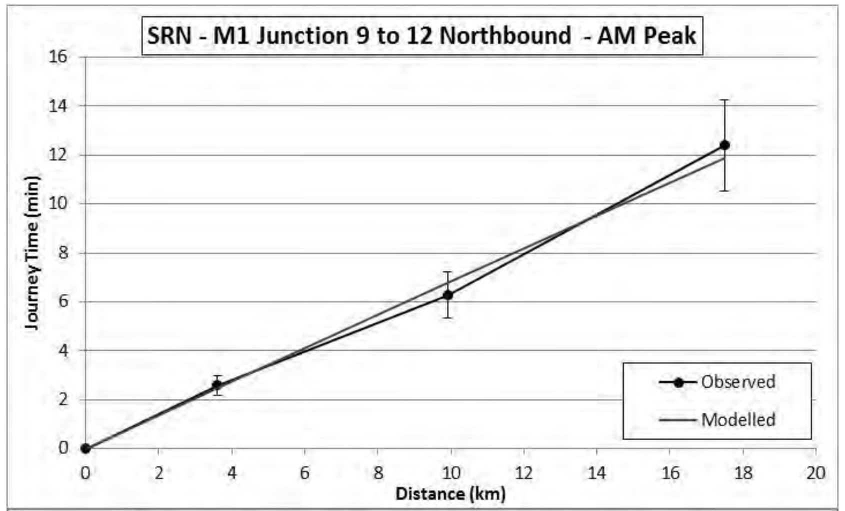


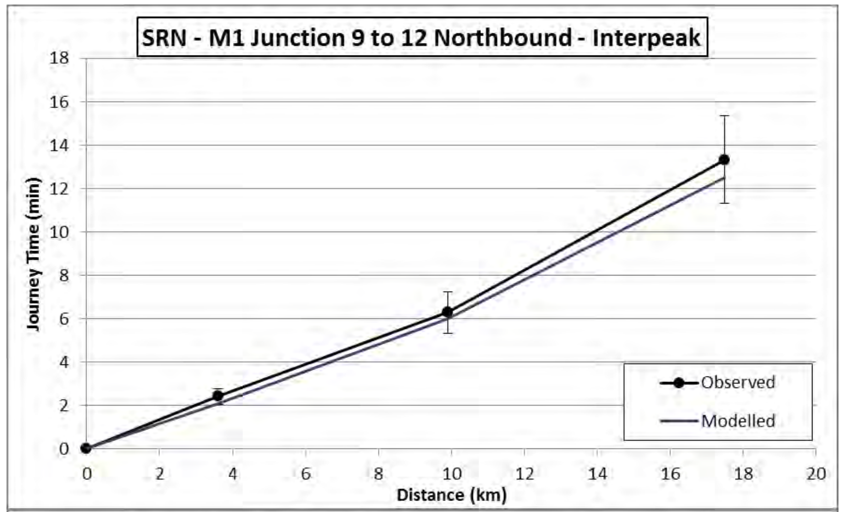
AM Peak Hour | Interpeak Hour | PM Peak Hour

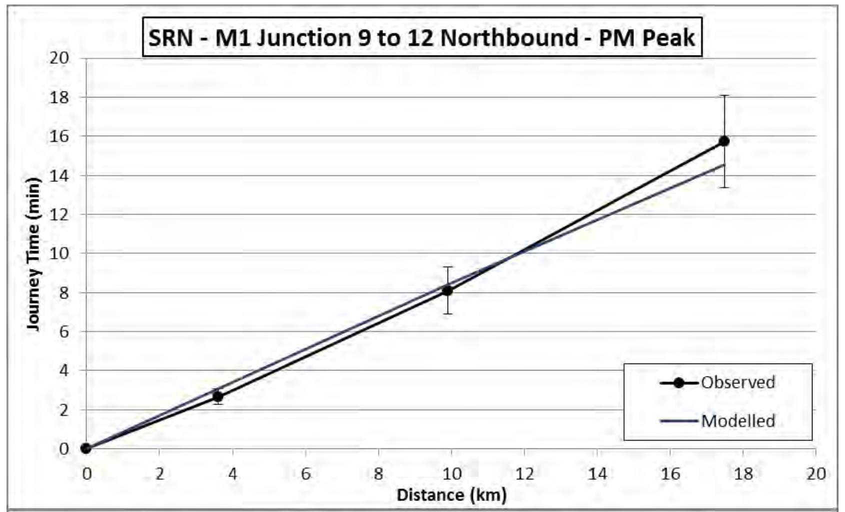
HGV: WebTAG Pass / Fail (Luton)

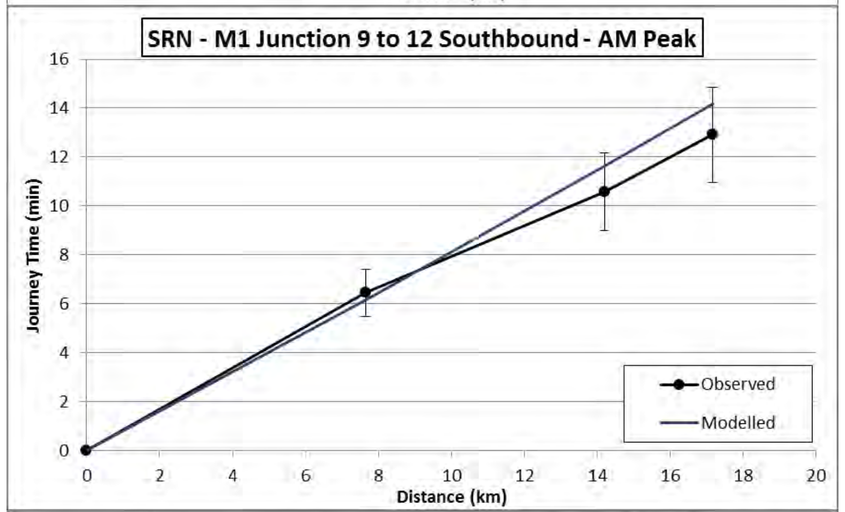
HGV: Modelled vs. Observed Flow Difference (Lutron)

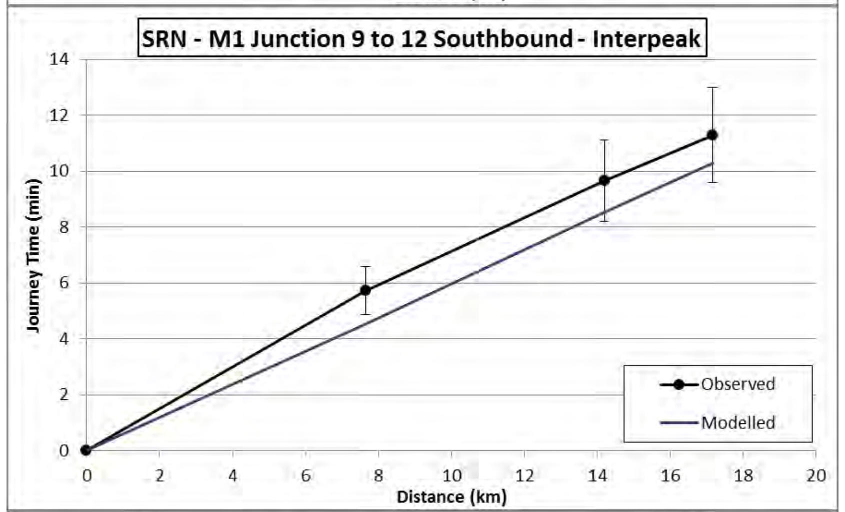
Appendix D – Journey Time Validation Graphs

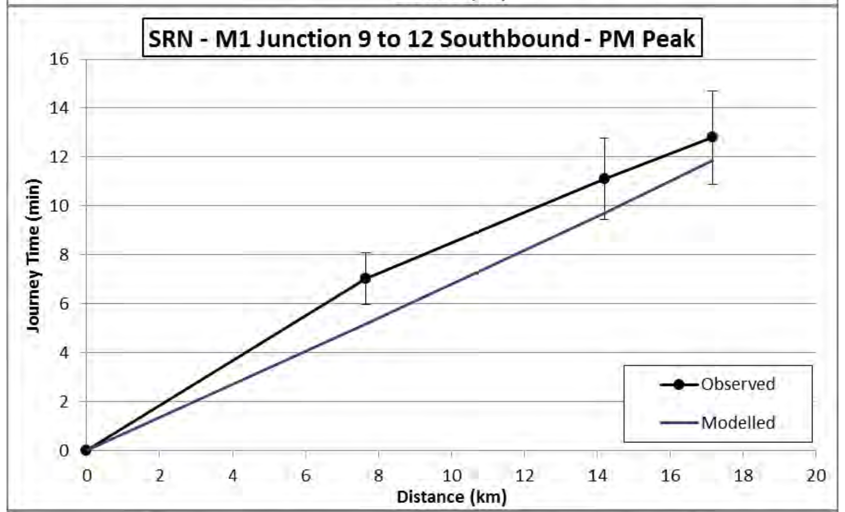


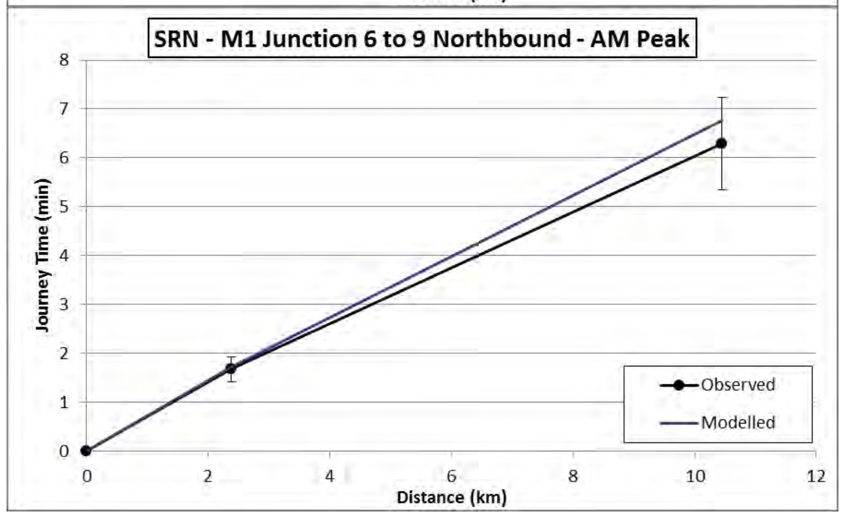


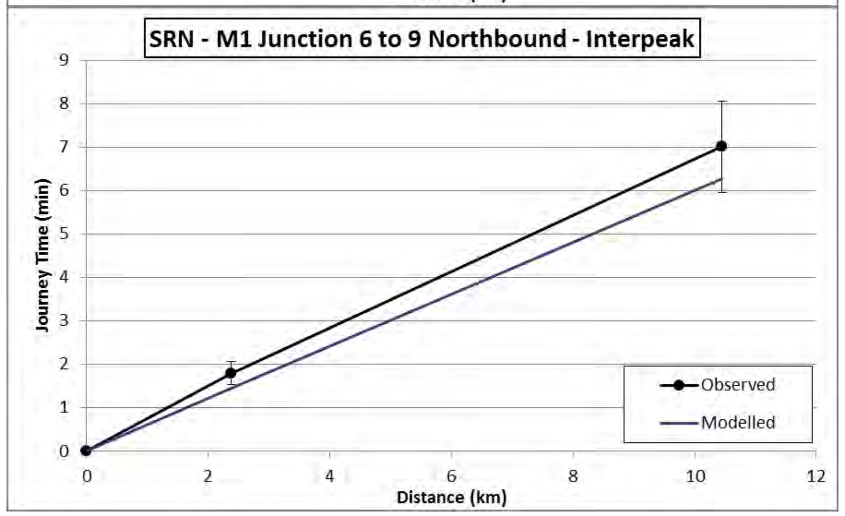


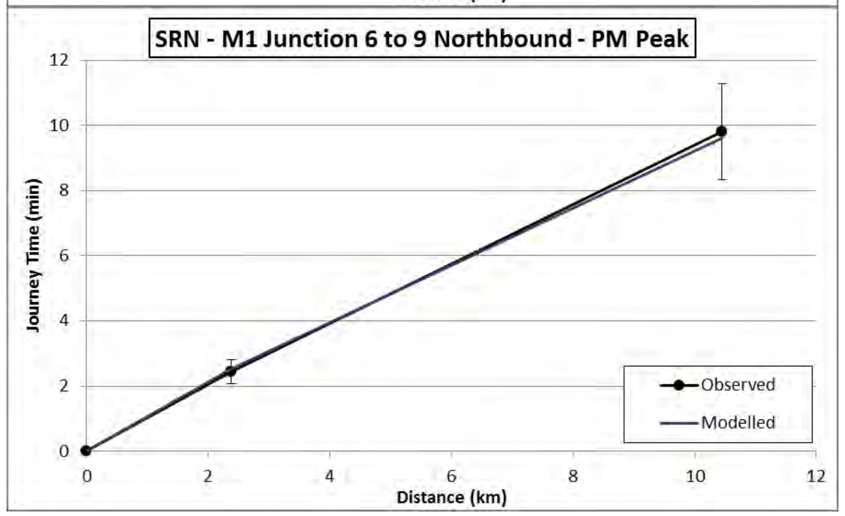


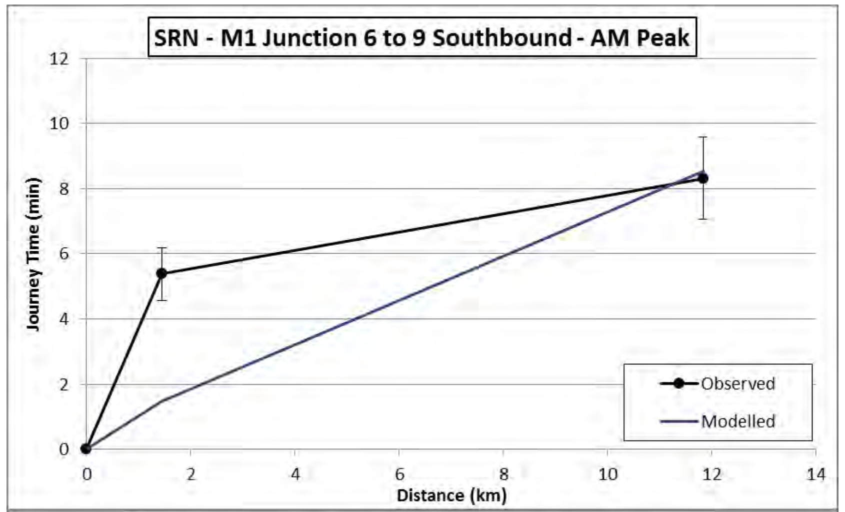


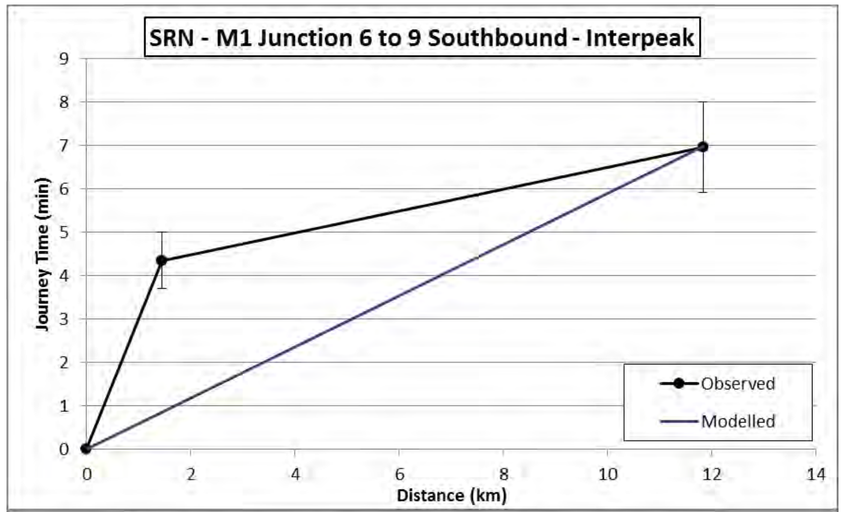


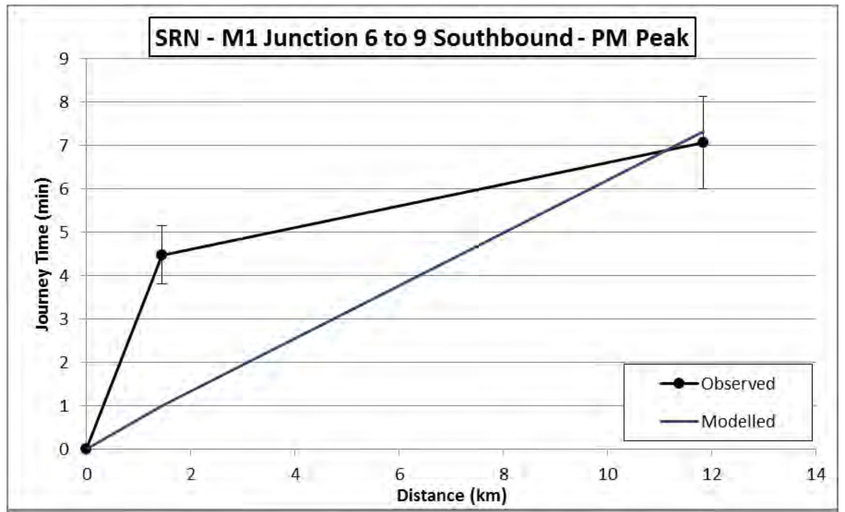


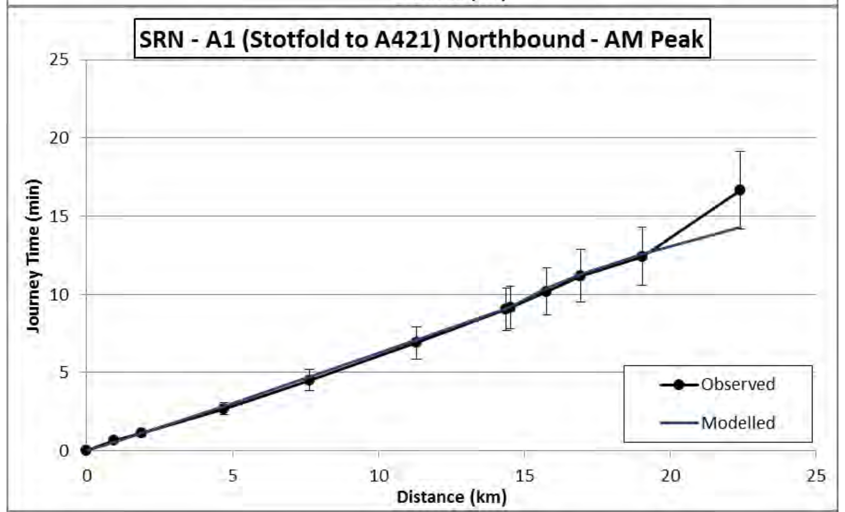


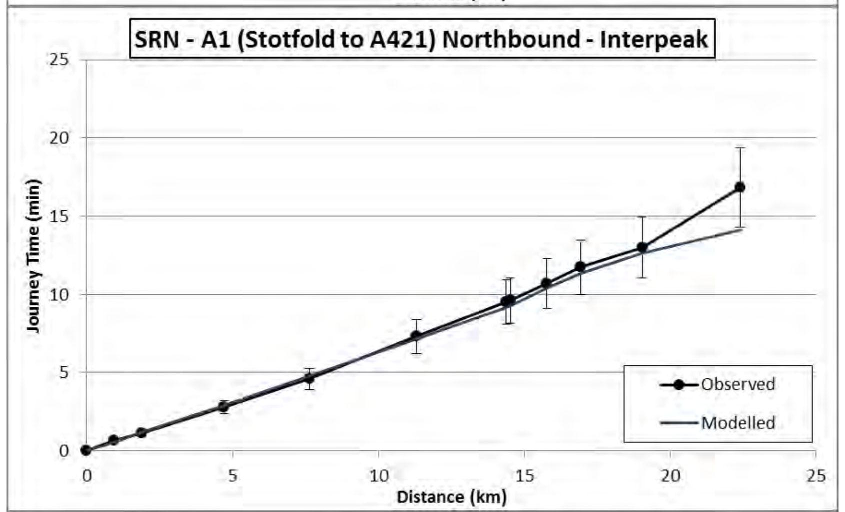


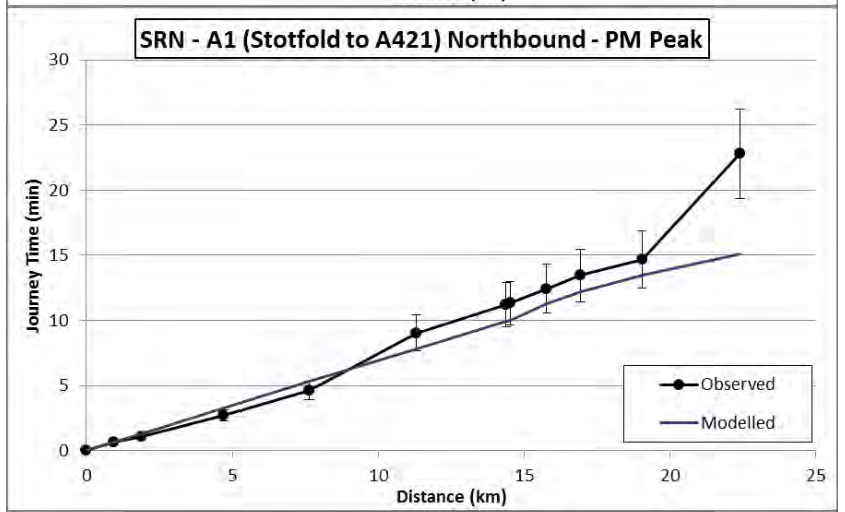

SRN - M1 Junction 6 to 9 Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

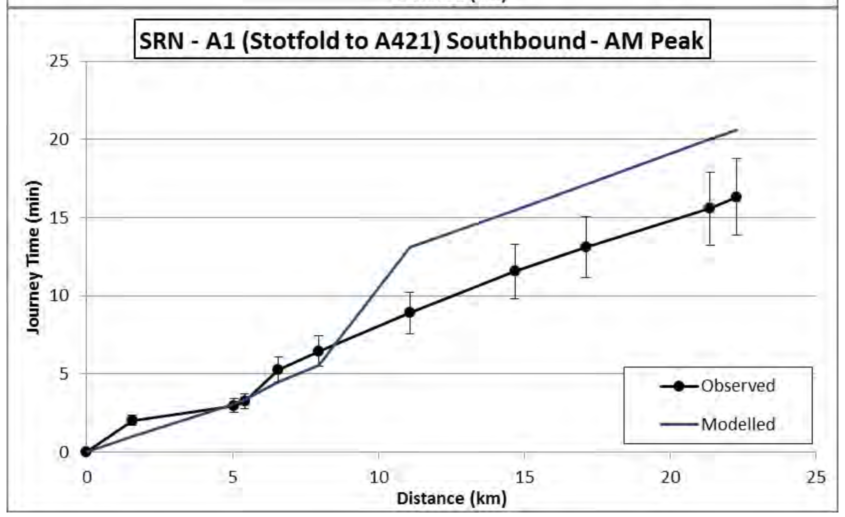

SRN - M1 Junction 6 to 9 Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

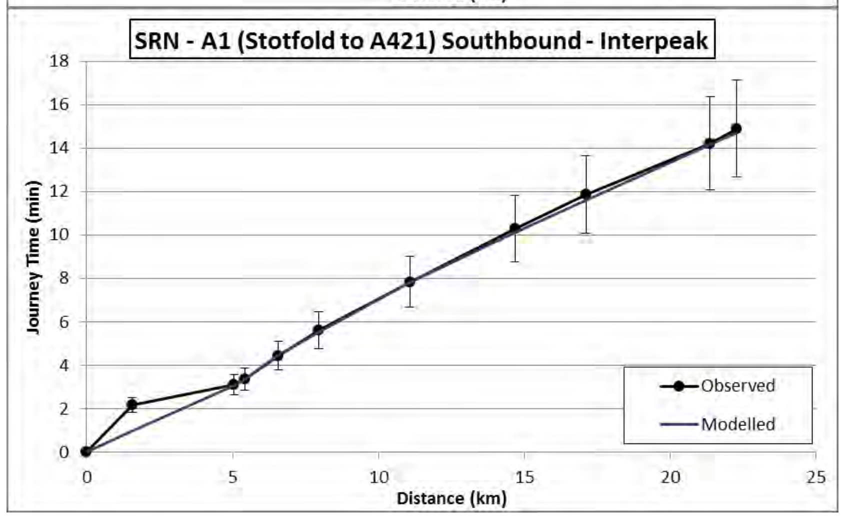

SRN - M1 Junction 6 to 9 Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

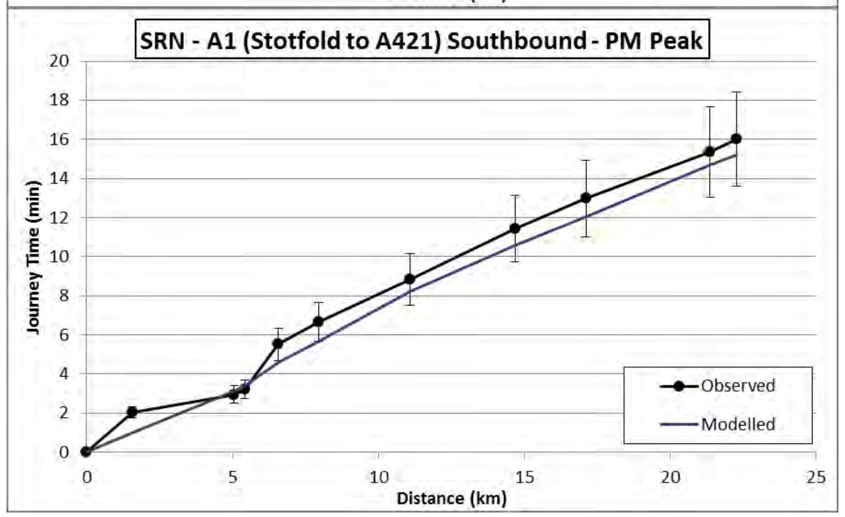

SRN - A1 (Stotfold to A421) Northbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

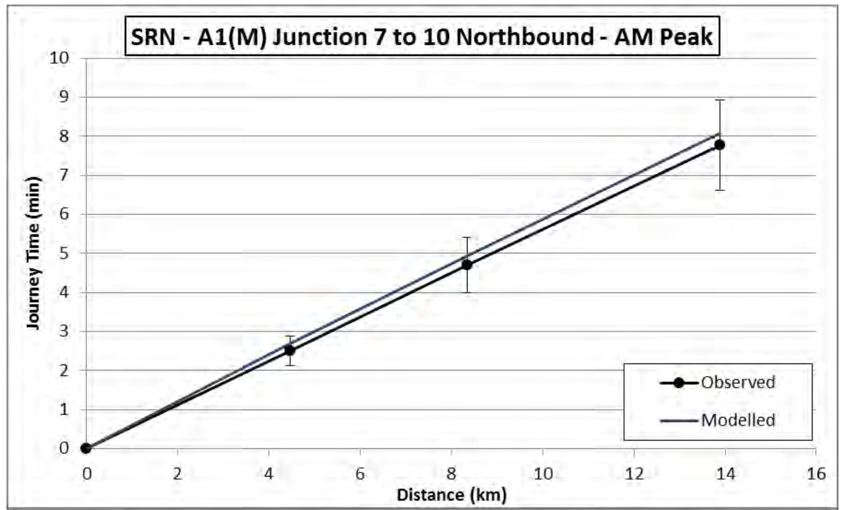

SRN - A1 (Stotfold to A421) Northbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

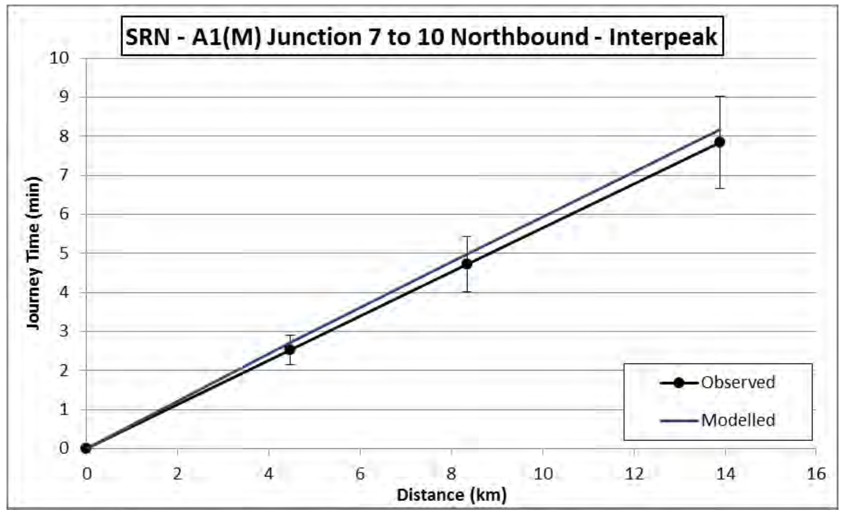

SRN - A1 (Stotfold to A421) Northbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

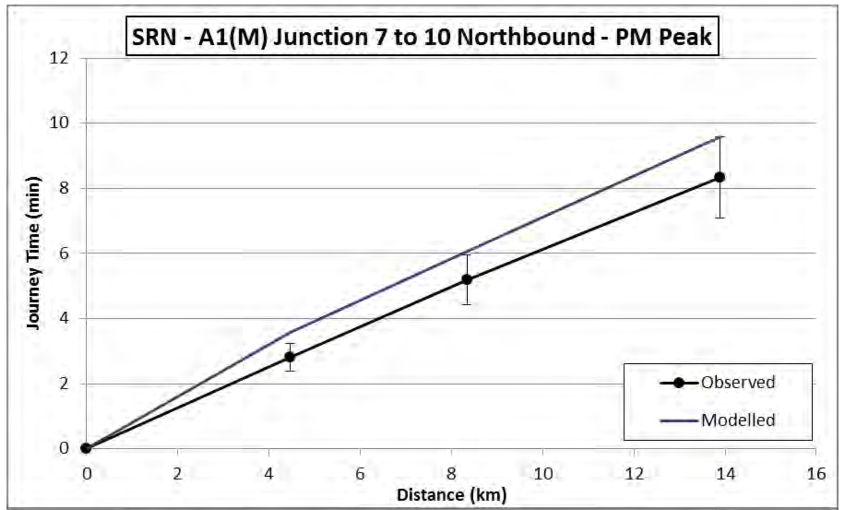

SRN - A1 (Stotfold to A421) Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

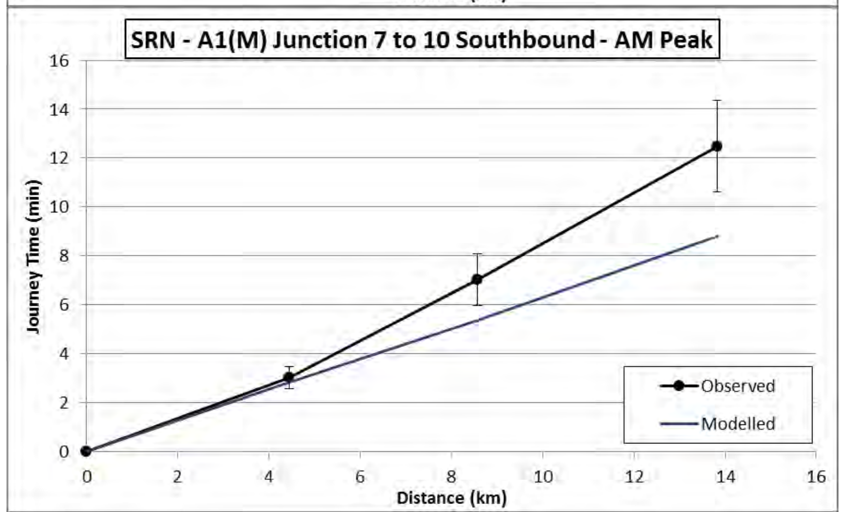

SRN - A1 (Stotfold to A421) Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

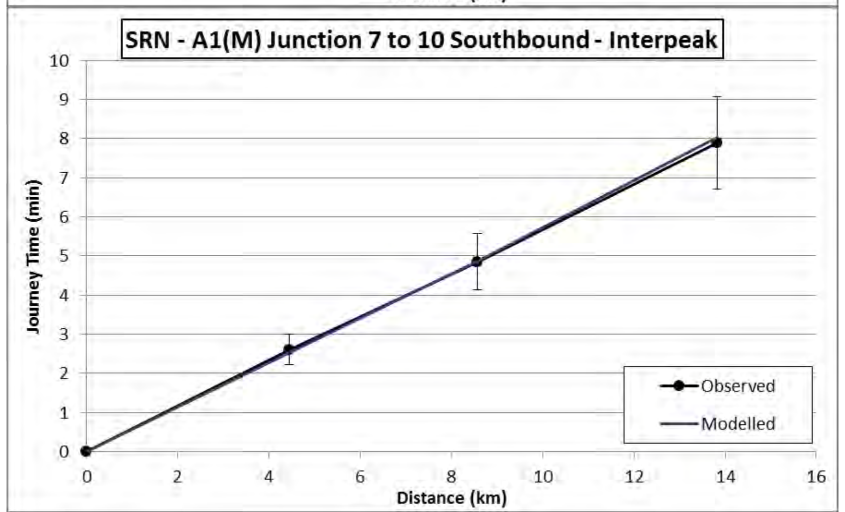

SRN - A1 (Stotfold to A421) Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

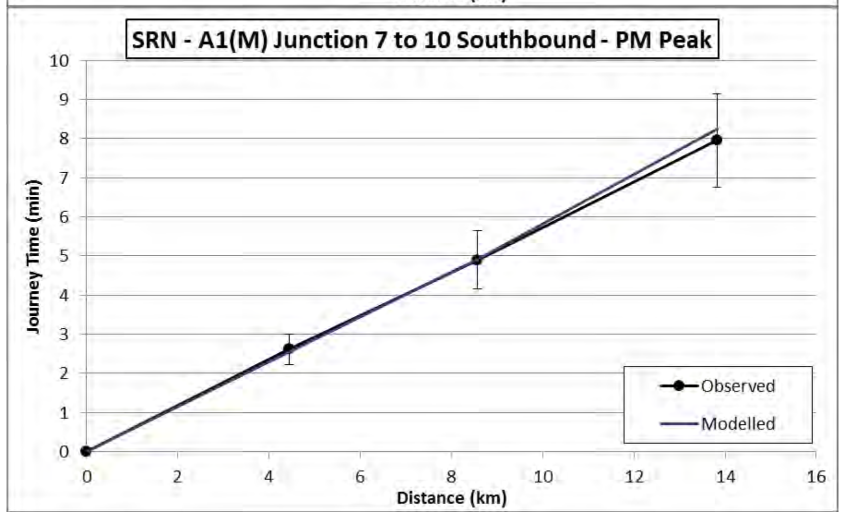

SRN - A1(M) Junction 7 to 10 Northbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

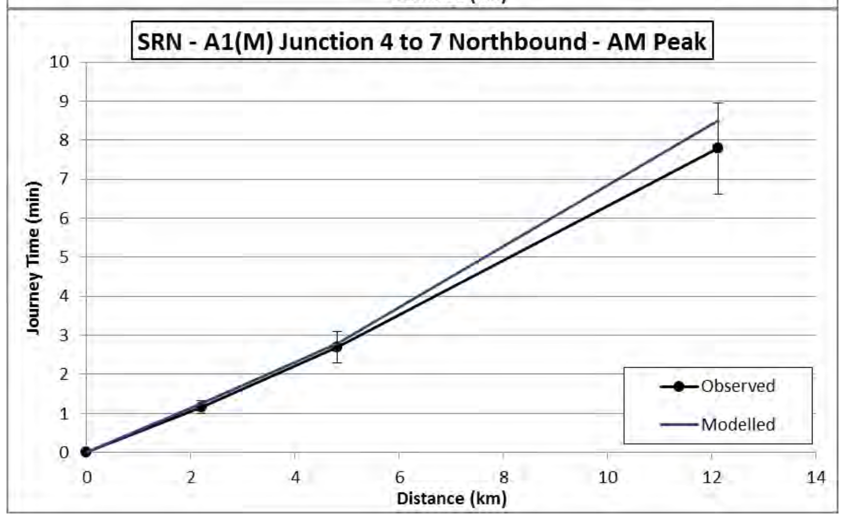

SRN - A1(M) Junction 7 to 10 Northbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

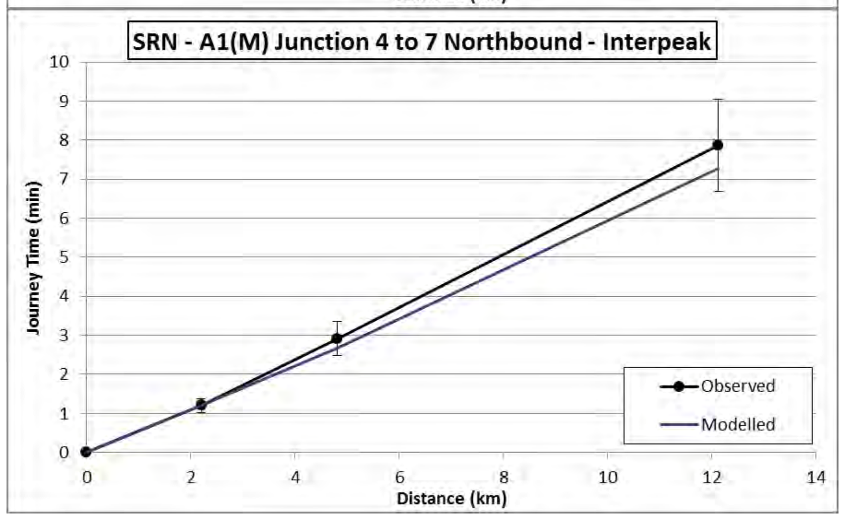

SRN - A1(M) Junction 7 to 10 Northbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

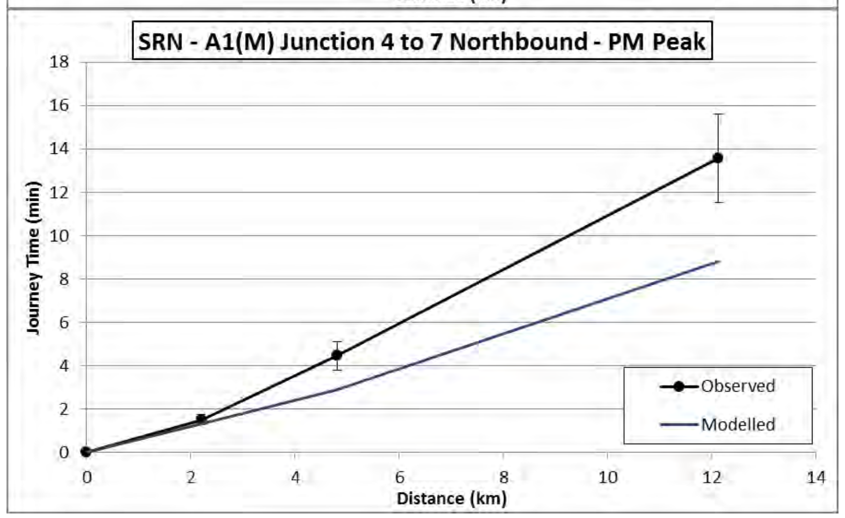

SRN - A1(M) Junction 7 to 10 Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

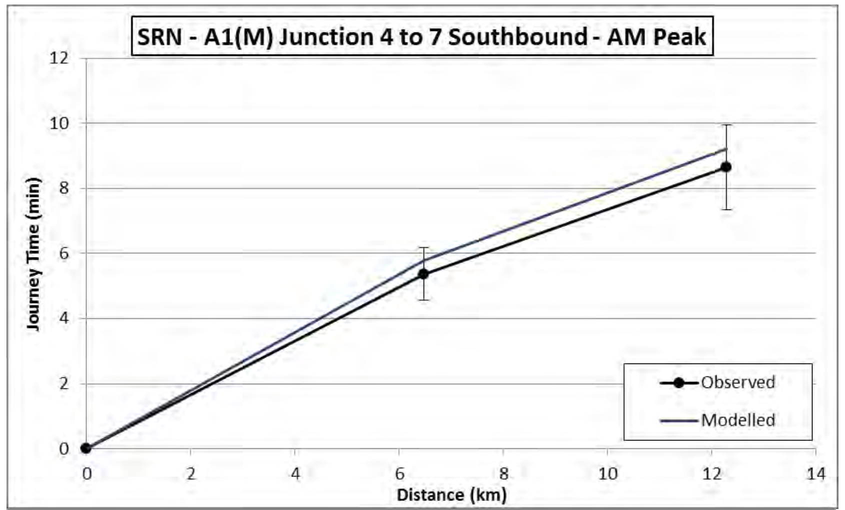

SRN - A1(M) Junction 7 to 10 Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

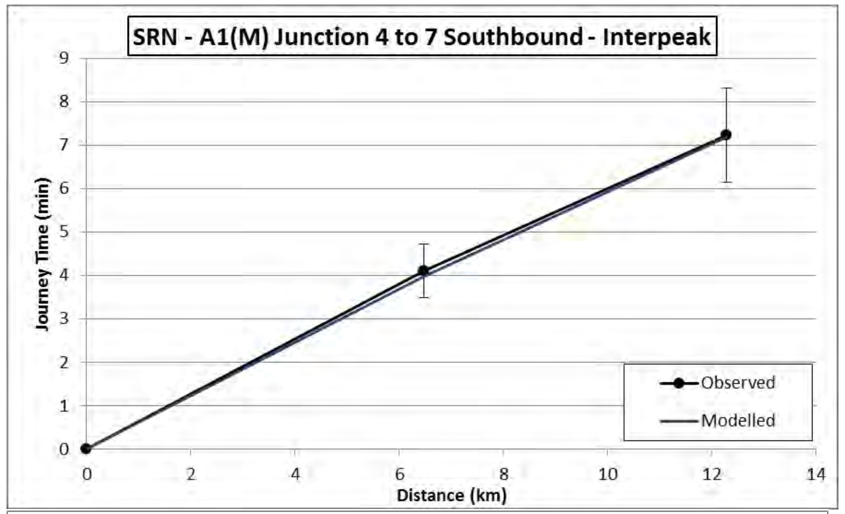

SRN - A1(M) Junction 7 to 10 Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

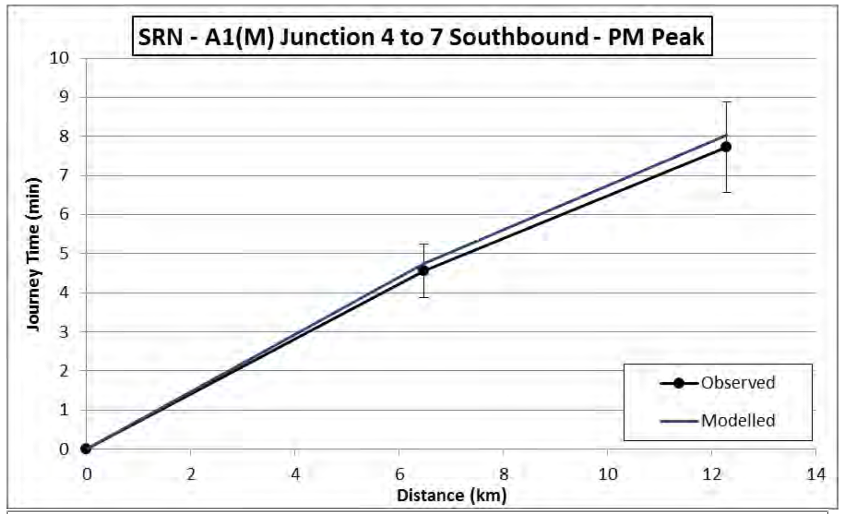

SRN - A1(M) Junction 4 to 7 Northbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

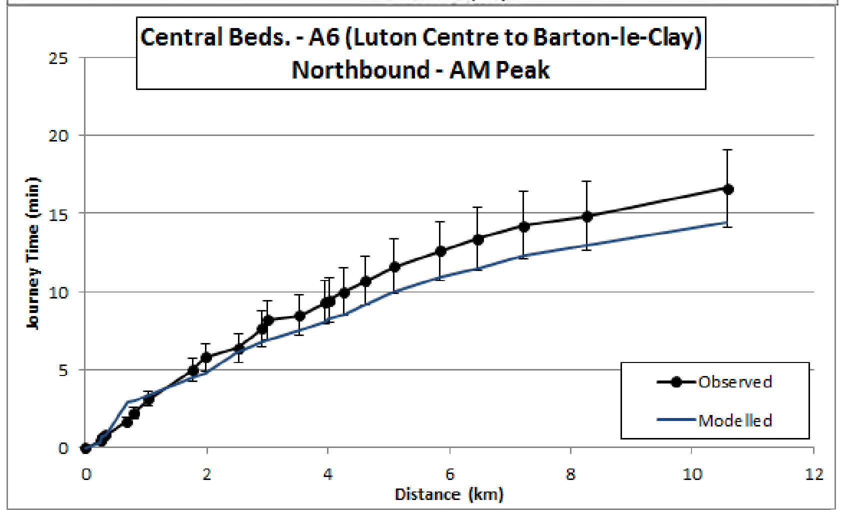

SRN - A1(M) Junction 4 to 7 Northbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

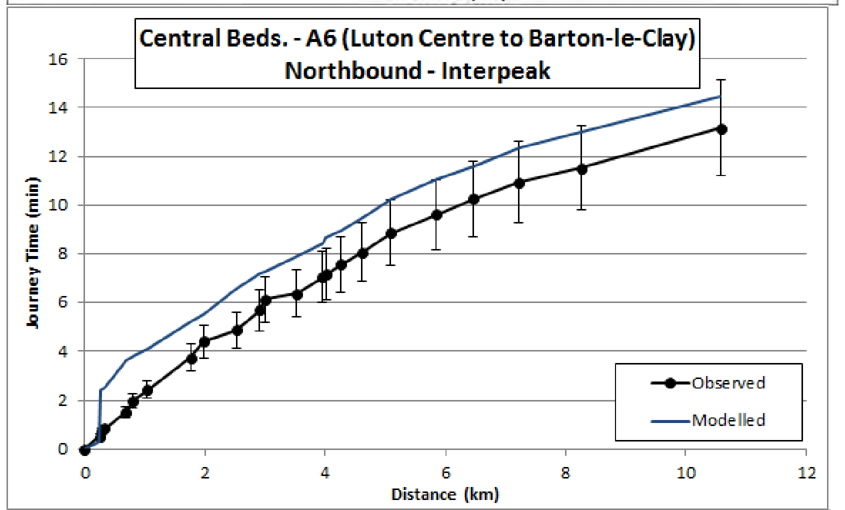

SRN - A1(M) Junction 4 to 7 Northbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

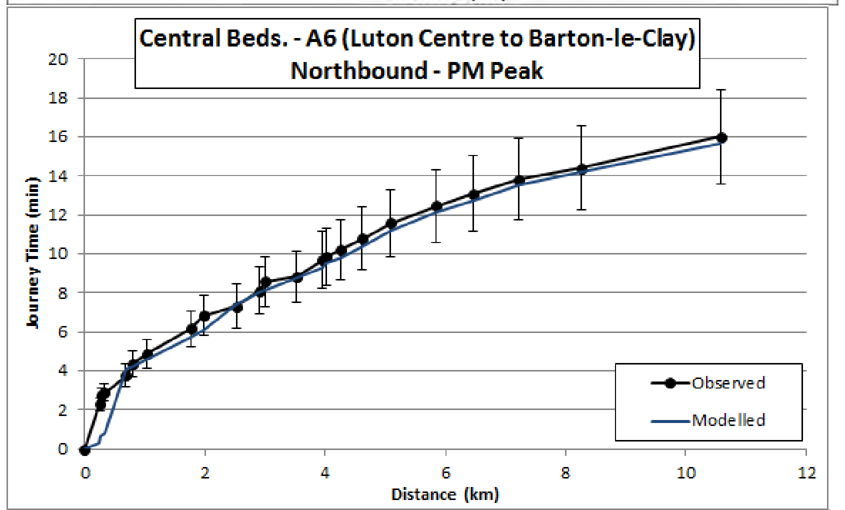

SRN - A1(M) Junction 4 to 7 Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

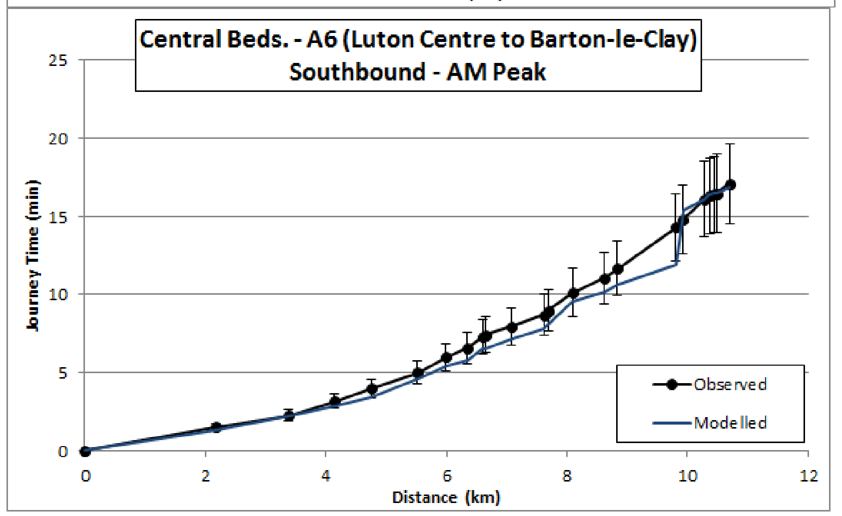

SRN - A1(M) Junction 4 to 7 Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

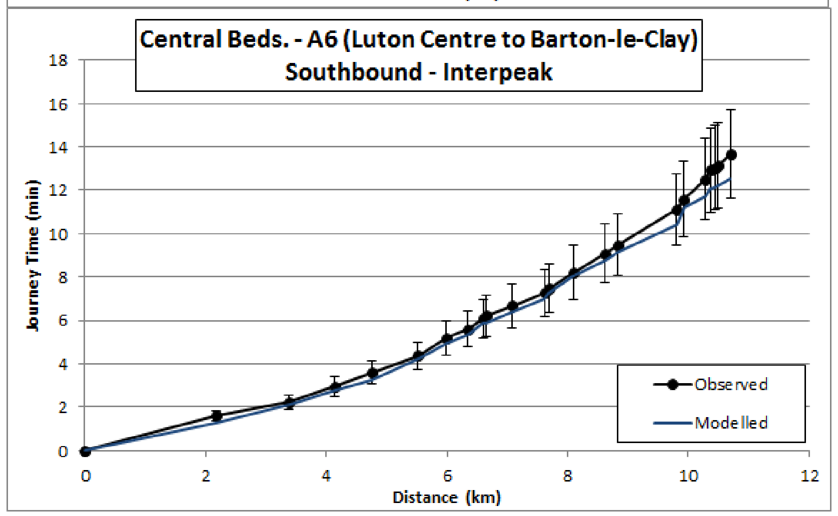

SRN - A1(M) Junction 4 to 7 Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

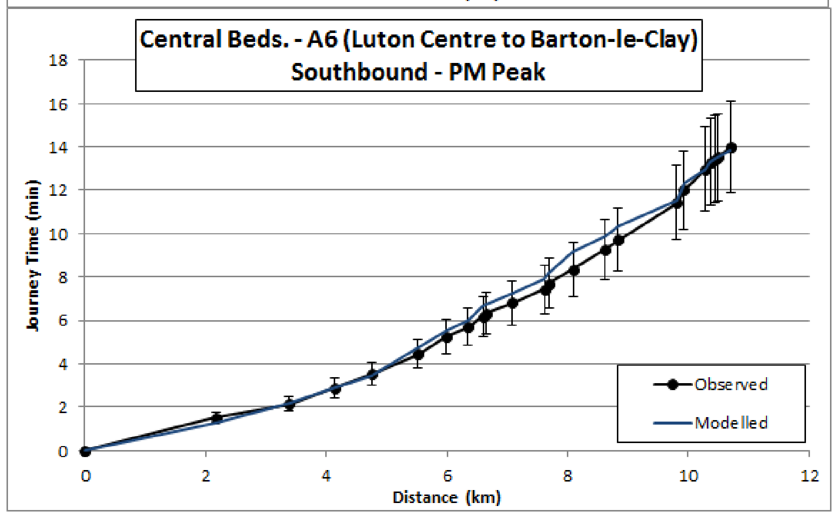

Central Beds. - A6 (Luton Centre to Barton-le-Clay)
Northbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

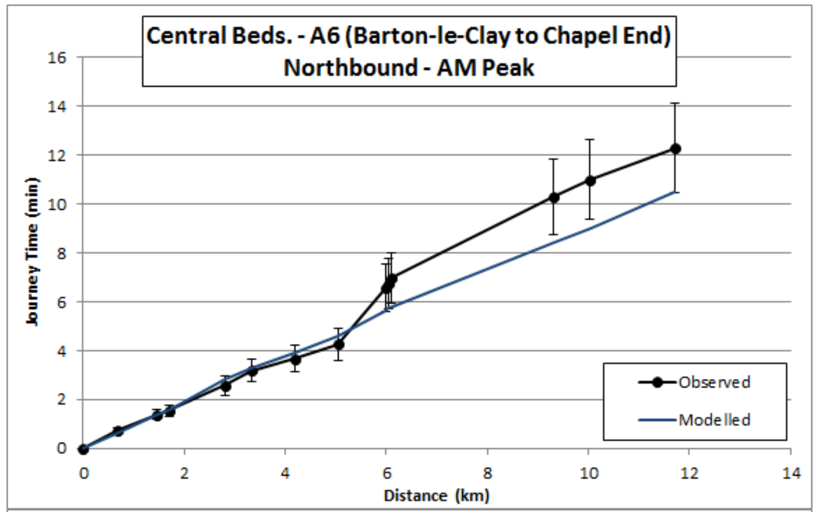

Central Beds. - A6 (Luton Centre to Barton-le-Clay)
Northbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

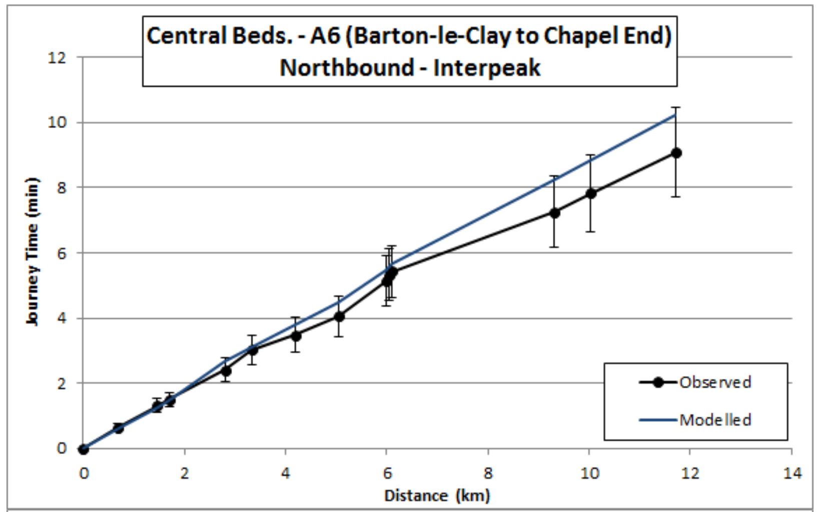

Central Beds. - A6 (Luton Centre to Barton-le-Clay)
Northbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

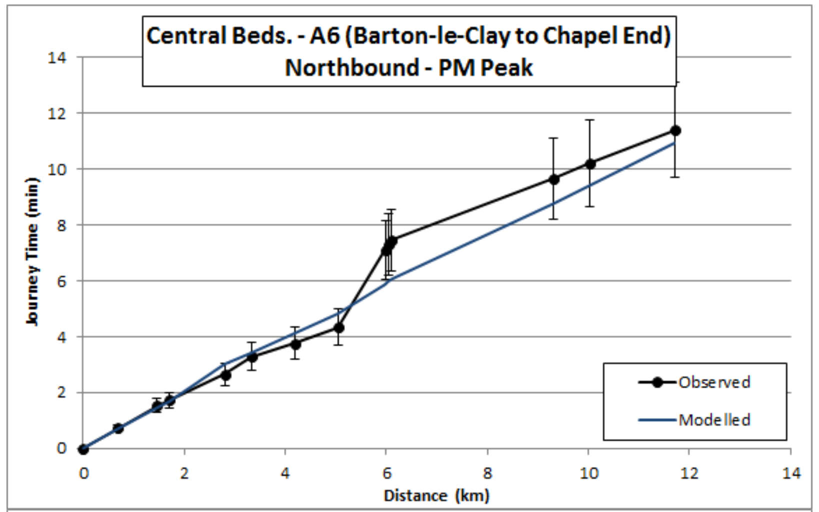

Central Beds. - A6 (Luton Centre to Barton-le-Clay)
Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

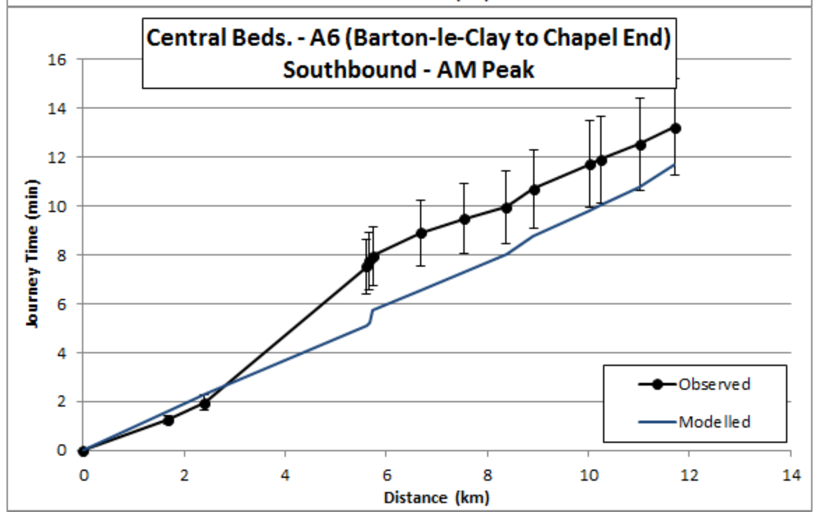

Central Beds. - A6 (Luton Centre to Barton-le-Clay)
Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

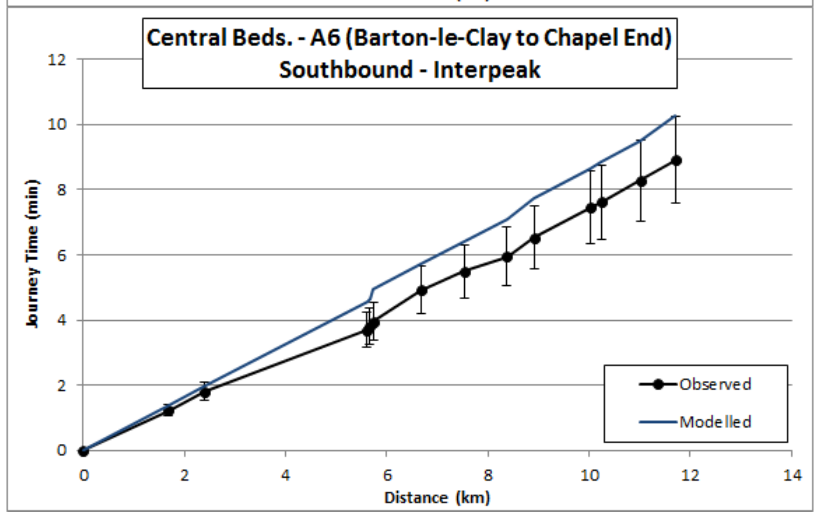

Central Beds. - A6 (Luton Centre to Barton-le-Clay)
Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

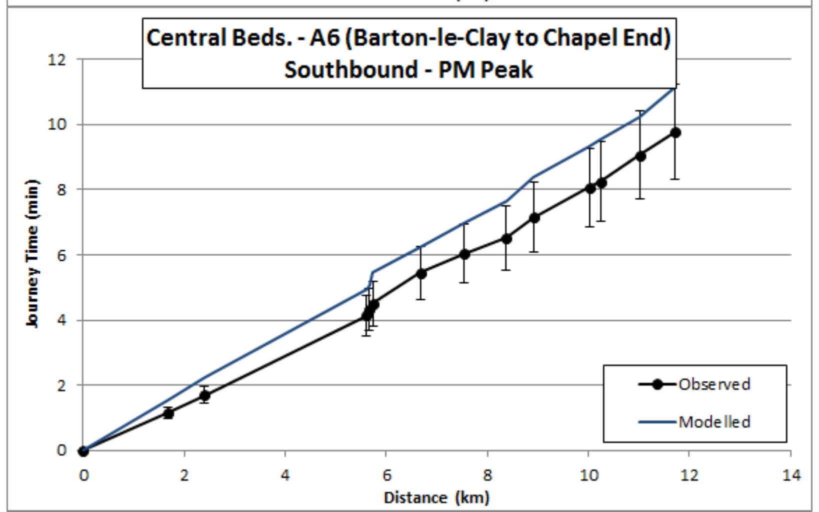

Central Beds. - A6 (Barton-le-Clay to Chapel End)
Northbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

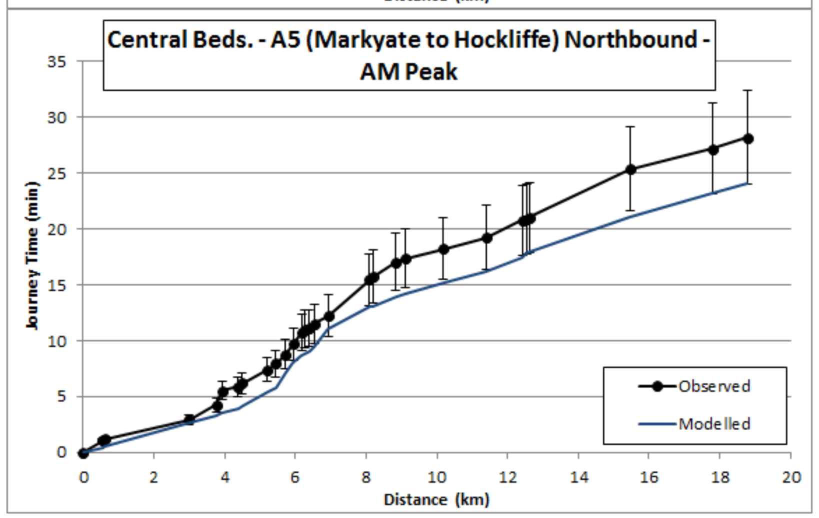

Central Beds. - A6 (Barton-le-Clay to Chapel End)
Northbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

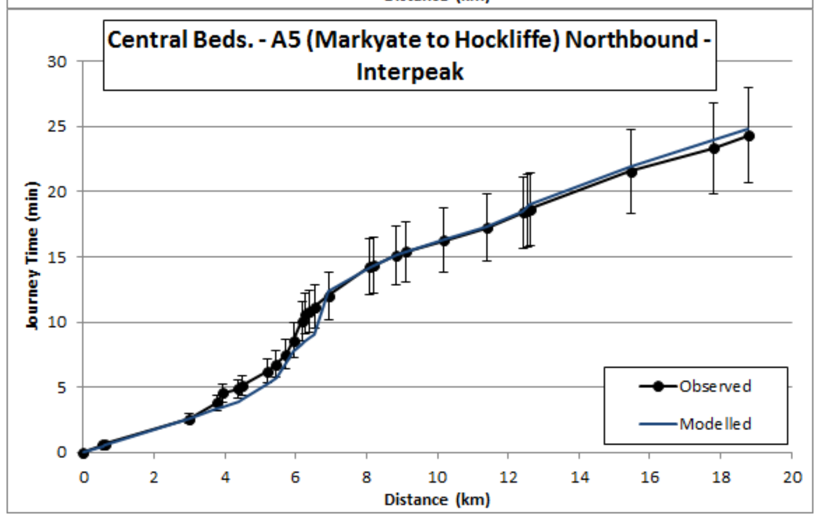

Central Beds. - A6 (Barton-le-Clay to Chapel End)
Northbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

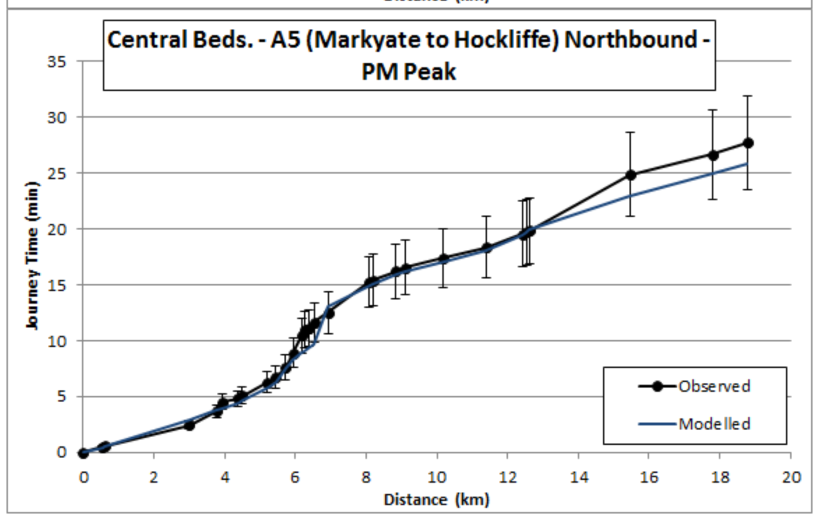

Central Beds. - A6 (Barton-le-Clay to Chapel End)
Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

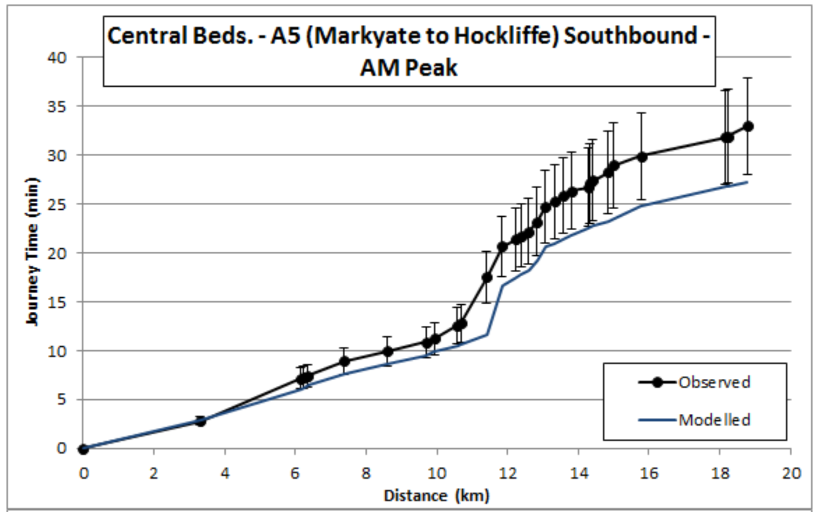

Central Beds. - A6 (Barton-le-Clay to Chapel End)
Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

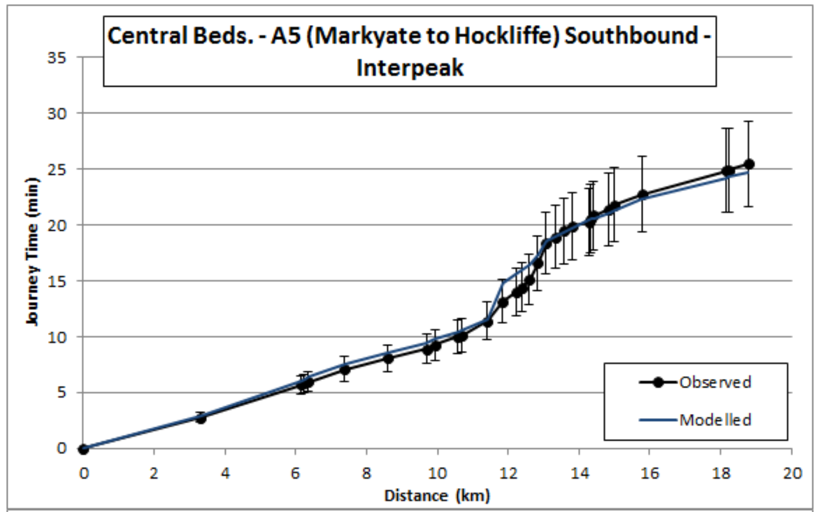

Central Beds. - A6 (Barton-le-Clay to Chapel End)
Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

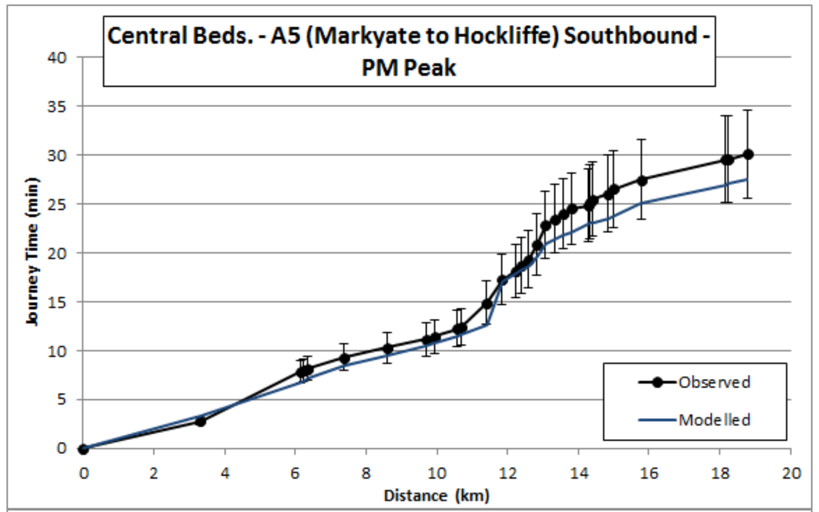

Central Beds. - A5 (Markyate to Hockliffe) Northbound -
AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

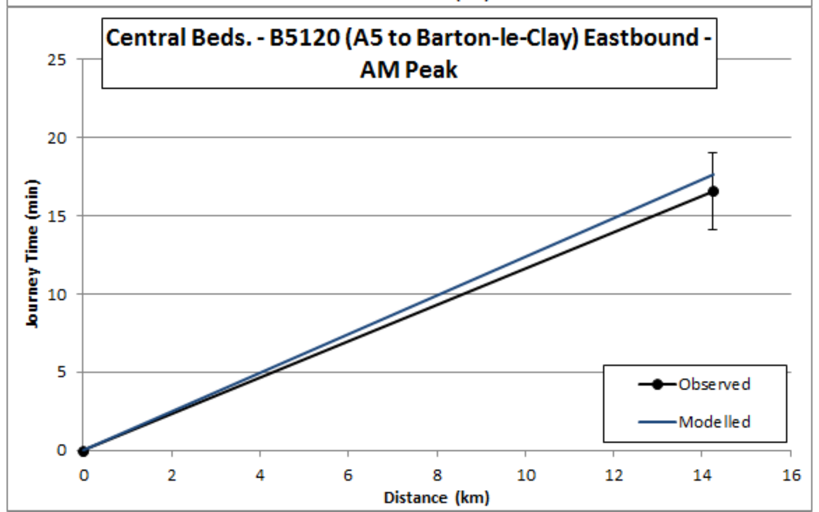

Central Beds. - A5 (Markyate to Hockliffe) Northbound -
Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

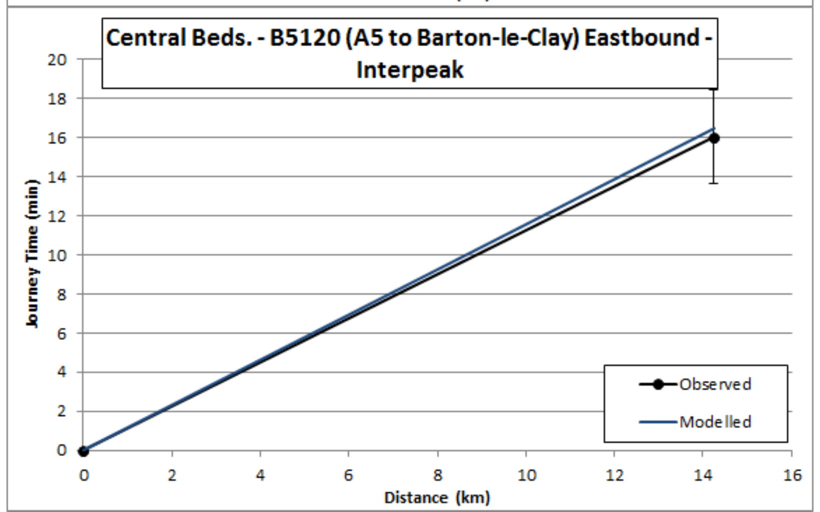

Central Beds. - A5 (Markyate to Hockliffe) Northbound -
PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

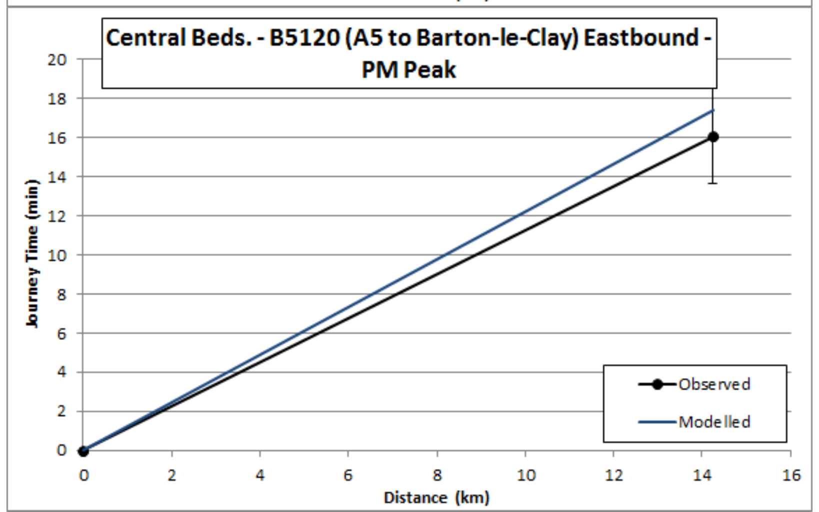

Central Beds. - A5 (Markyate to Hockliffe) Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

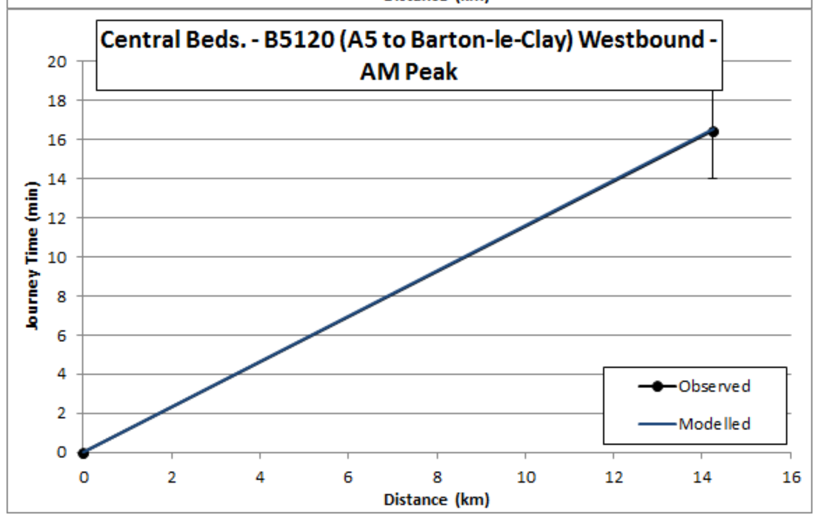

Central Beds. - A5 (Markyate to Hockliffe) Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

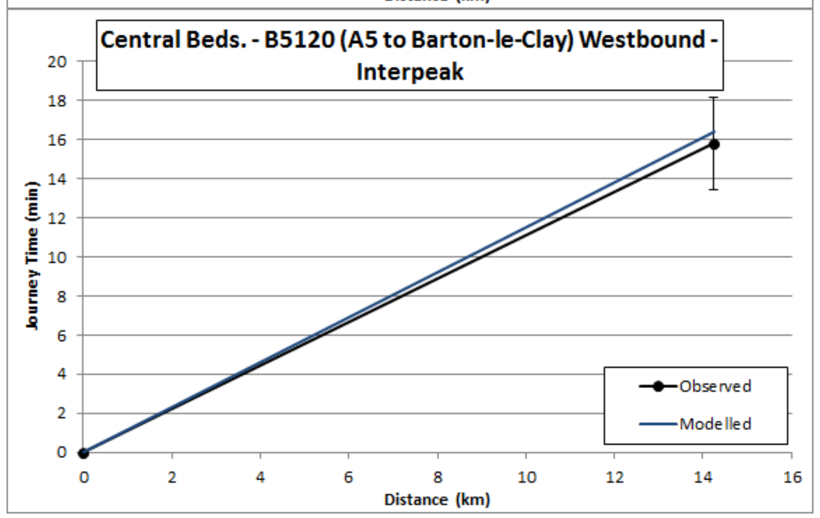

Central Beds. - A5 (Markyate to Hockliffe) Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

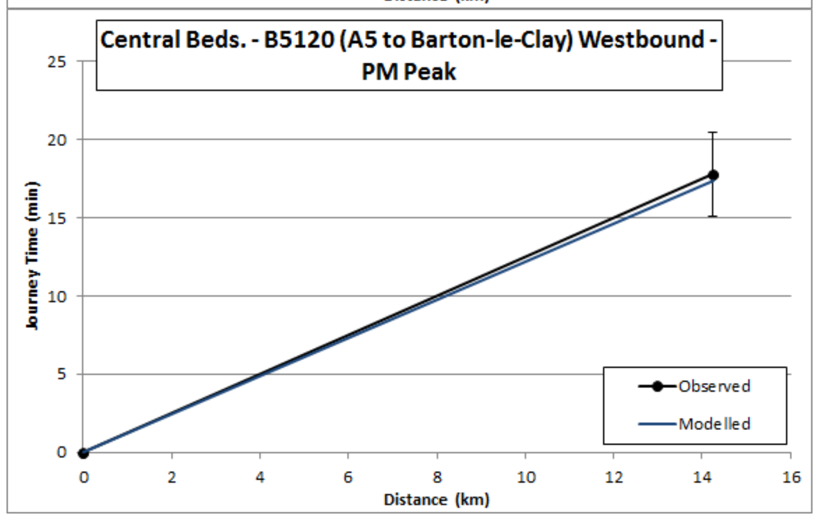

Central Beds. - B5120 (A5 to Barton-le-Clay) Eastbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

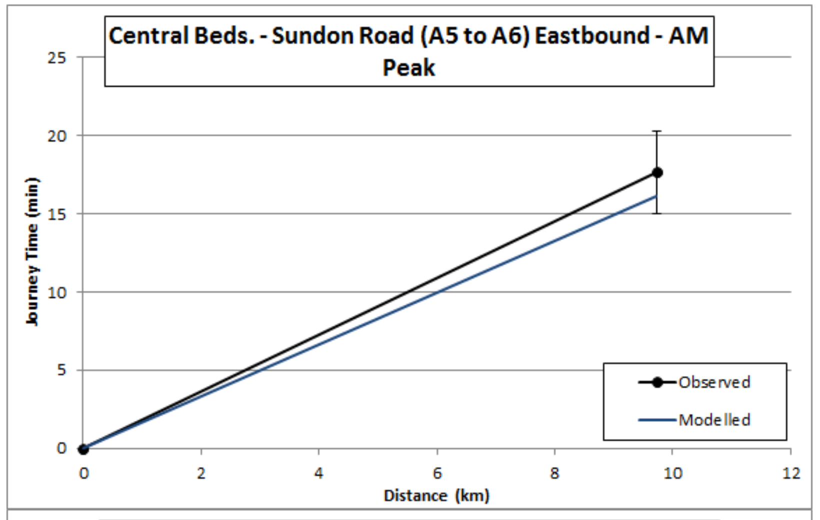

Central Beds. - B5120 (A5 to Barton-le-Clay) Eastbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

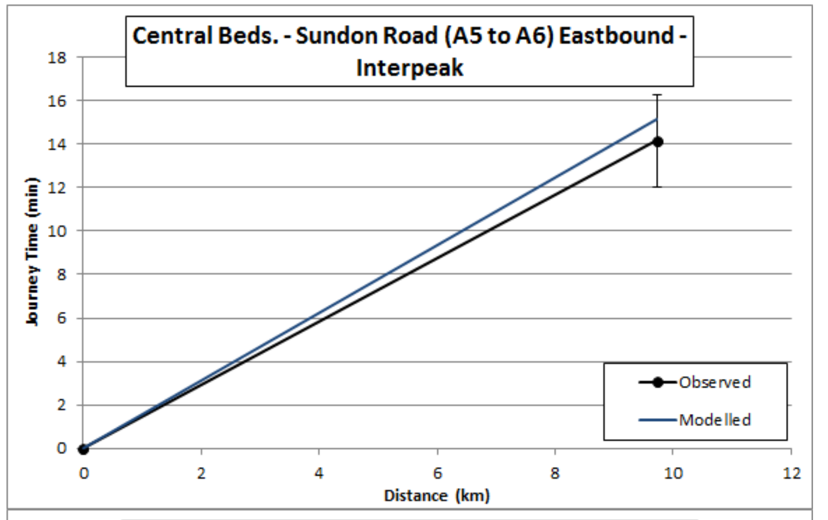

Central Beds. - B5120 (A5 to Barton-le-Clay) Eastbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

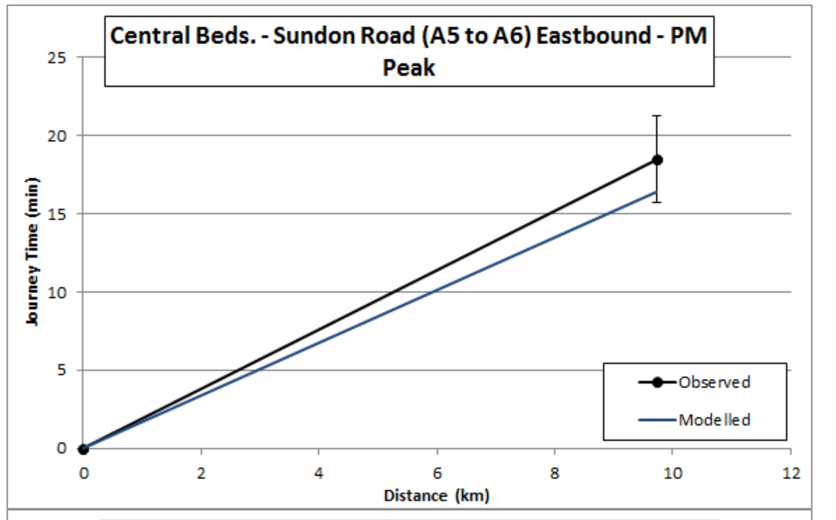

Central Beds. - B5120 (A5 to Barton-le-Clay) Westbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

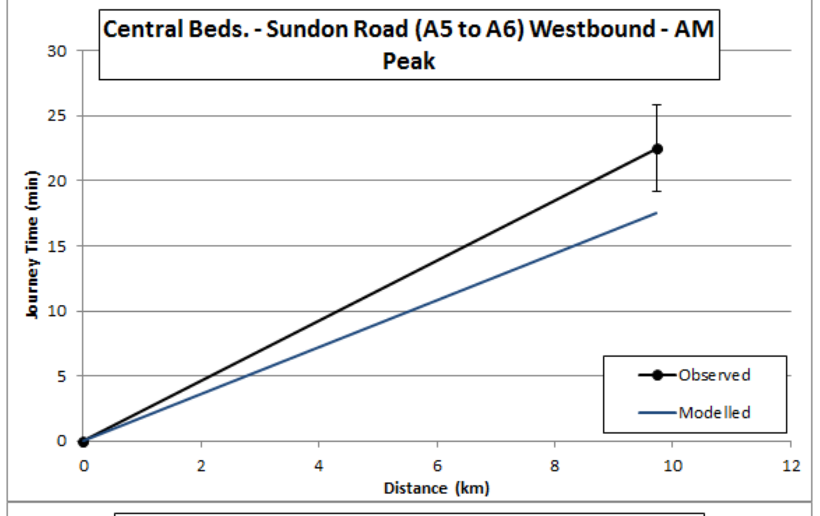

Central Beds. - B5120 (A5 to Barton-le-Clay) Westbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

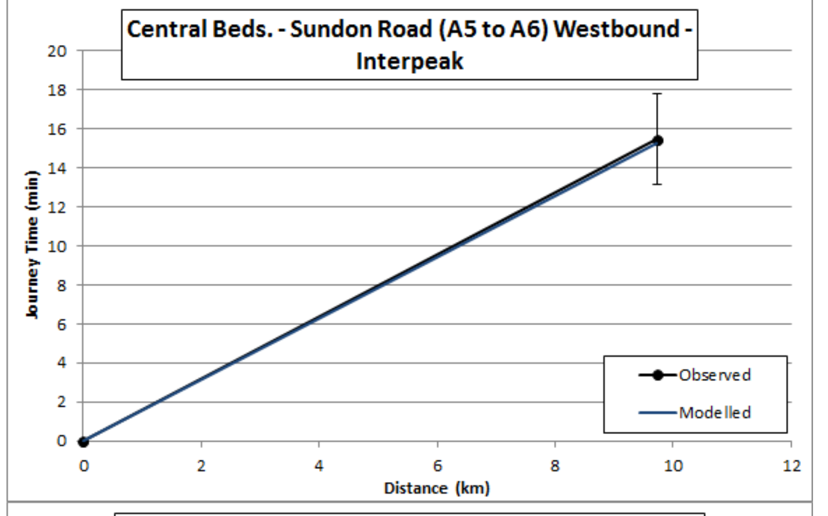

Central Beds. - B5120 (A5 to Barton-le-Clay) Westbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

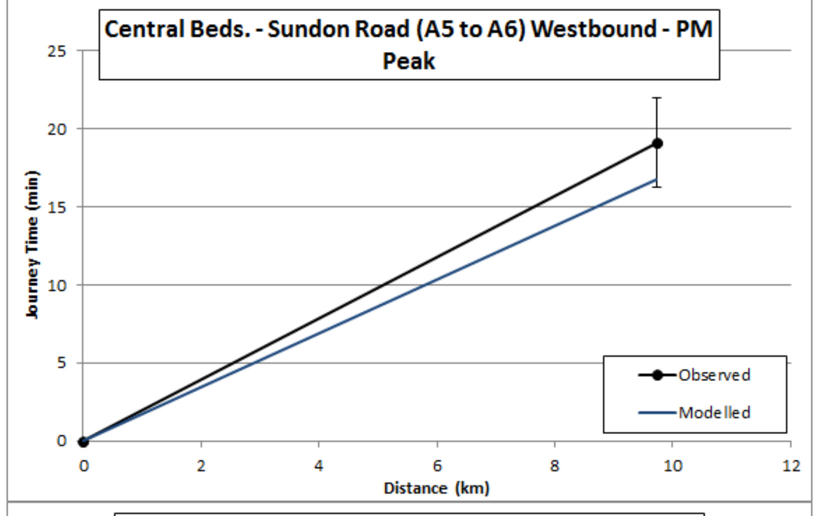

Central Beds. - Sundon Road (A5 to A6) Eastbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

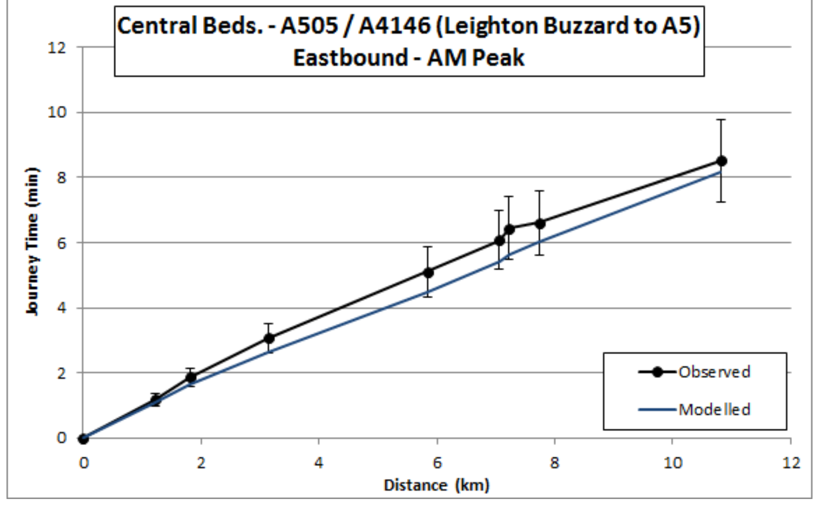

Central Beds. - Sundon Road (A5 to A6) Eastbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

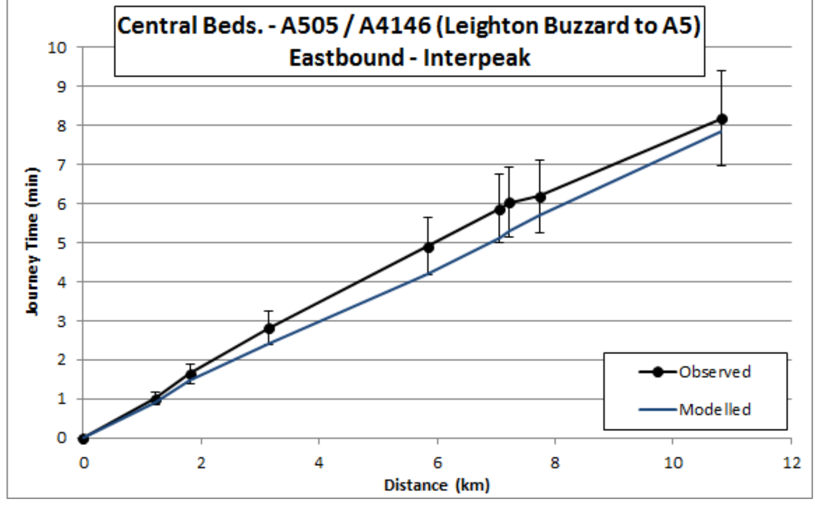

Central Beds. - Sundon Road (A5 to A6) Eastbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

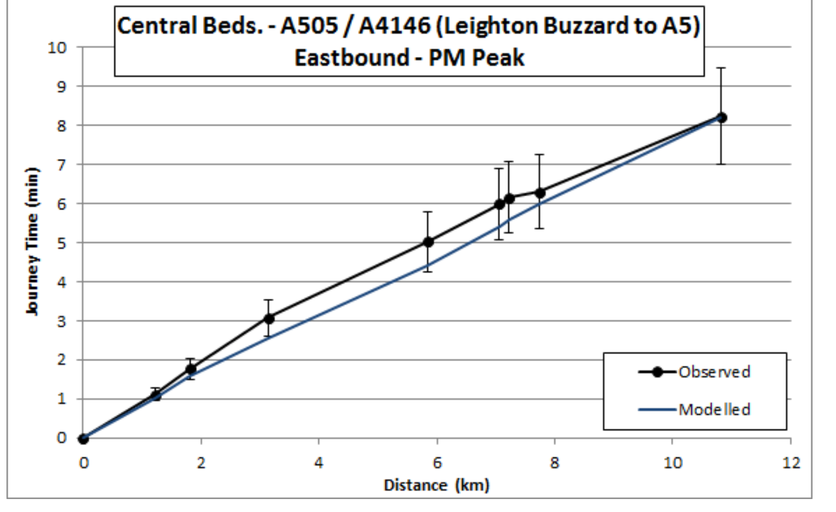

Central Beds. - Sundon Road (A5 to A6) Westbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

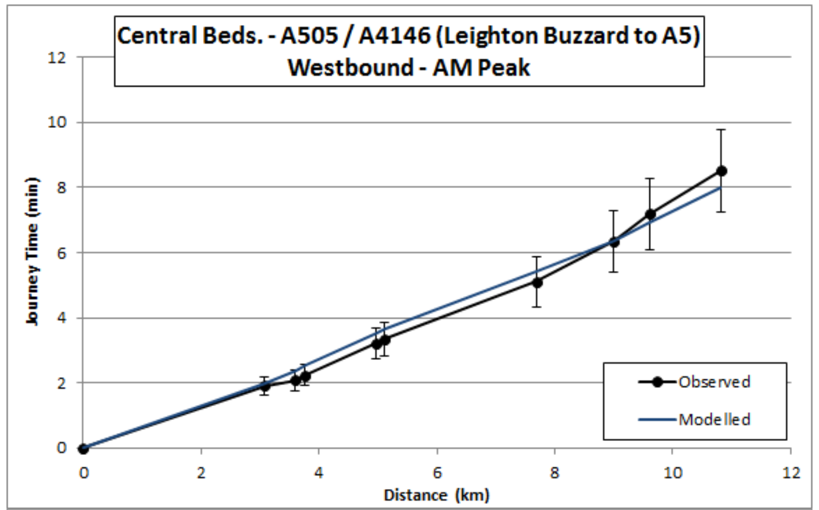

Central Beds. - Sundon Road (A5 to A6) Westbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

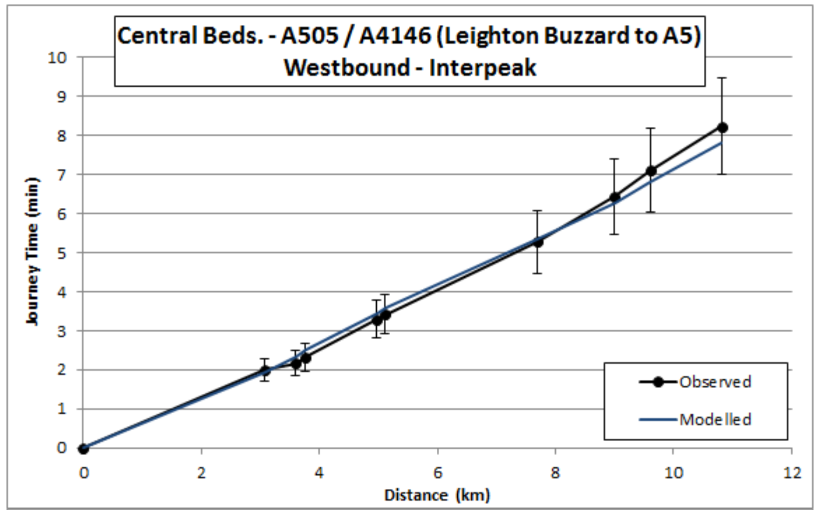

Central Beds. - Sundon Road (A5 to A6) Westbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

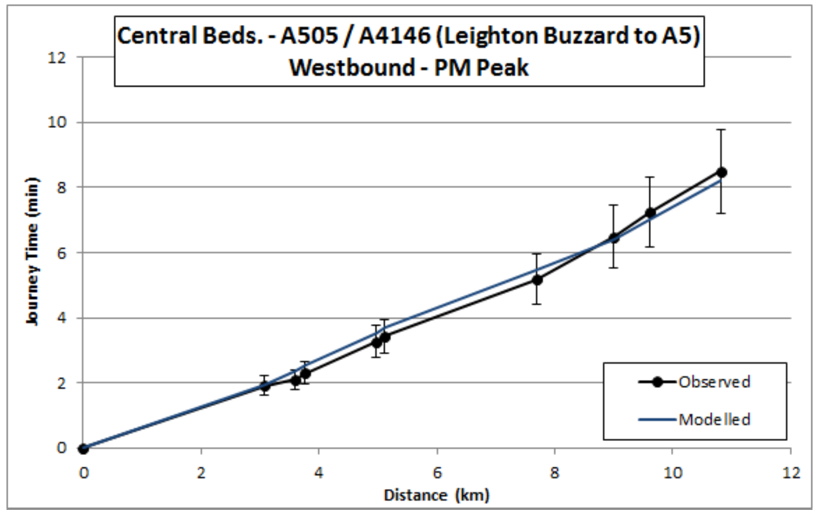

Central Beds. - A505 / A4146 (Leighton Buzzard to A5) Eastbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

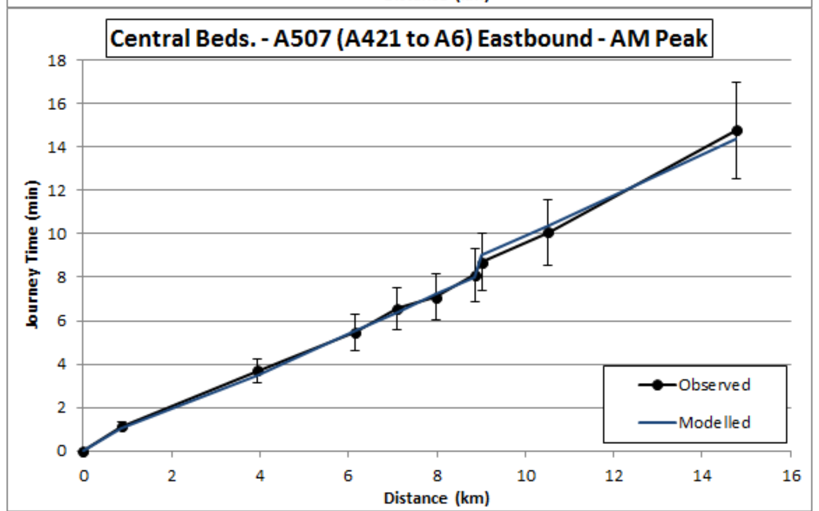

Central Beds. - A505 / A4146 (Leighton Buzzard to A5) Eastbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

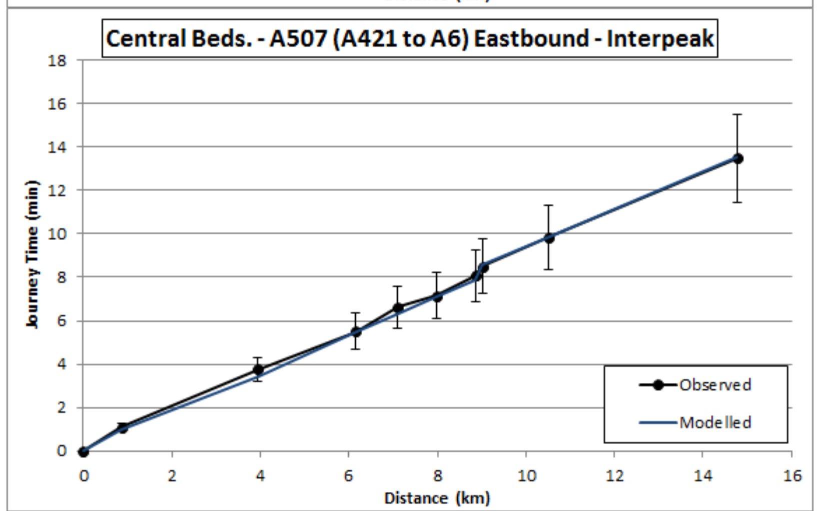

Central Beds. - A505 / A4146 (Leighton Buzzard to A5) Eastbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

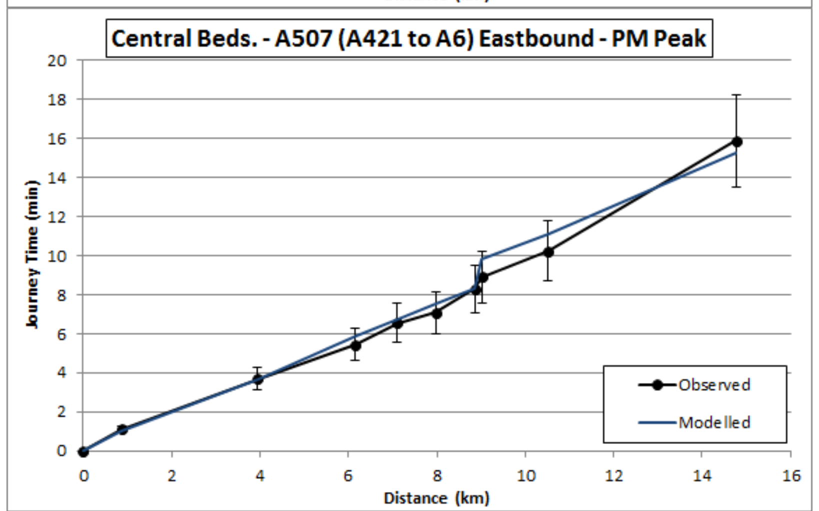

Central Beds. - A505 / A4146 (Leighton Buzzard to A5)
Westbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

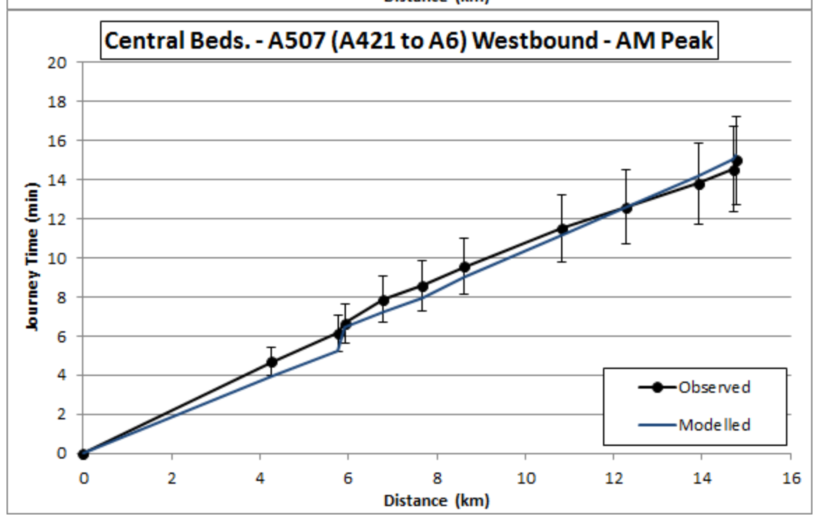

Central Beds. - A505 / A4146 (Leighton Buzzard to A5)
Westbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

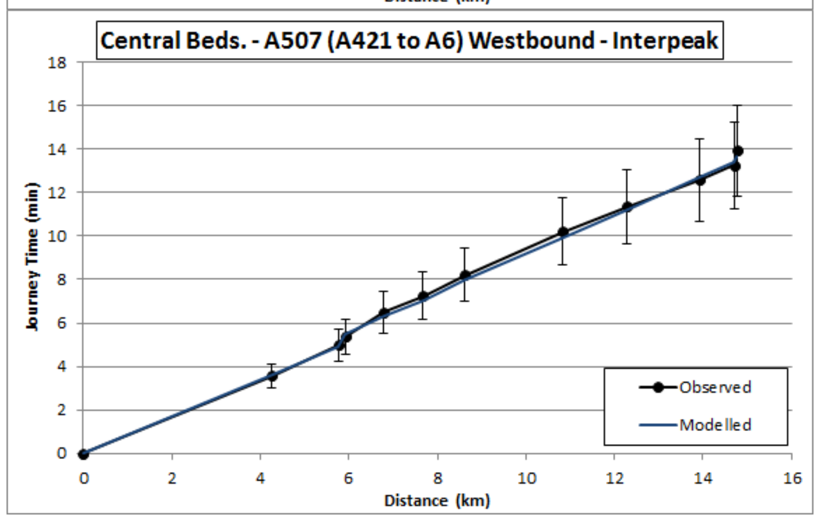

Central Beds. - A505 / A4146 (Leighton Buzzard to A5)
Westbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

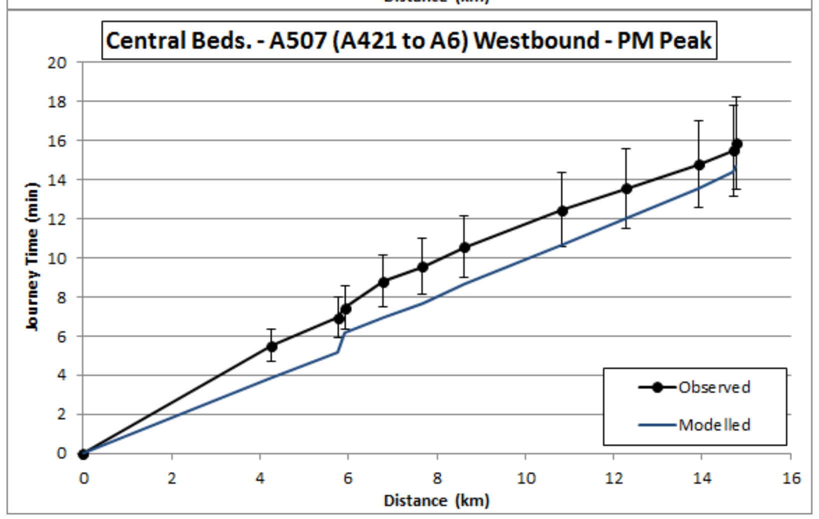

Central Beds. - A507 (A421 to A6) Eastbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

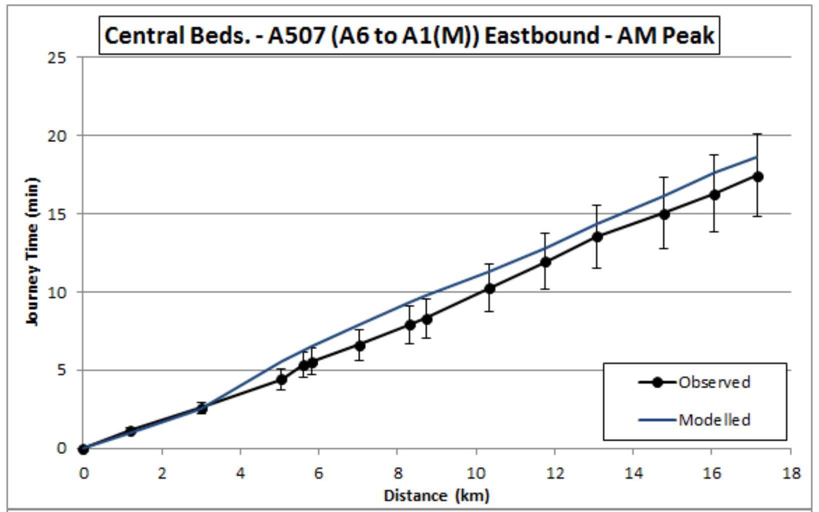

Central Beds. - A507 (A421 to A6) Eastbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

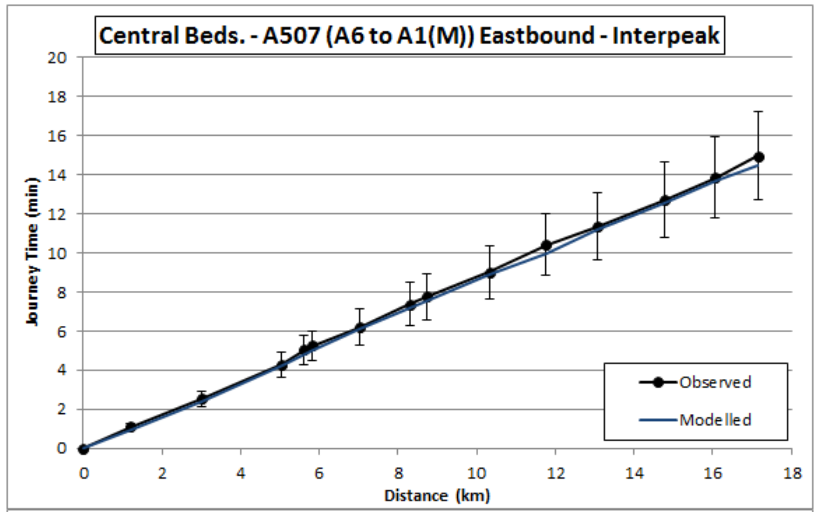

Central Beds. - A507 (A421 to A6) Eastbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

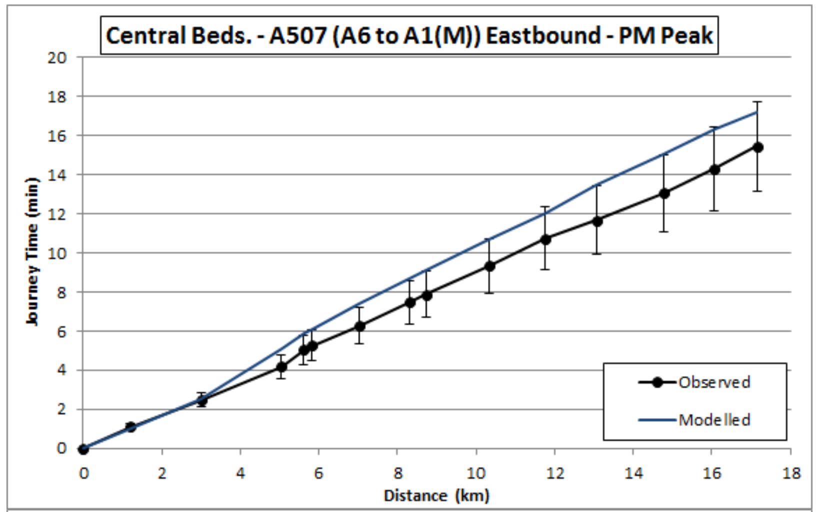

Central Beds. - A507 (A421 to A6) Westbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

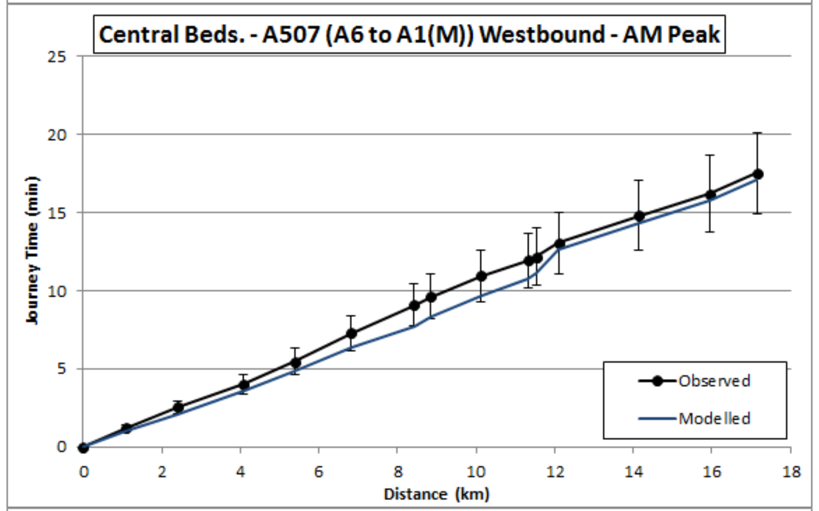

Central Beds. - A507 (A421 to A6) Westbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

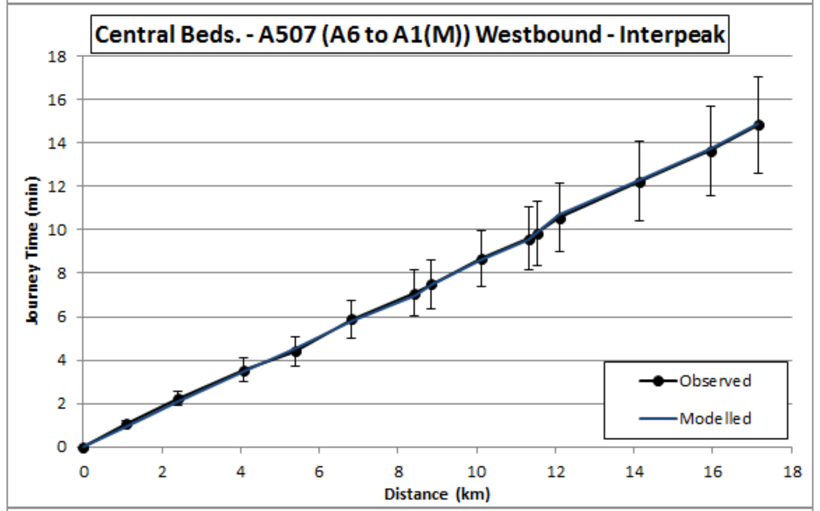

Central Beds. - A507 (A421 to A6) Westbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

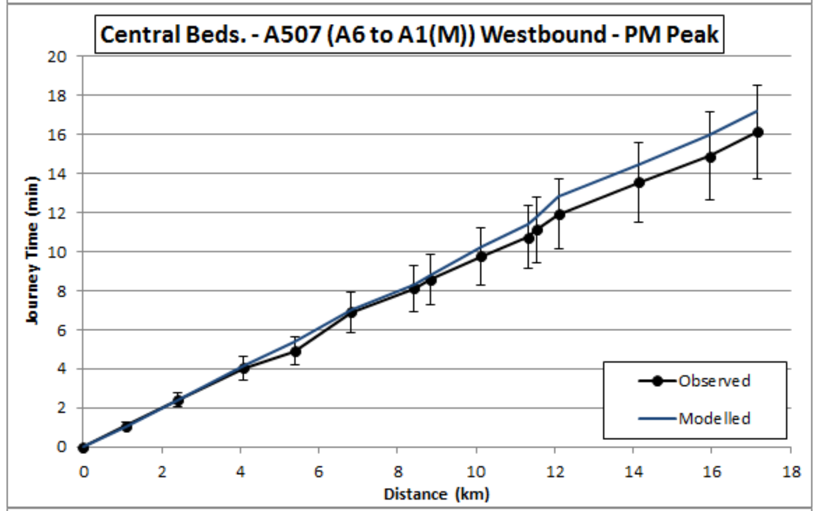

Central Beds. - A507 (A6 to A1(M)) Eastbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

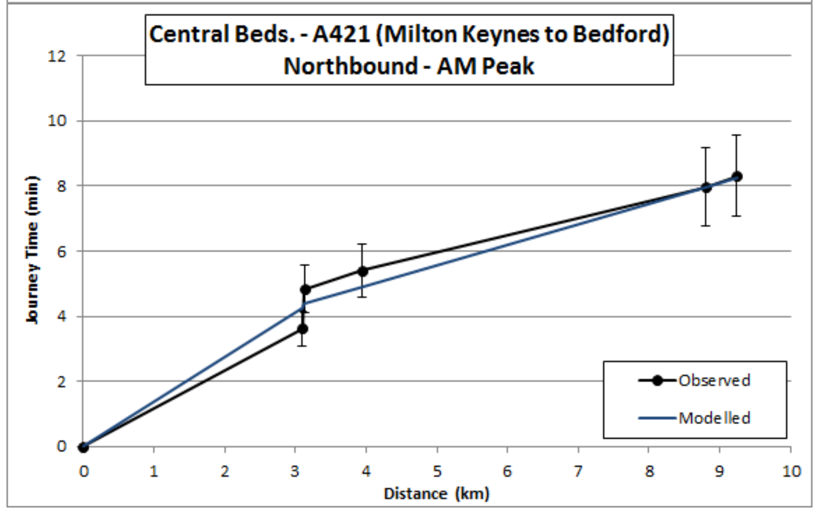

Central Beds. - A507 (A6 to A1(M)) Eastbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

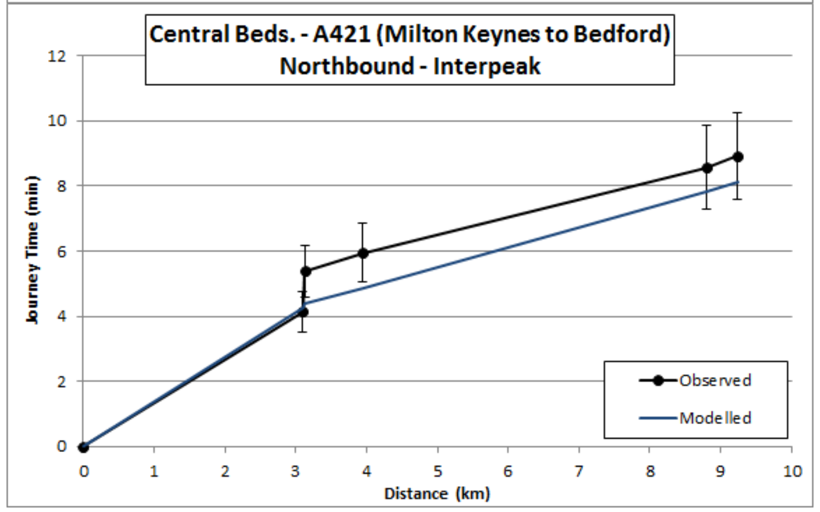

Central Beds. - A507 (A6 to A1(M)) Eastbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

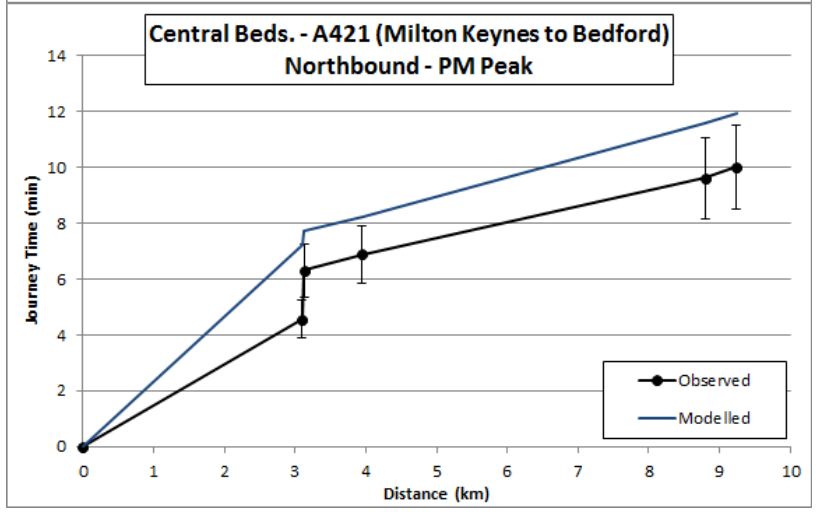

Central Beds. - A507 (A6 to A1(M)) Westbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

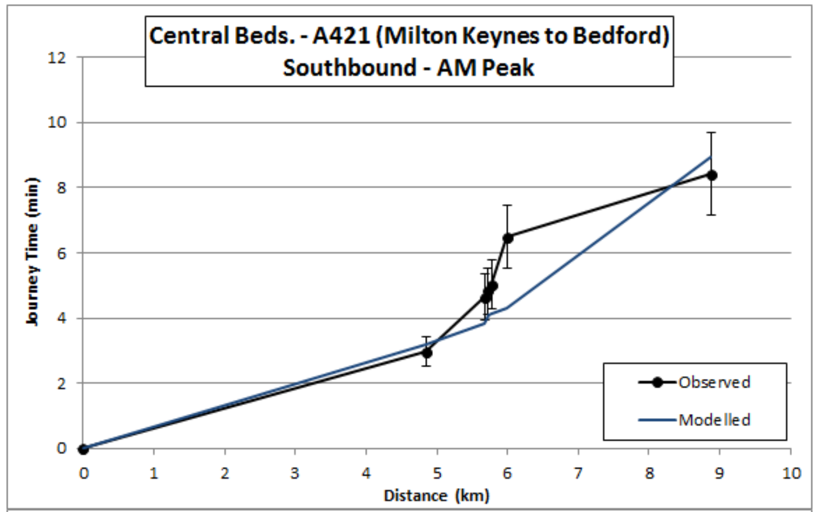

Central Beds. - A507 (A6 to A1(M)) Westbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

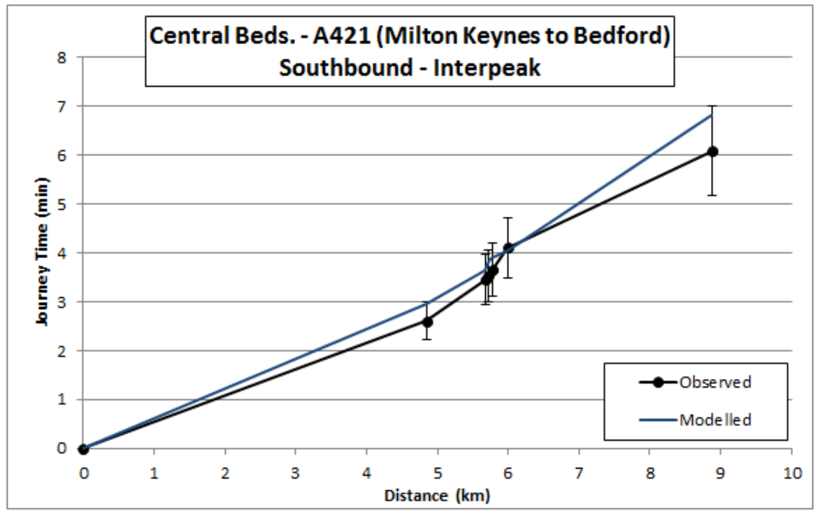

Central Beds. - A507 (A6 to A1(M)) Westbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

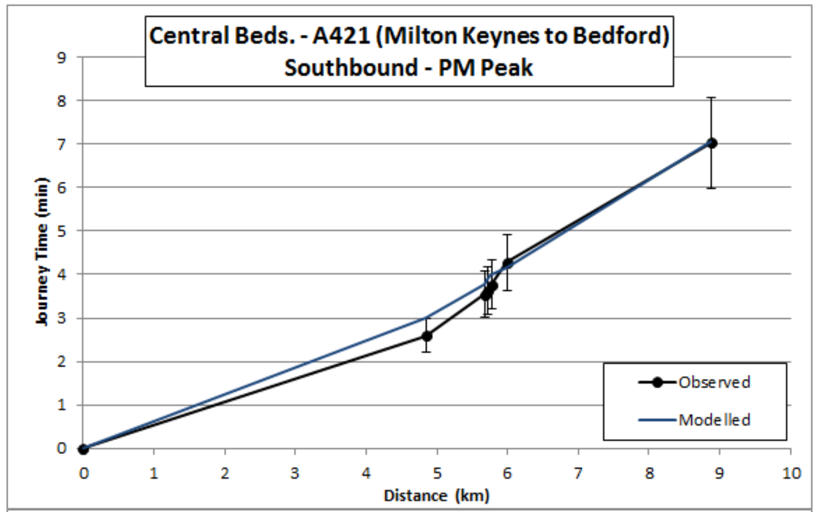

Central Beds. - A421 (Milton Keynes to Bedford)
Northbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

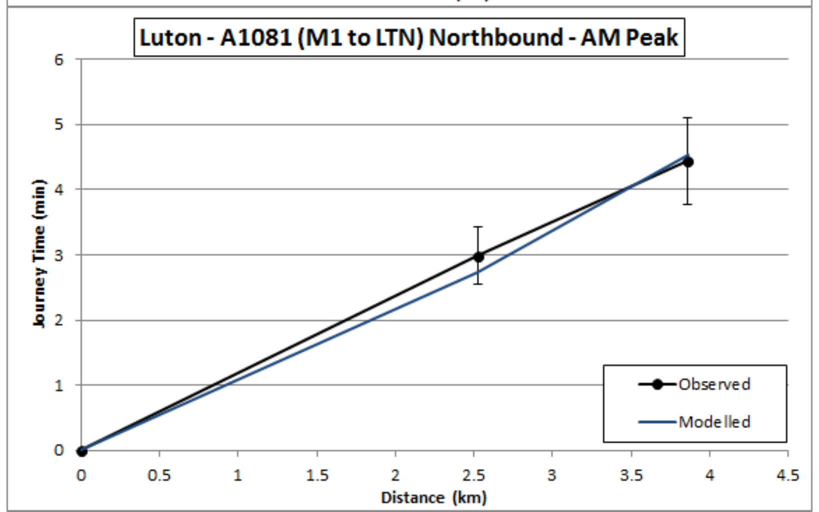

Central Beds. - A421 (Milton Keynes to Bedford)
Northbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled


Central Beds. - A421 (Milton Keynes to Bedford)
Northbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

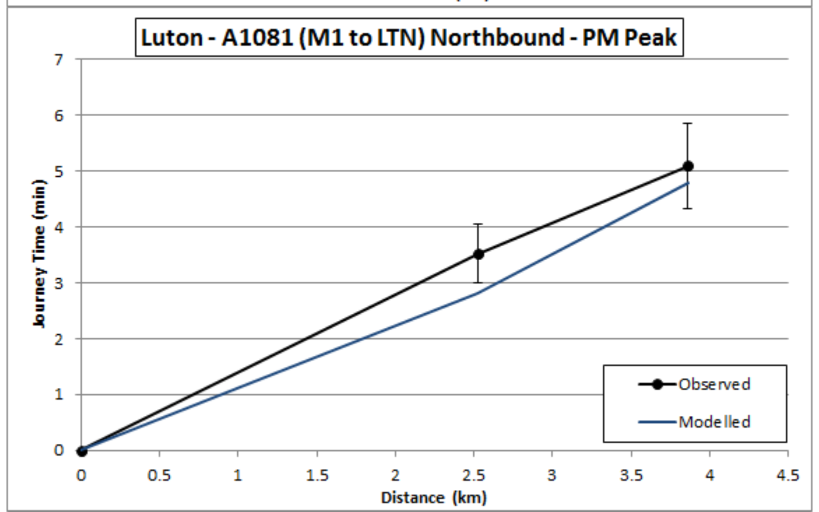


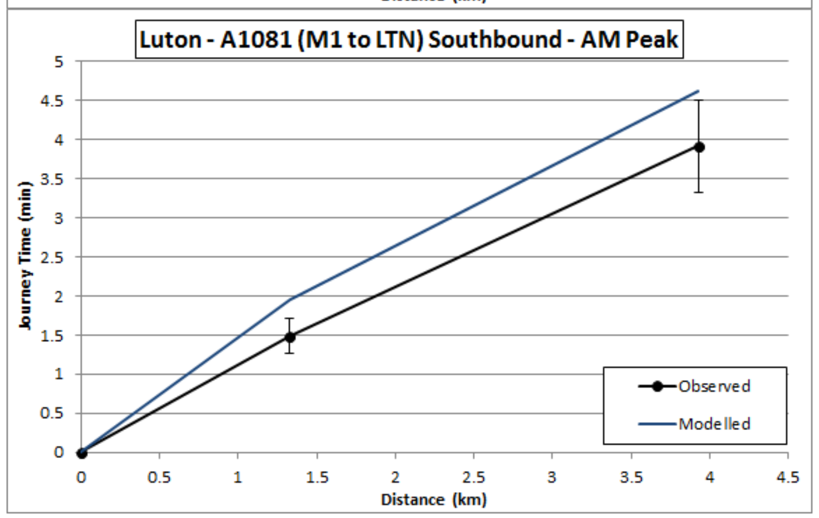




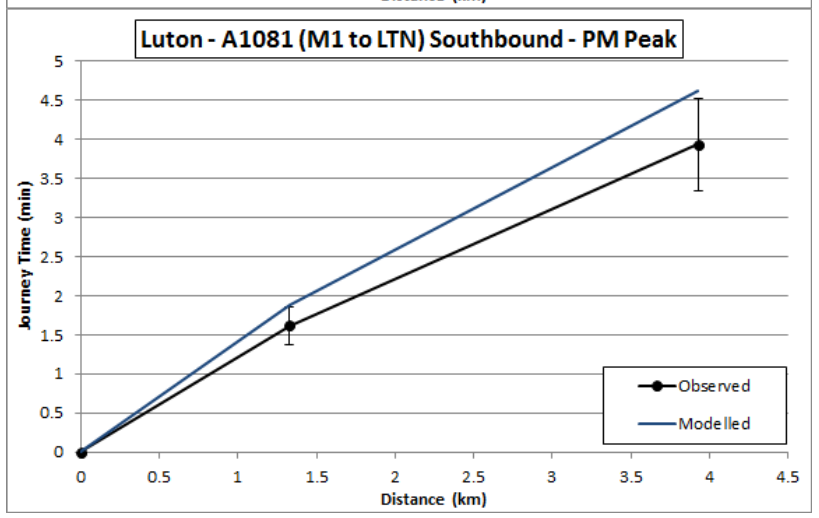


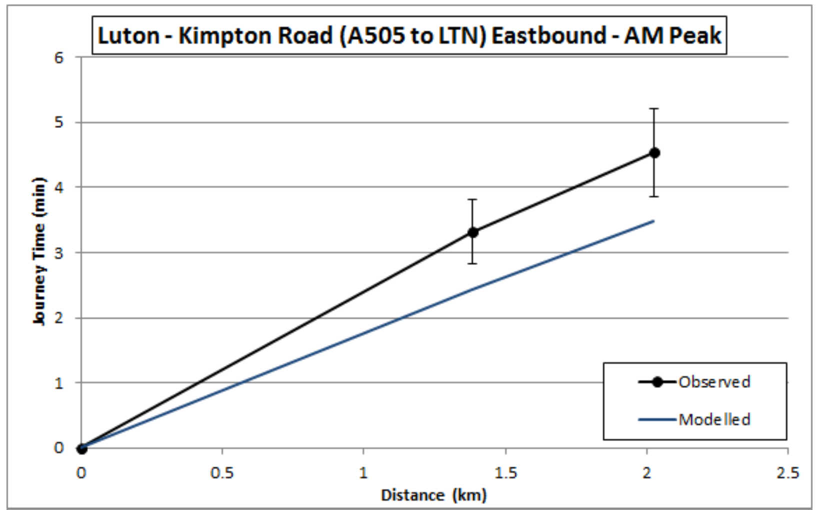
Luton journey times not observed for the interpeak



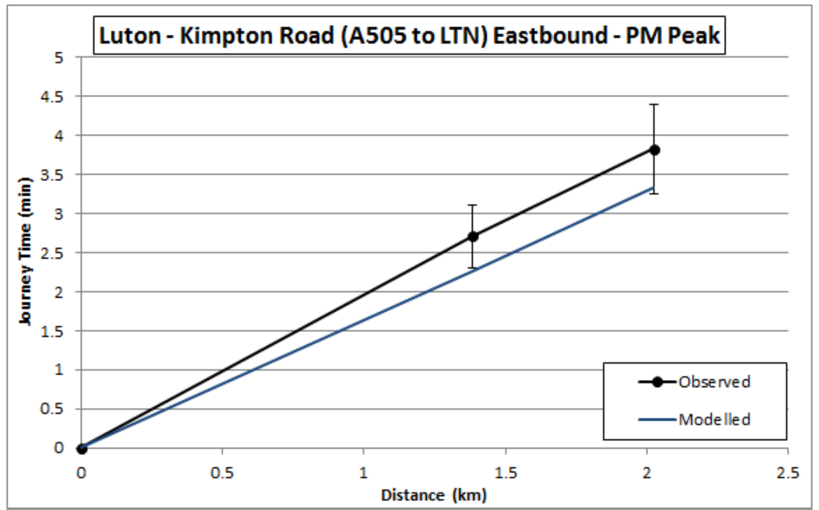


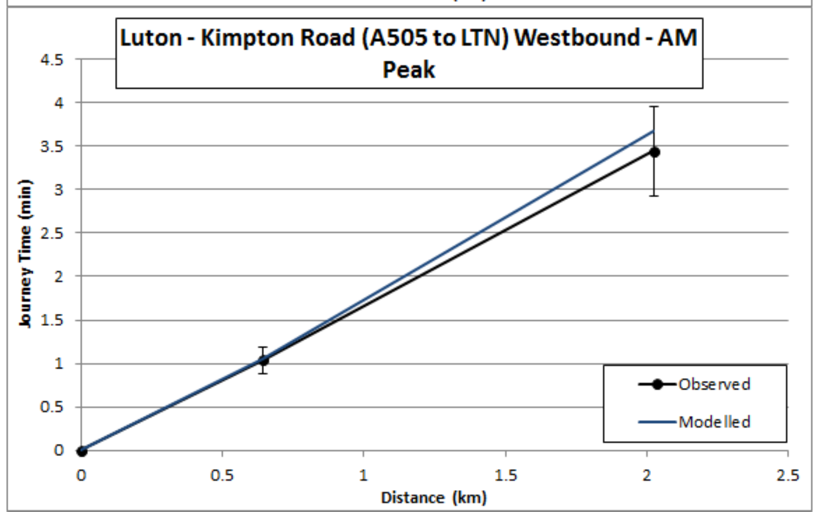
Luton journey times not observed for the interpeak





Luton journey times not observed for the interpeak





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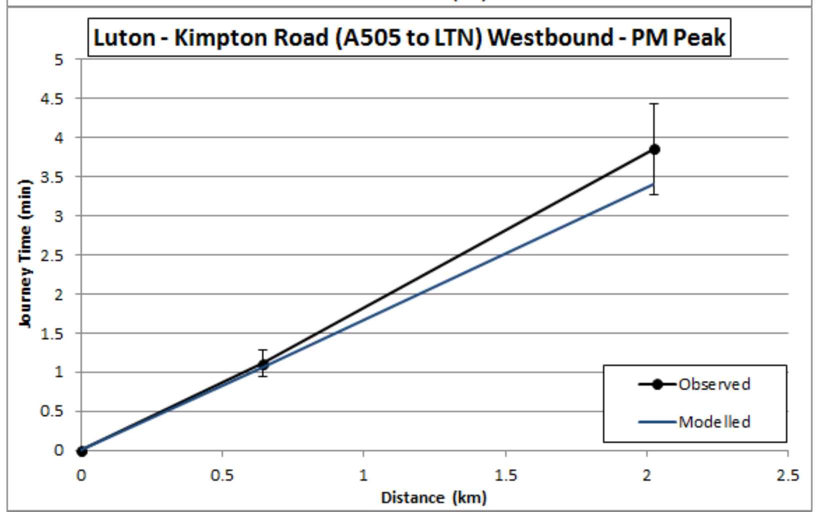

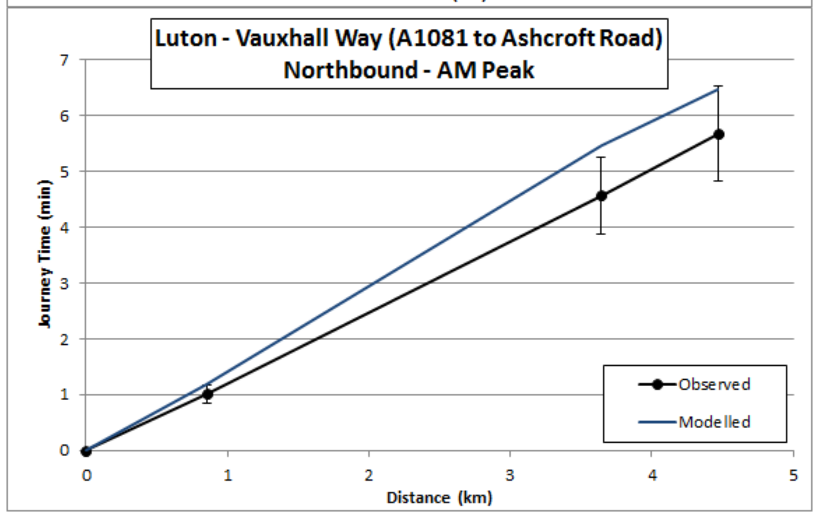

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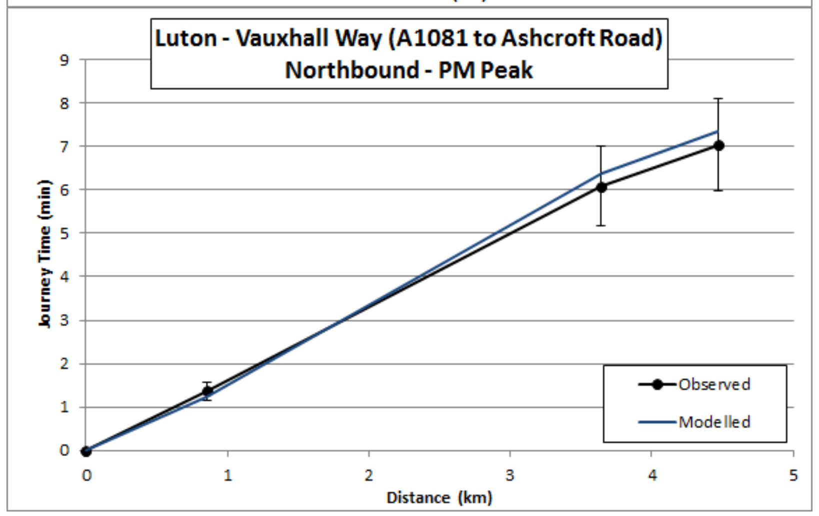

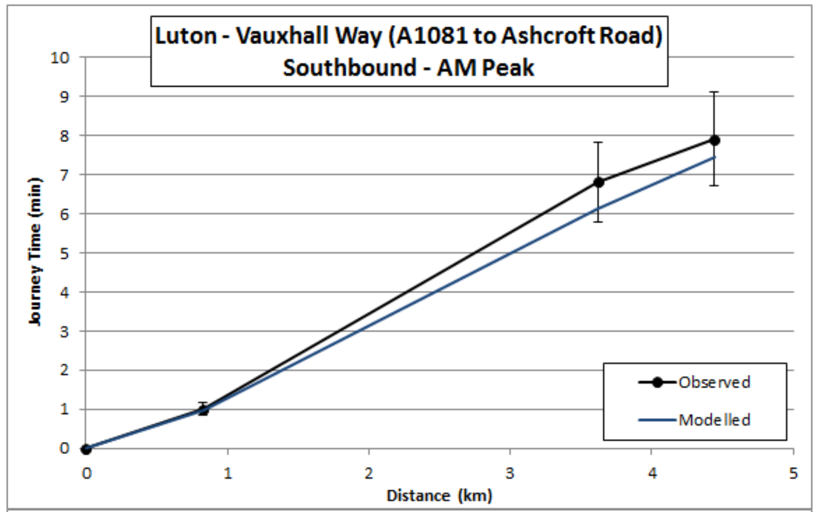

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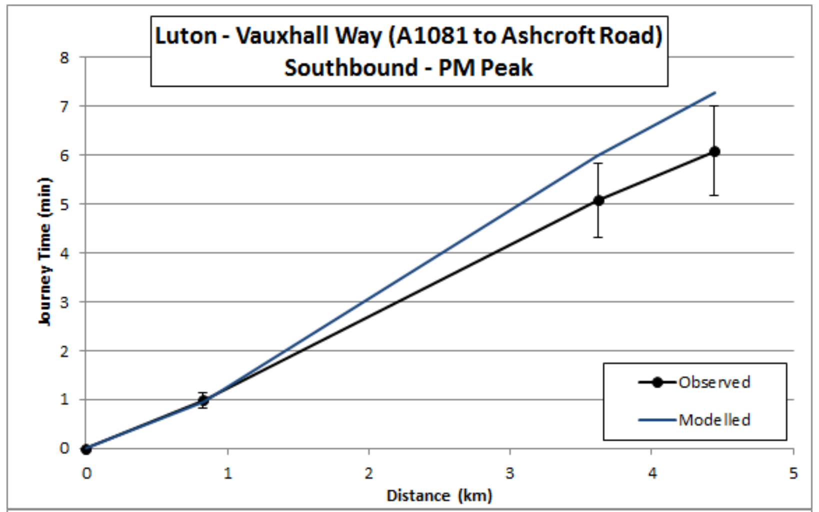

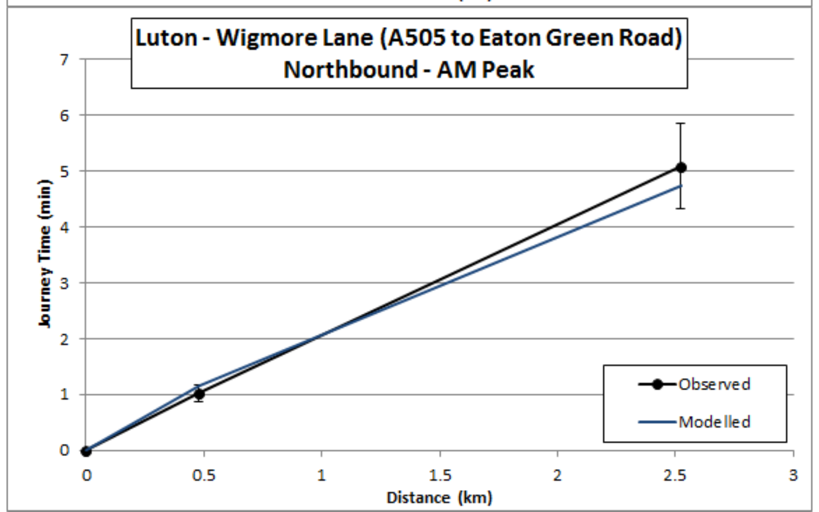

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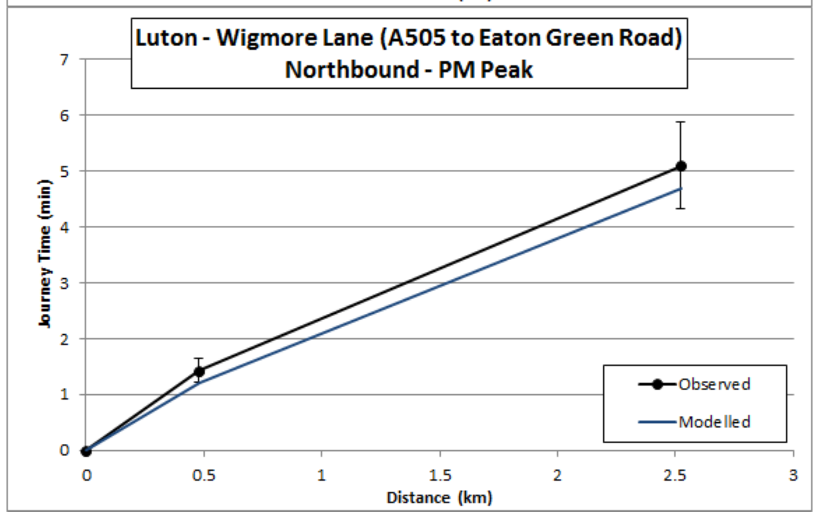

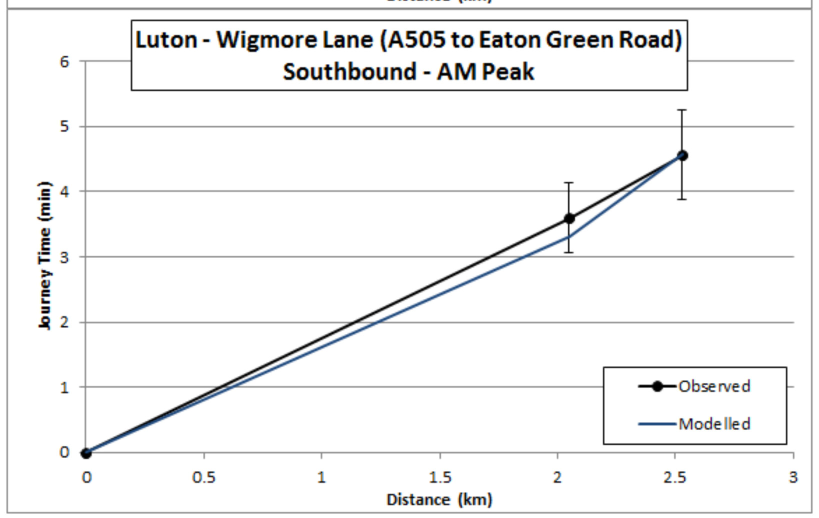

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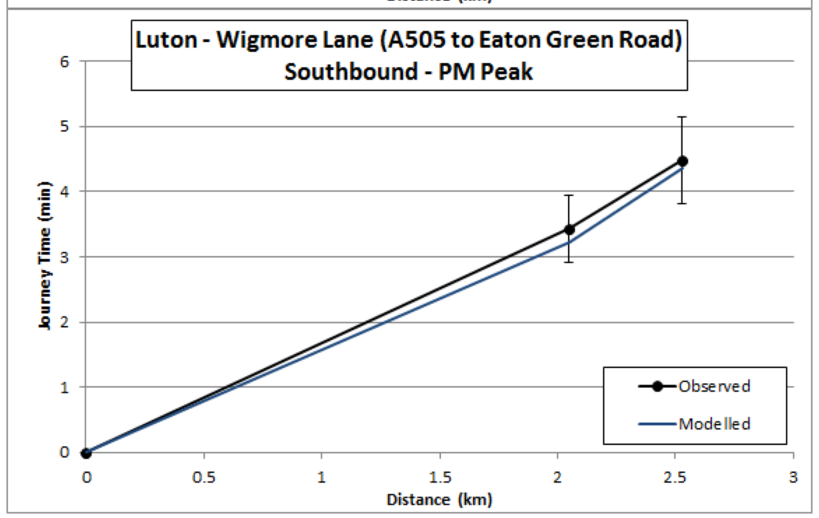

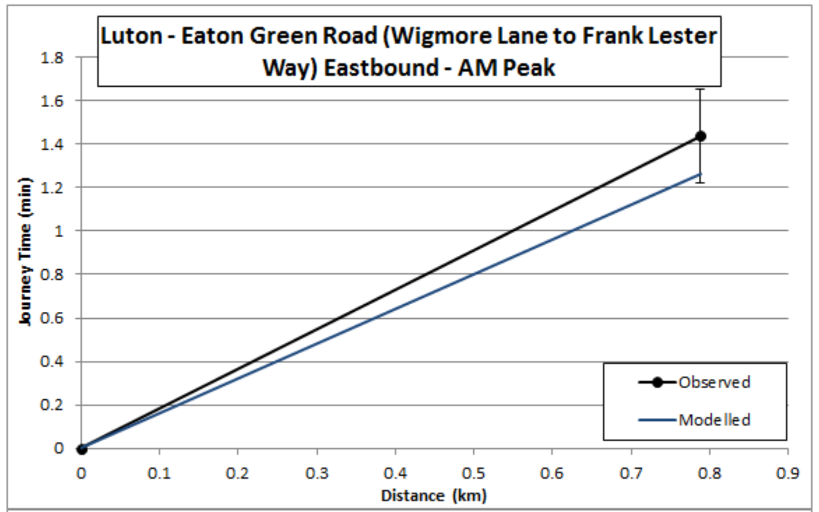

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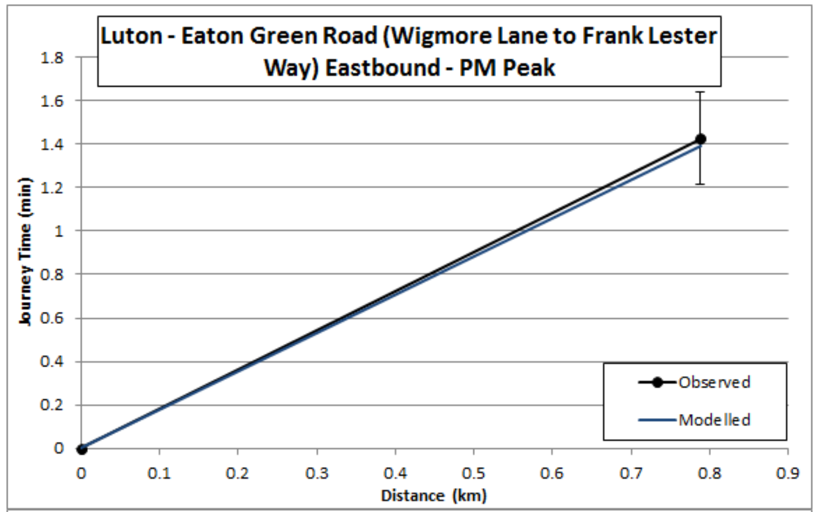

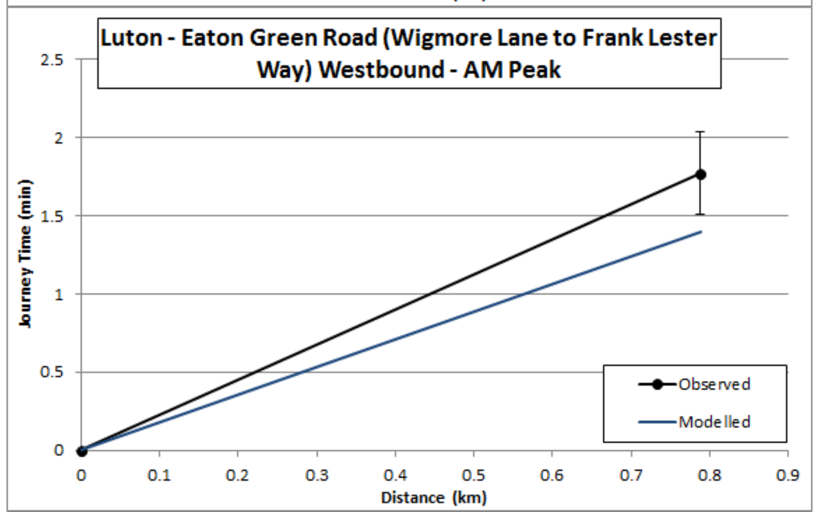

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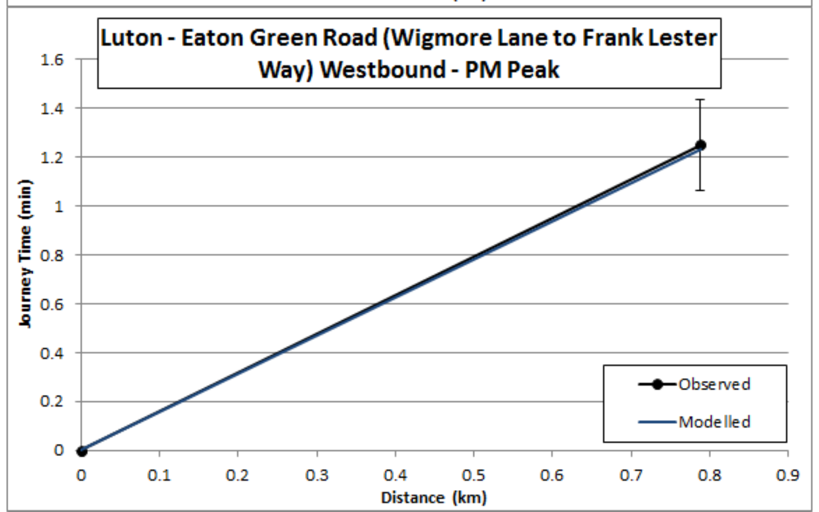

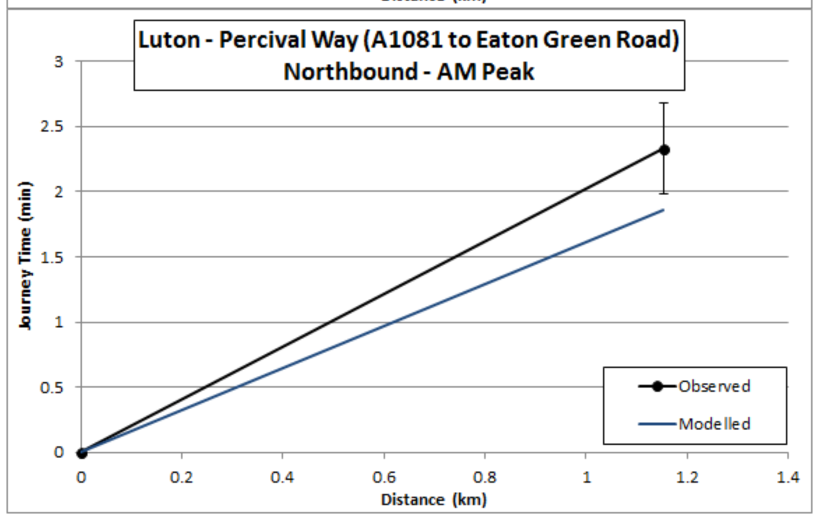

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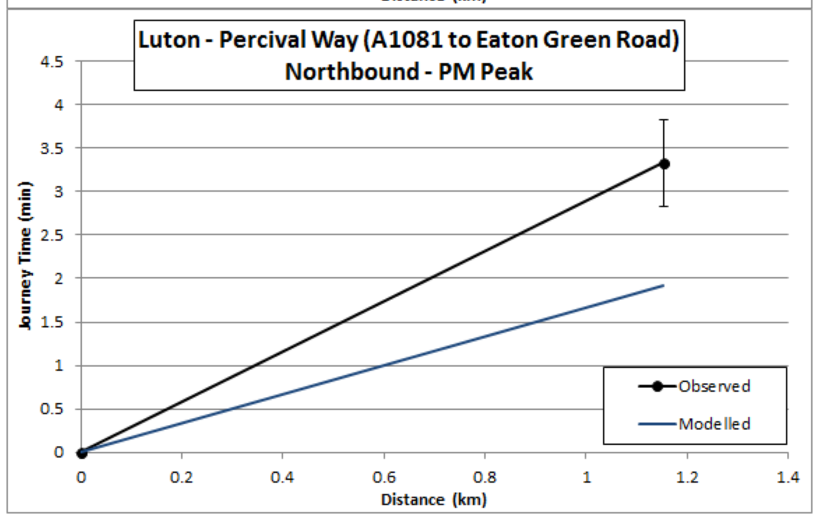

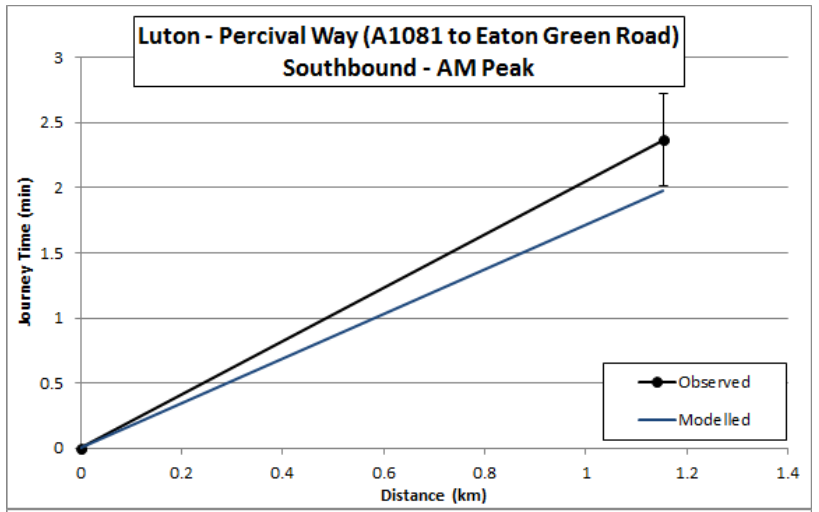

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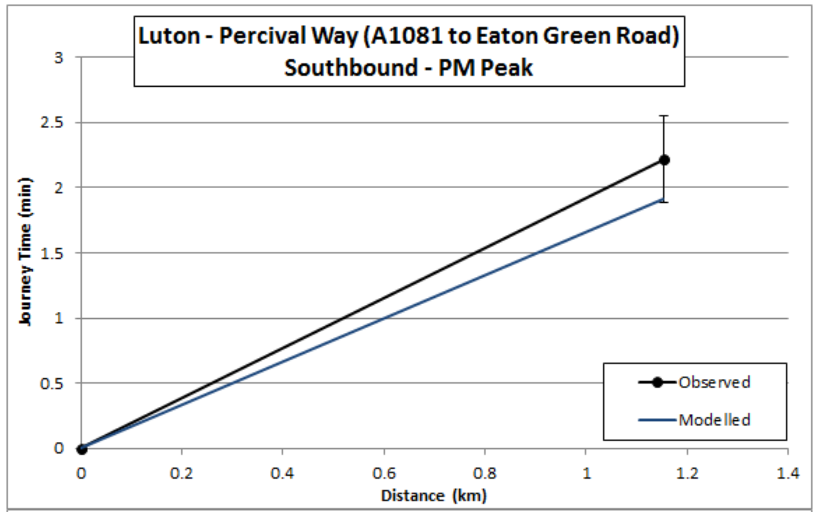
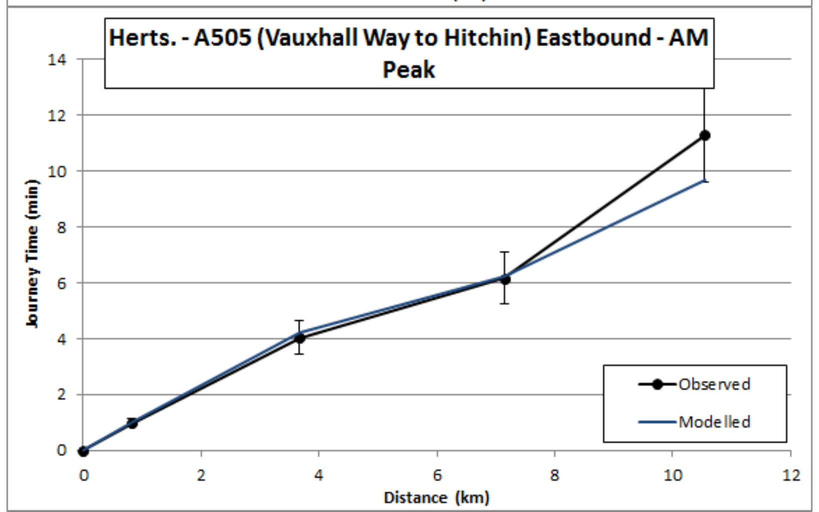
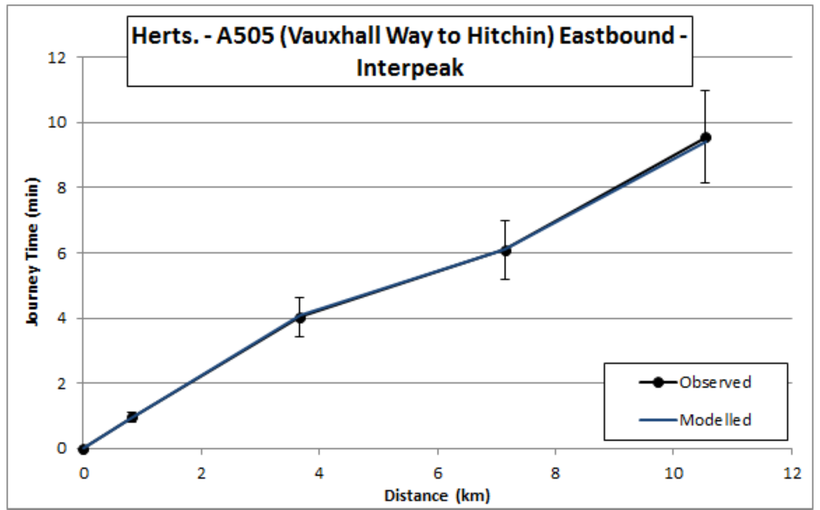
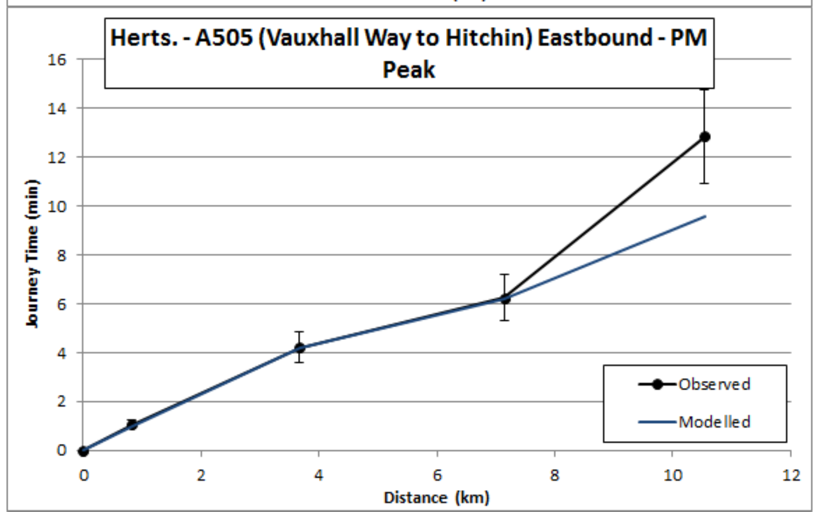
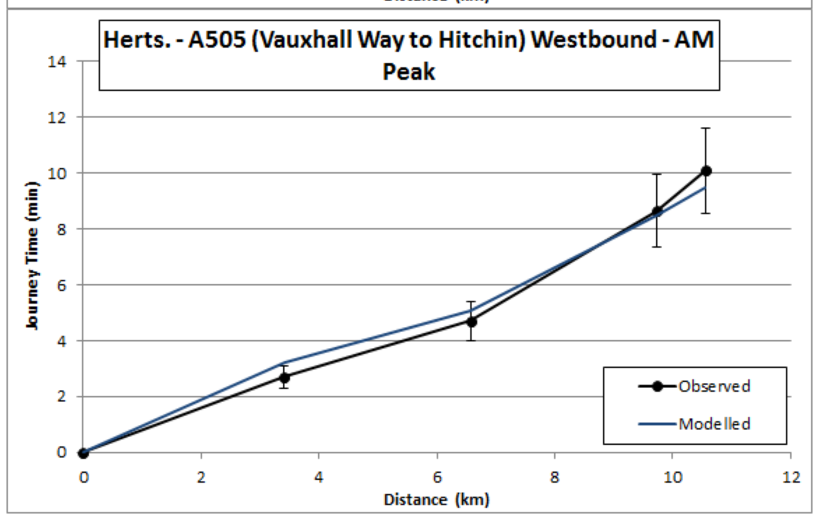
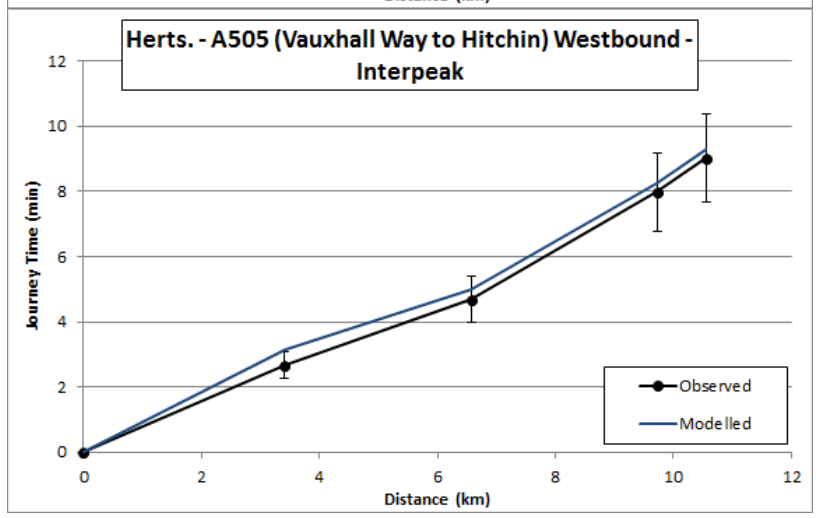


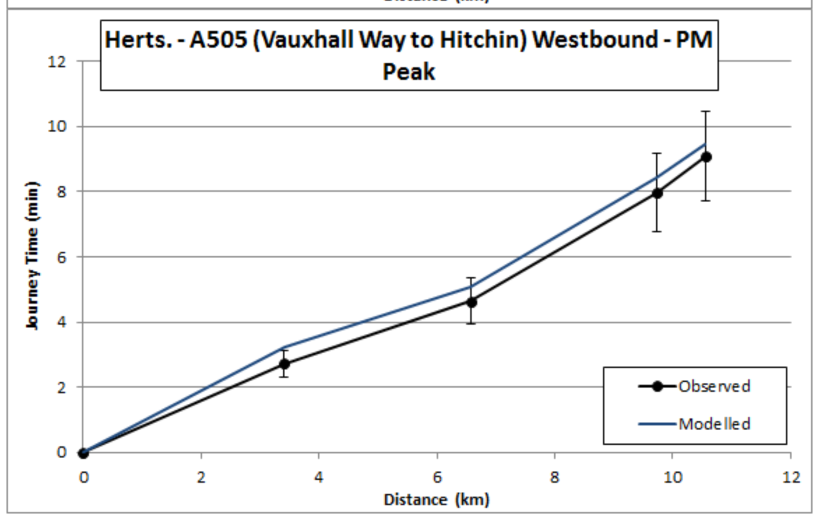


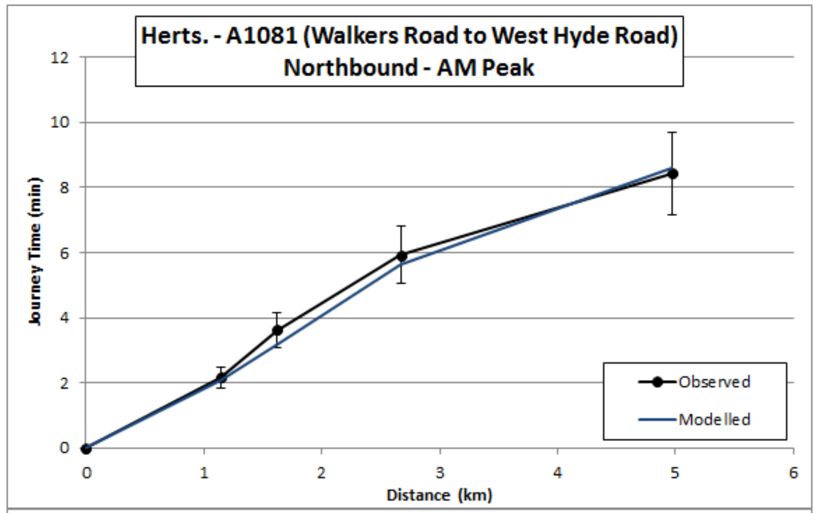


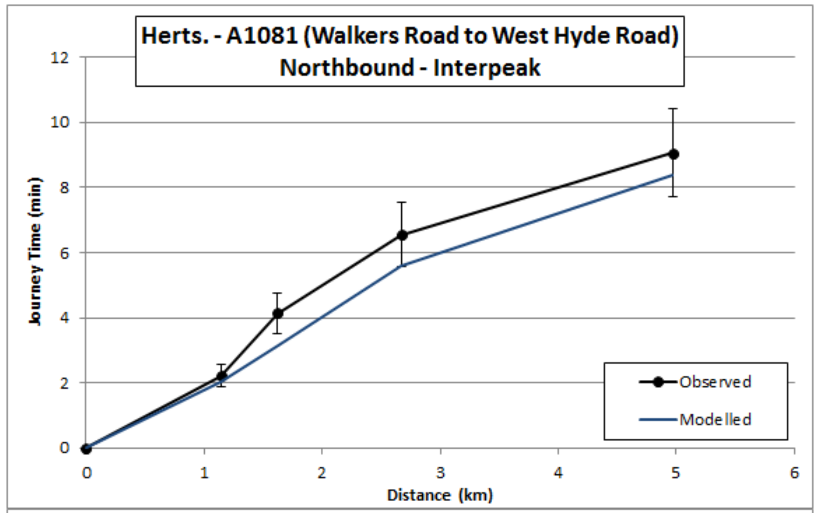


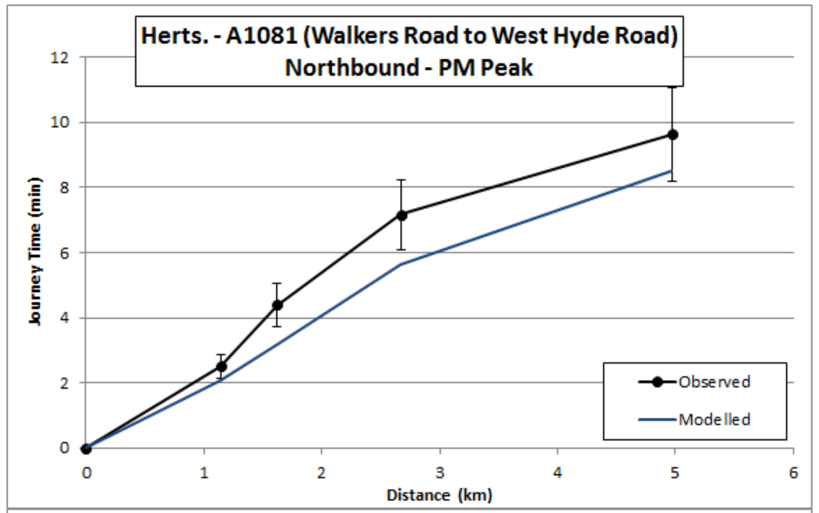


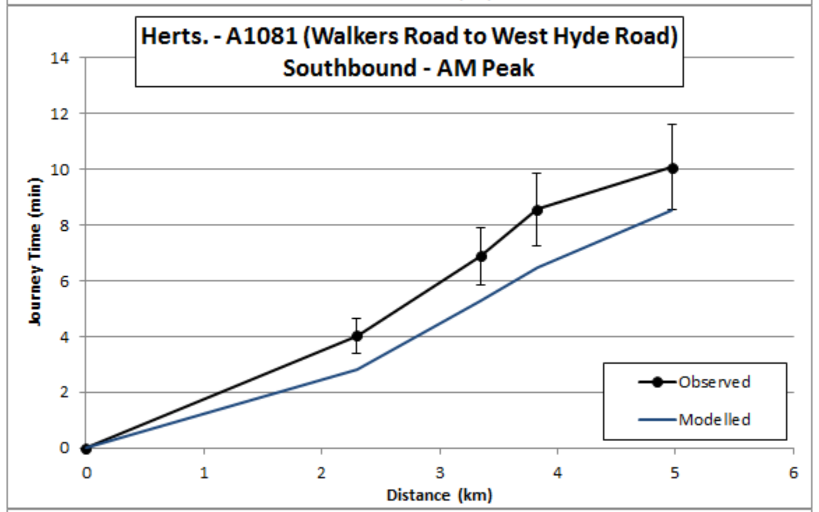


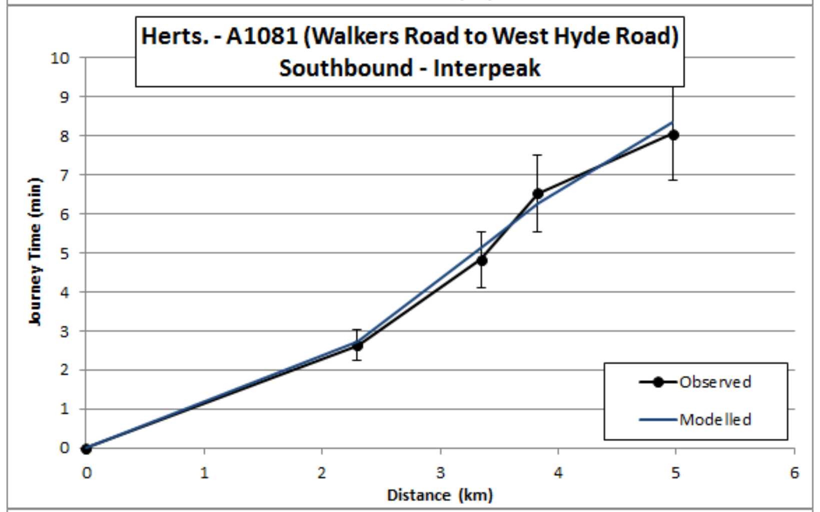


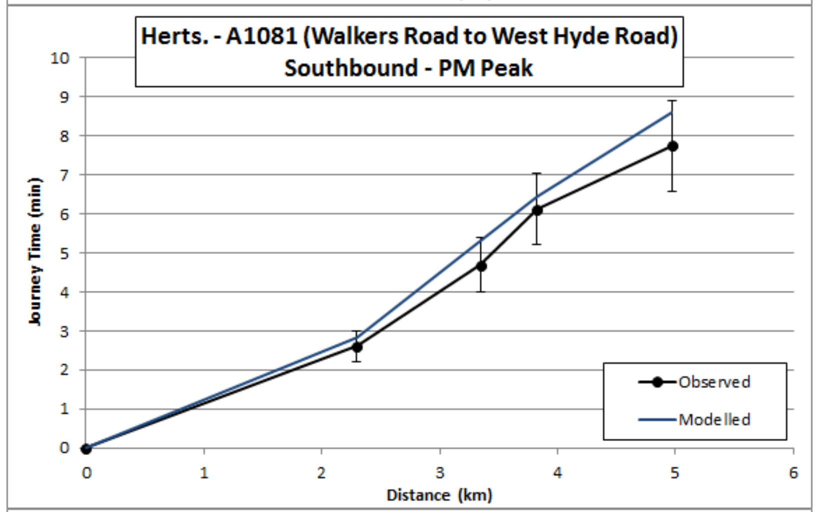

Herts. - A1081 (Walkers Road to West Hyde Road) Northbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

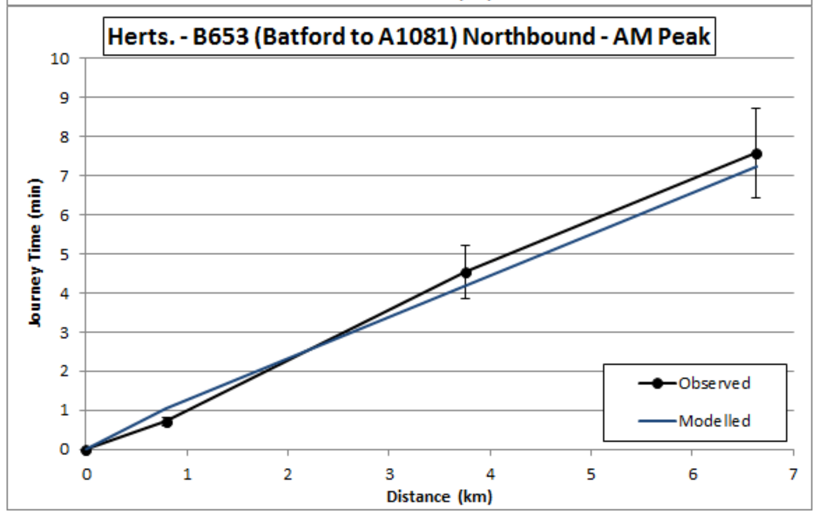

Herts. - A1081 (Walkers Road to West Hyde Road) Northbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

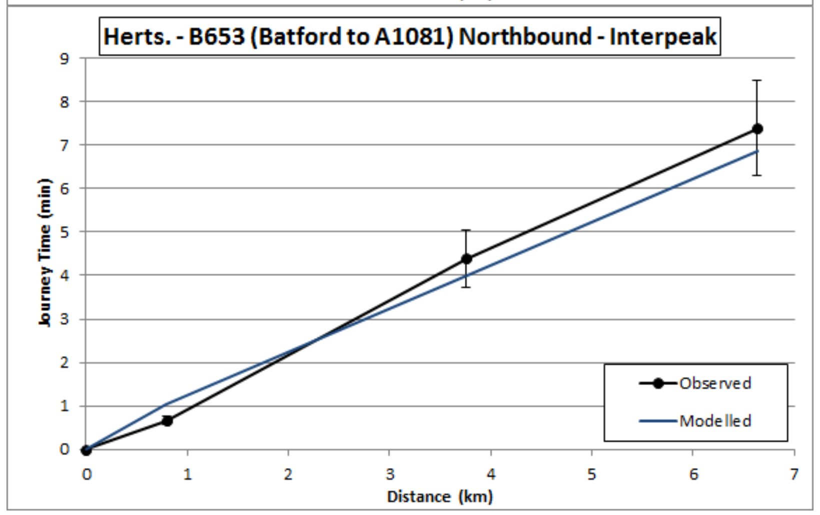

Herts. - A1081 (Walkers Road to West Hyde Road) Northbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

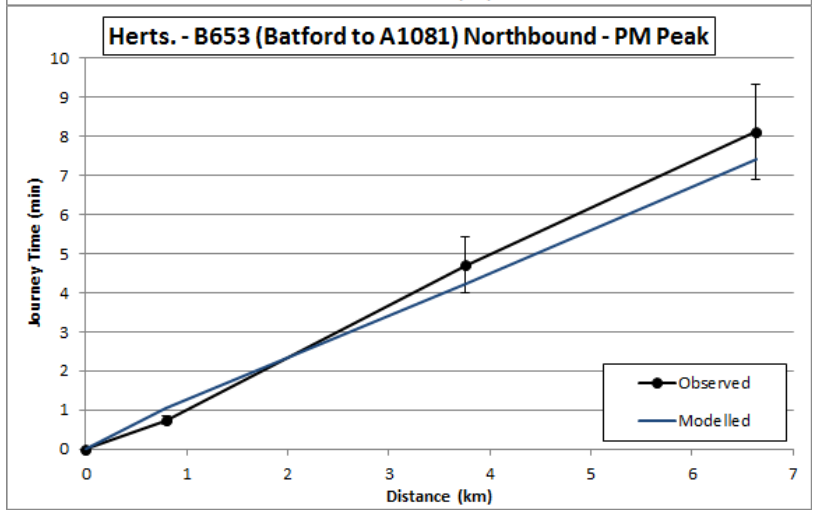

Herts. - A1081 (Walkers Road to West Hyde Road) Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

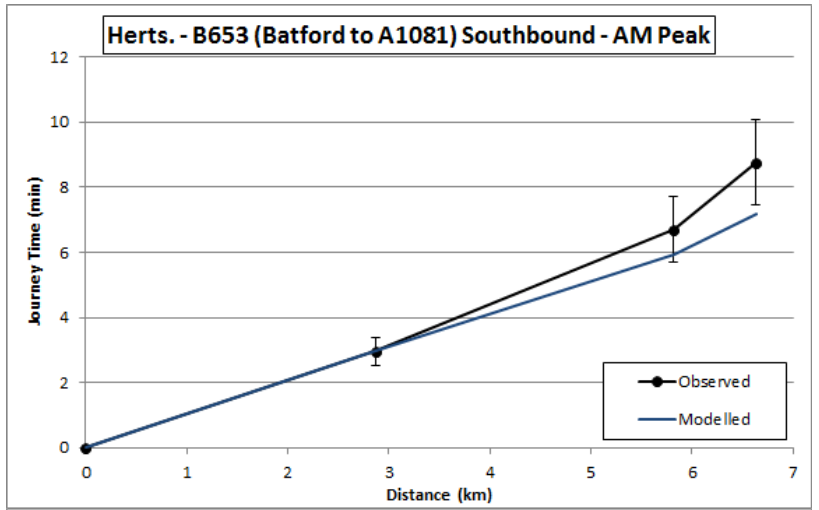

Herts. - A1081 (Walkers Road to West Hyde Road) Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

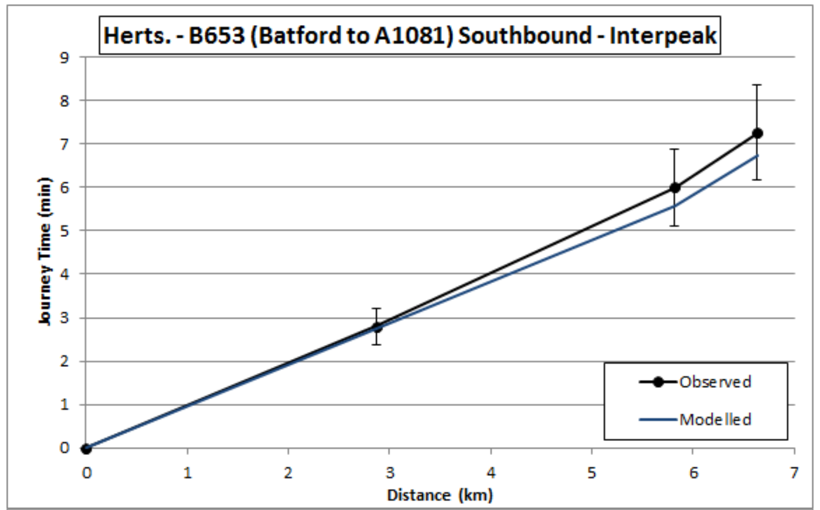

Herts. - A1081 (Walkers Road to West Hyde Road) Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

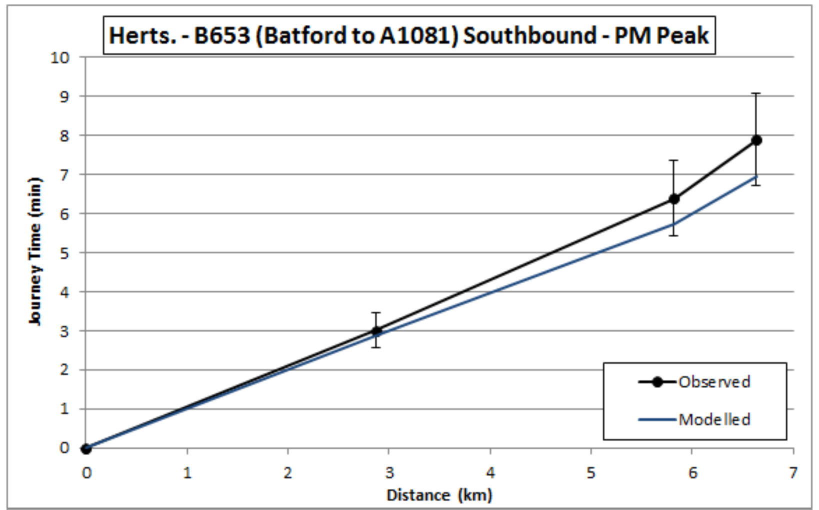

Herts. - B653 (Batford to A1081) Northbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

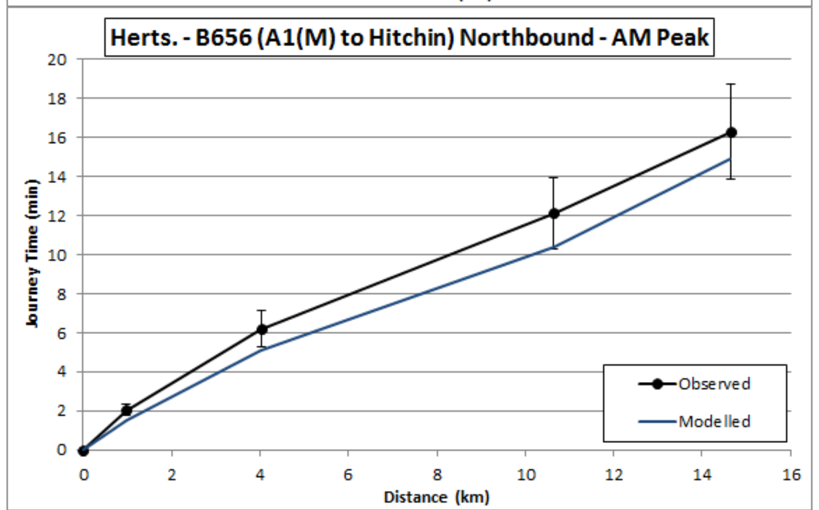

Herts. - B653 (Batford to A1081) Northbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

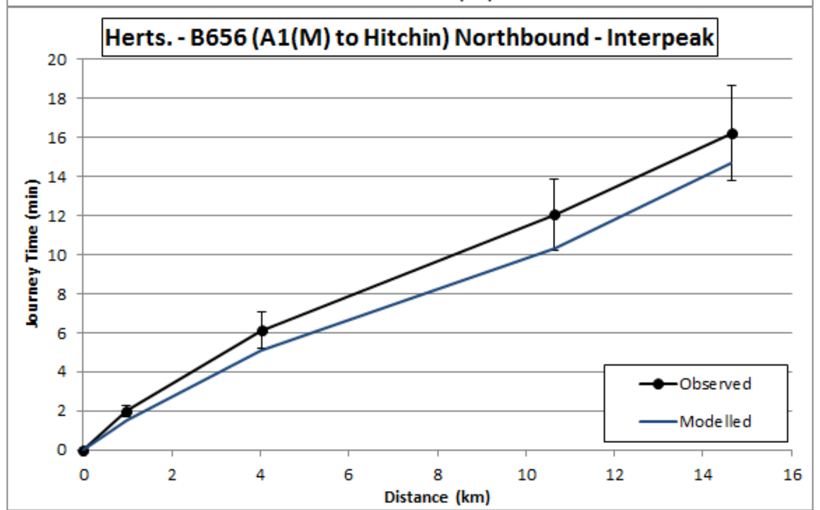

Herts. - B653 (Batford to A1081) Northbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

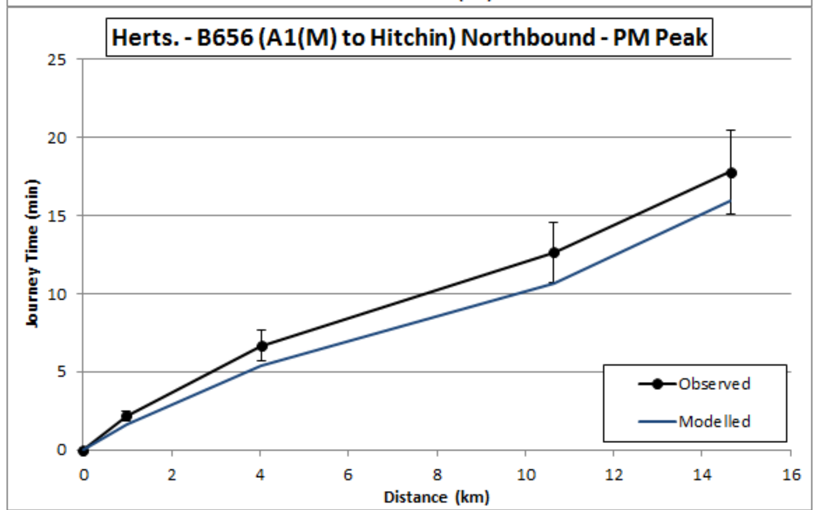

Herts. - B653 (Batford to A1081) Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

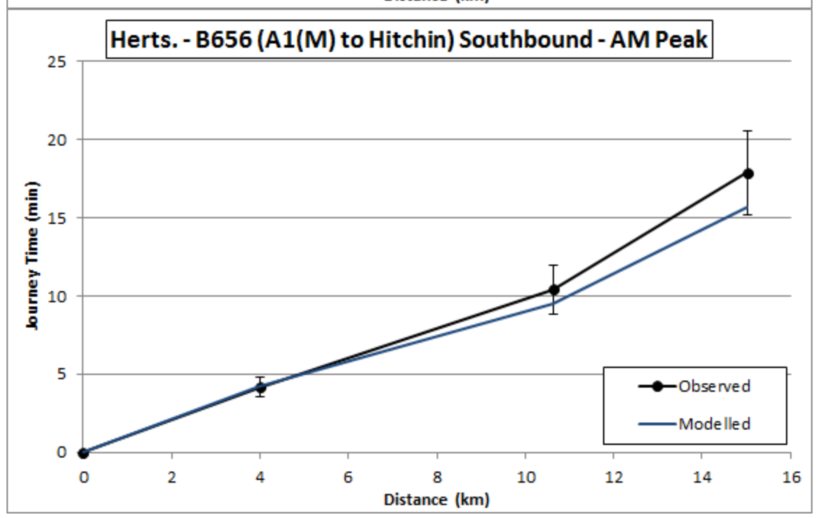

Herts. - B653 (Batford to A1081) Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled

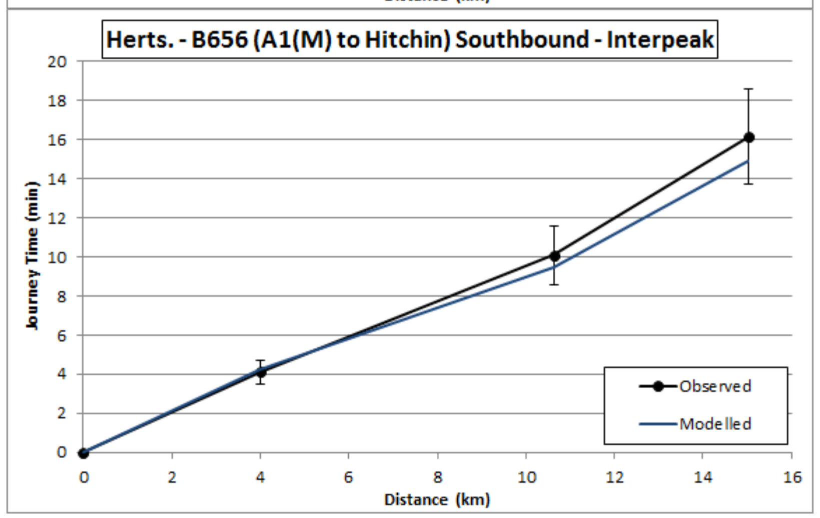

Herts. - B653 (Batford to A1081) Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

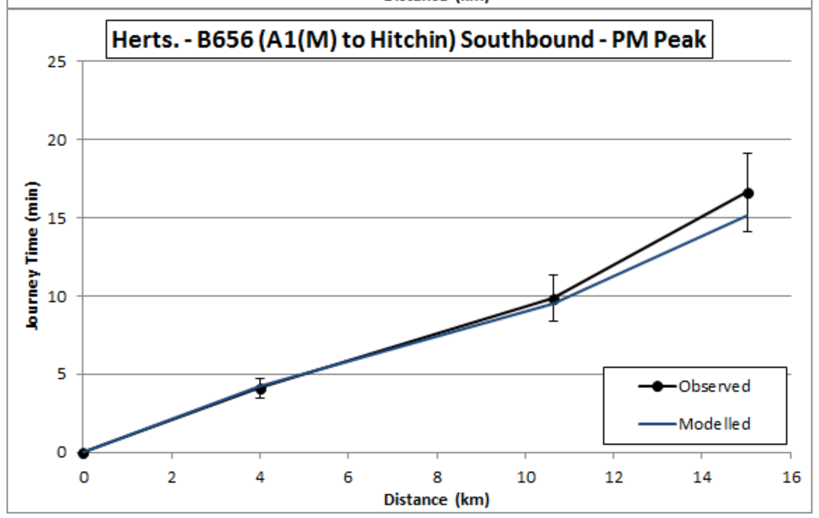

Herts. - B656 (A1(M) to Hitchin) Northbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled


Herts. - B656 (A1(M) to Hitchin) Northbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled


Herts. - B656 (A1(M) to Hitchin) Northbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled


Herts. - B656 (A1(M) to Hitchin) Southbound - AM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

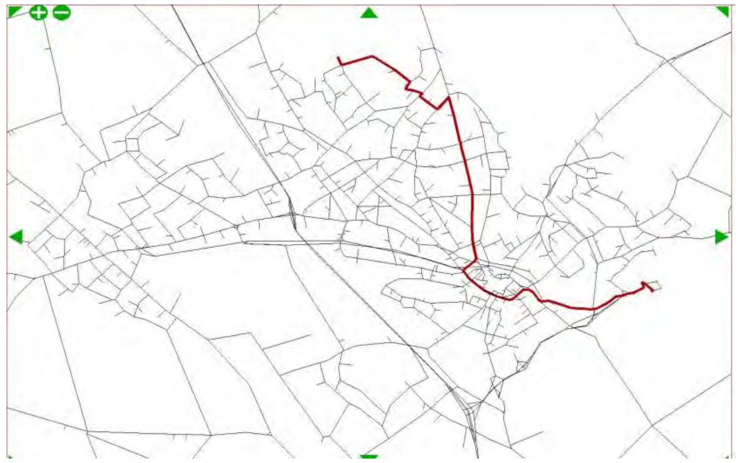

Herts. - B656 (A1(M) to Hitchin) Southbound - Interpeak
Journey Time (min)
Distance (km)
Observed
Modelled


Herts. - B656 (A1(M) to Hitchin) Southbound - PM Peak
Journey Time (min)
Distance (km)
Observed
Modelled

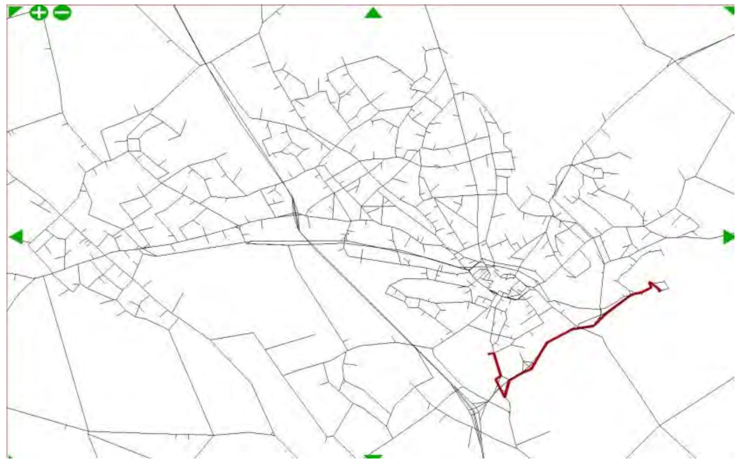
Appendix E – Route Choice Validation

E1 AM Route Choice Analysis: Car (Commute)

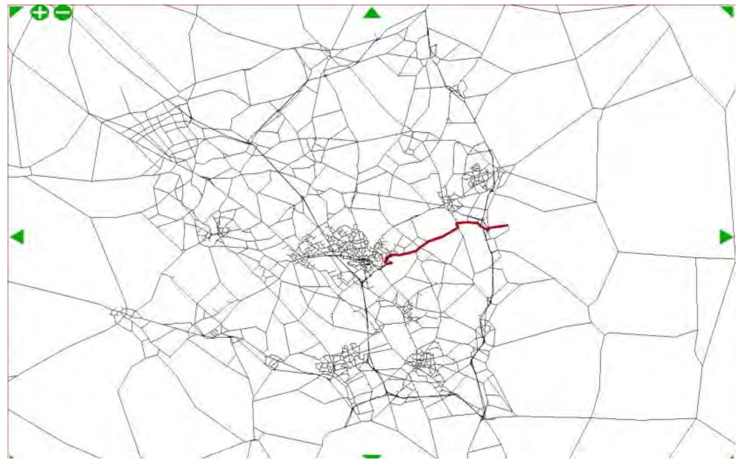
Luton Airport to Luton North



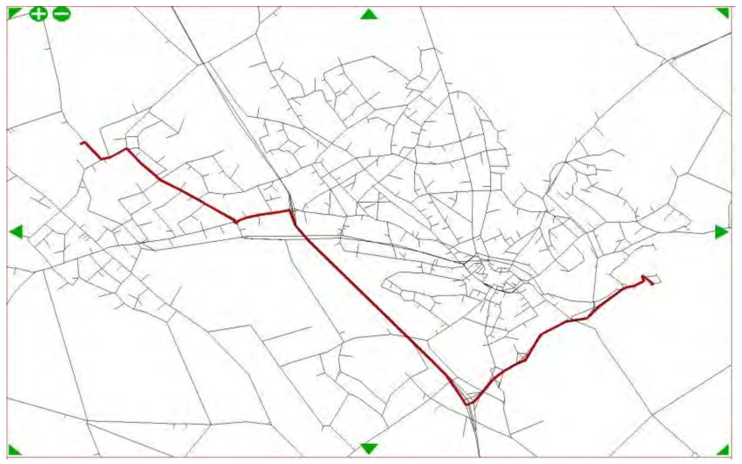
Luton Airport to Luton South



Luton Airport to External East

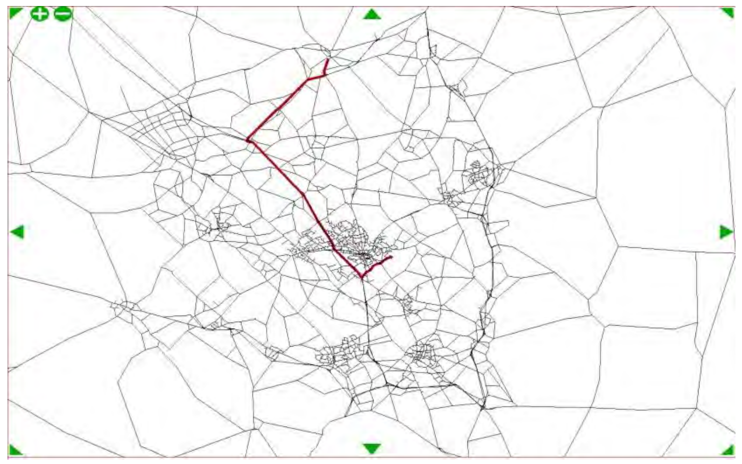


Luton Airport to Luton West

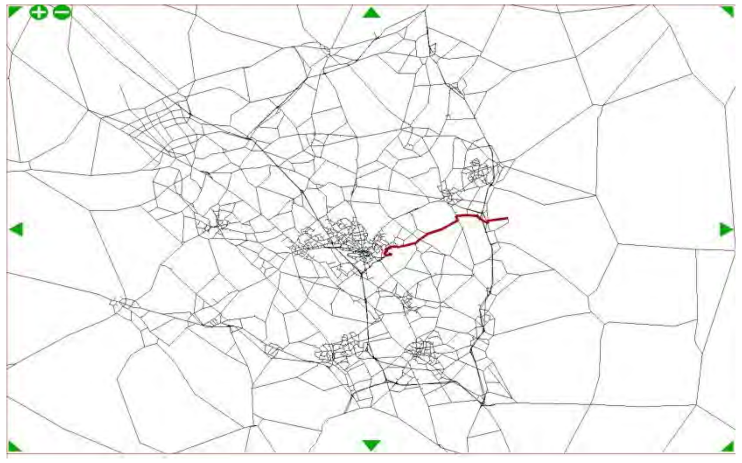


Luton Airport to M1 J11

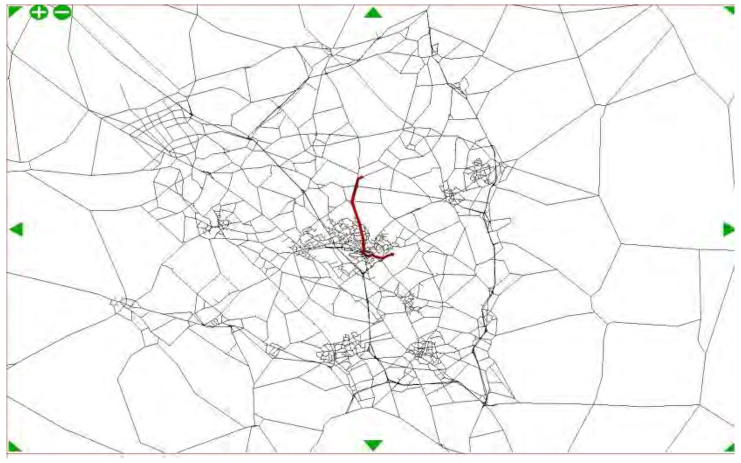
Luton Airport to Bedford



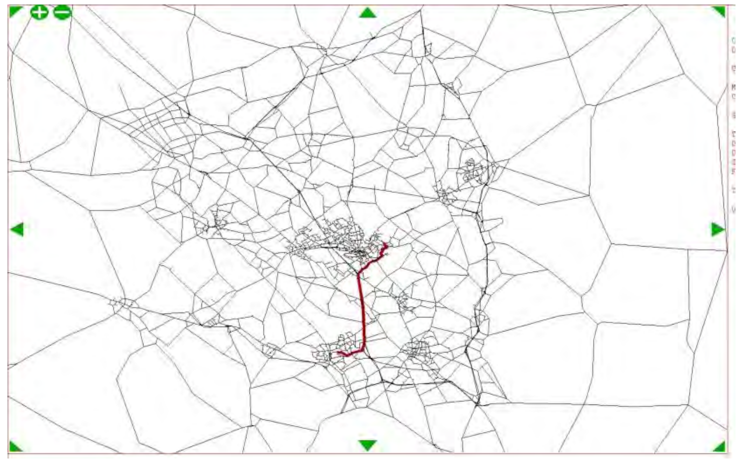
Luton Airport to External East



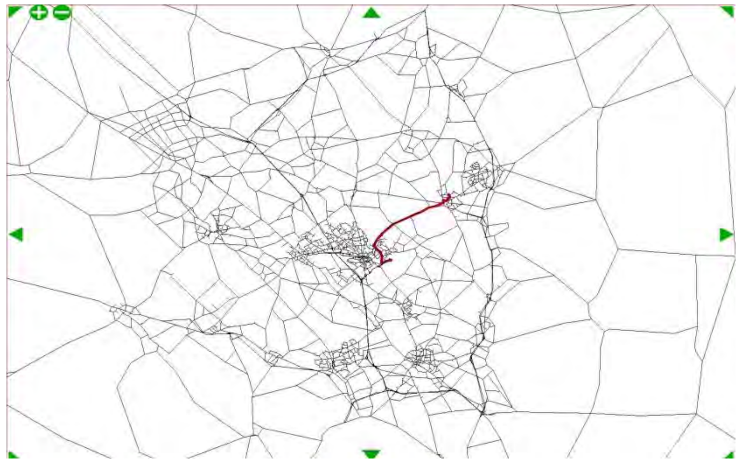
Luton Airport to A6



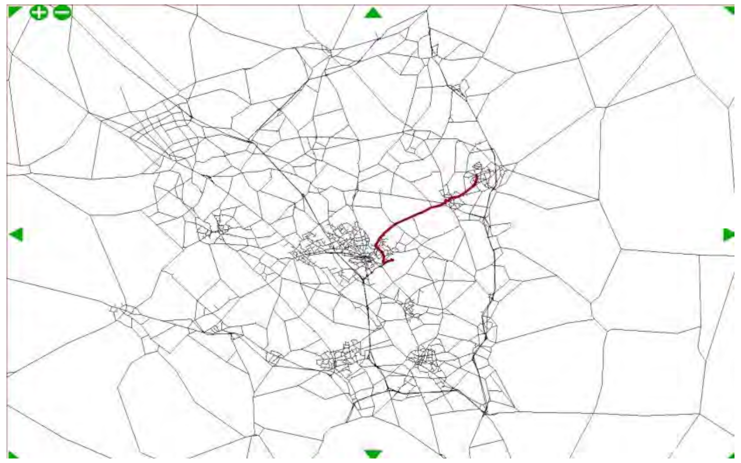
Luton Airport to Hemel Hampstead



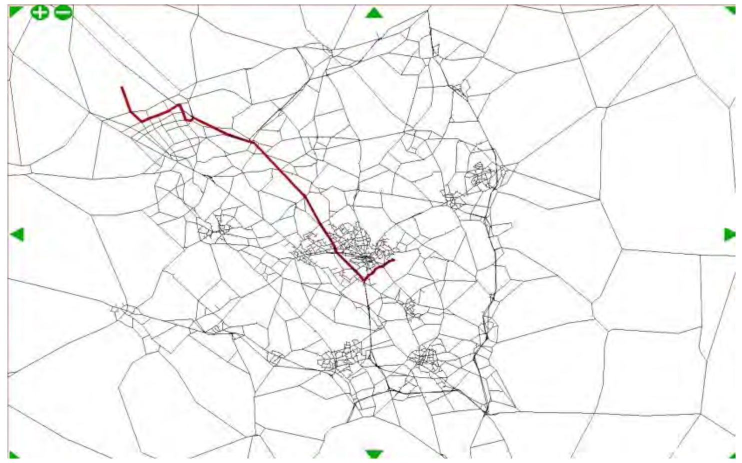
Luton Airport to Hitchin



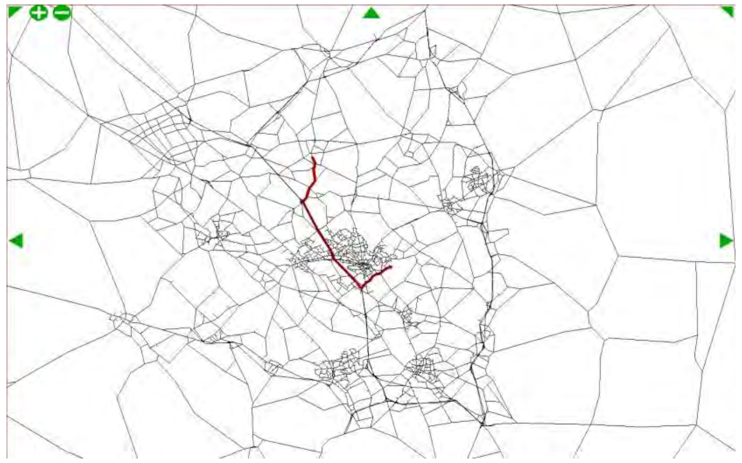
Luton Airport to Letchworth



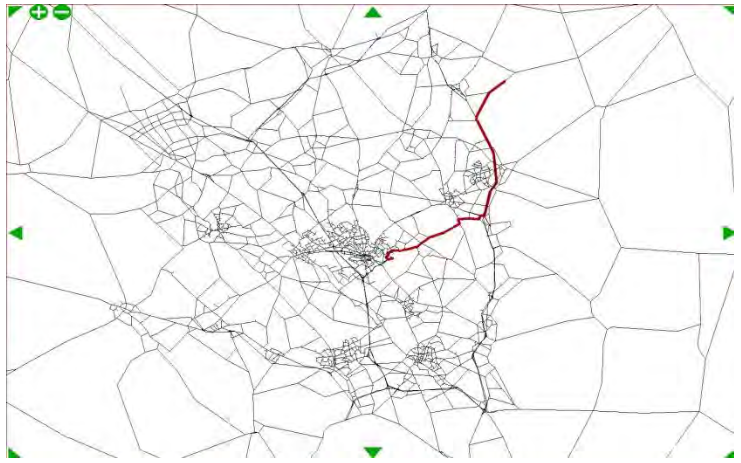
Luton Airport to External North-West



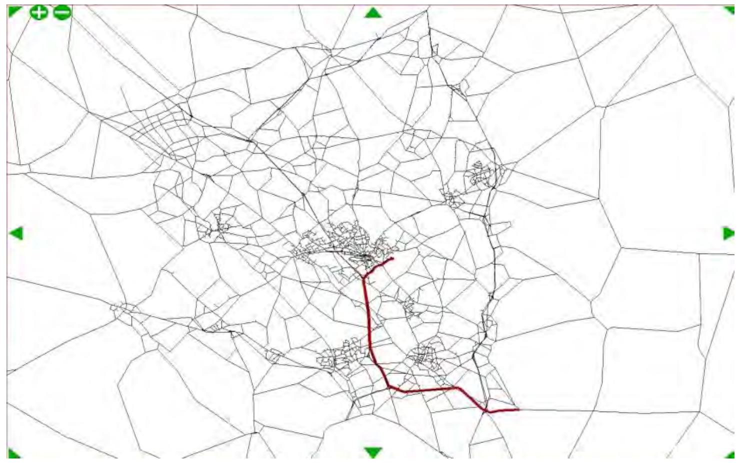
Luton Airport to External North



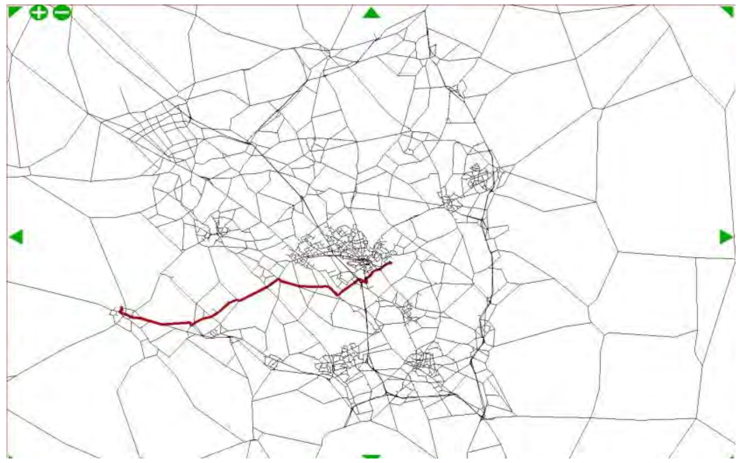
Luton Airport to External North-East



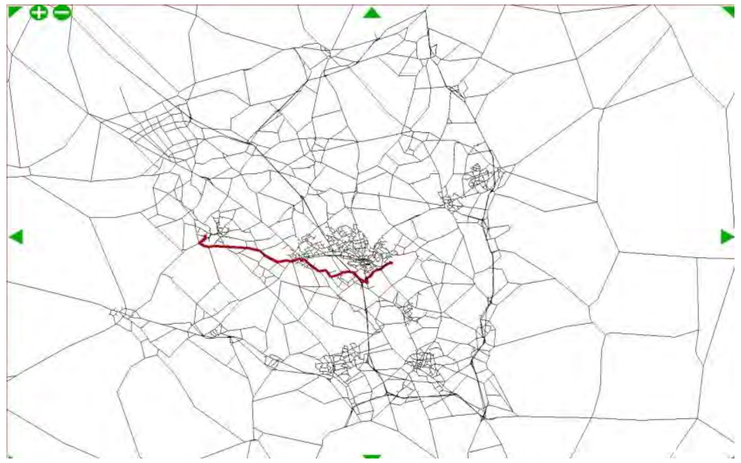
Luton Airport to External South-East



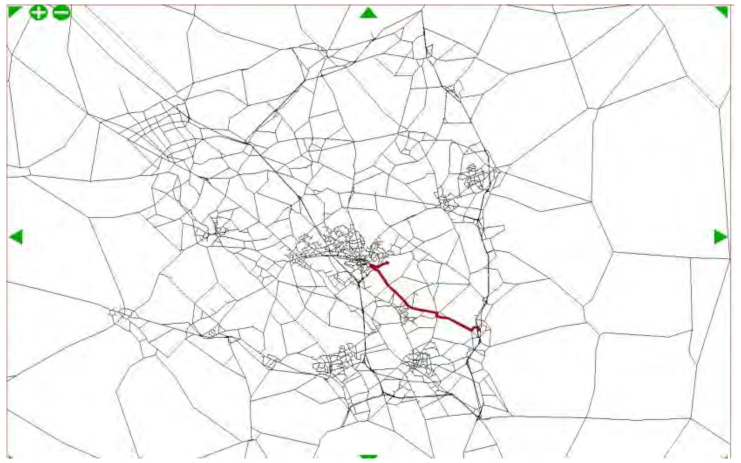
Luton Airport to External South-West



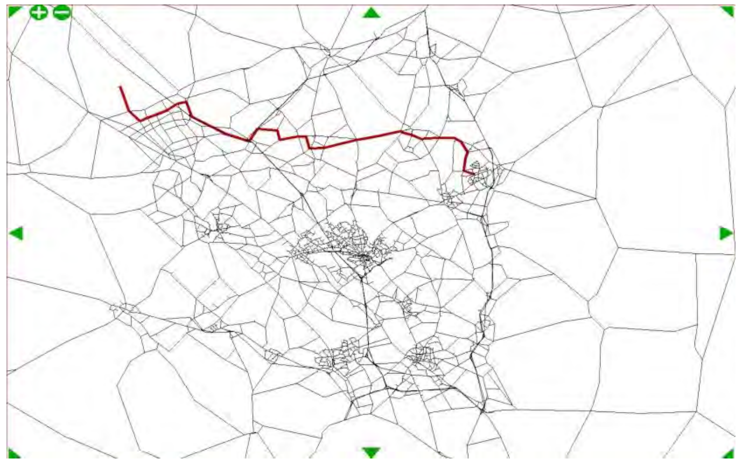
Luton Airport to External West



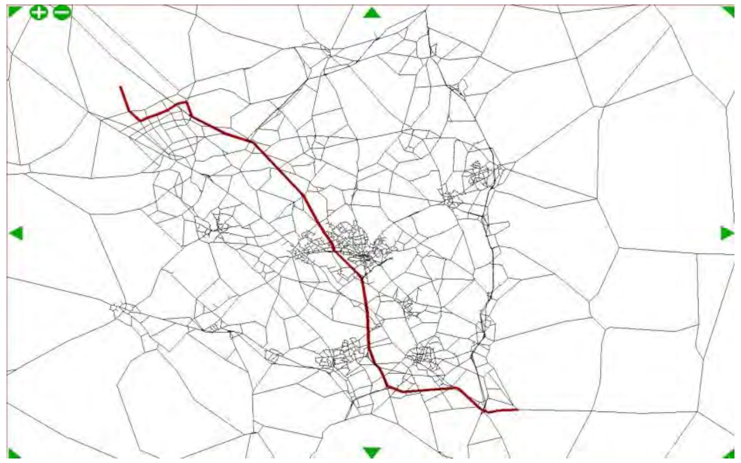
Luton Airport to Welwyn Garden City



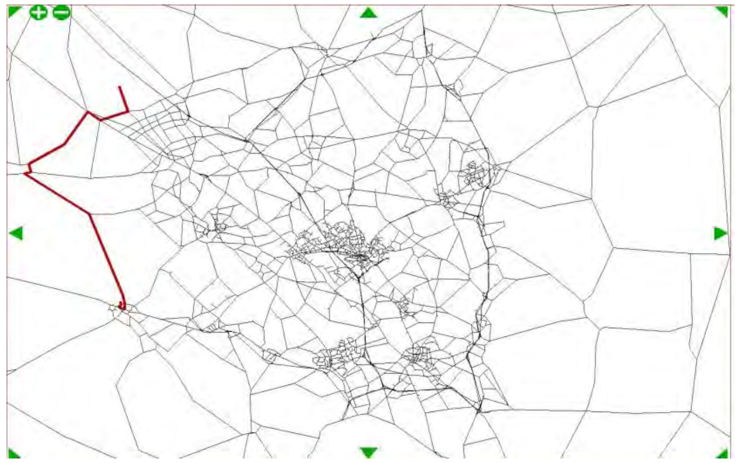
External North-West to Letchworth



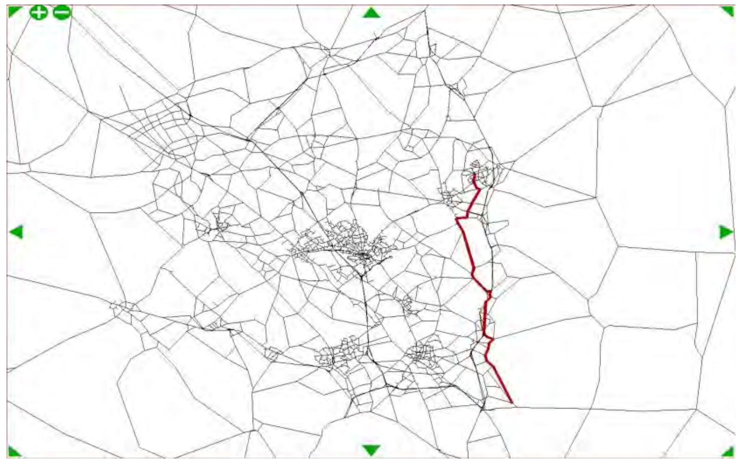
External North-West to External South East



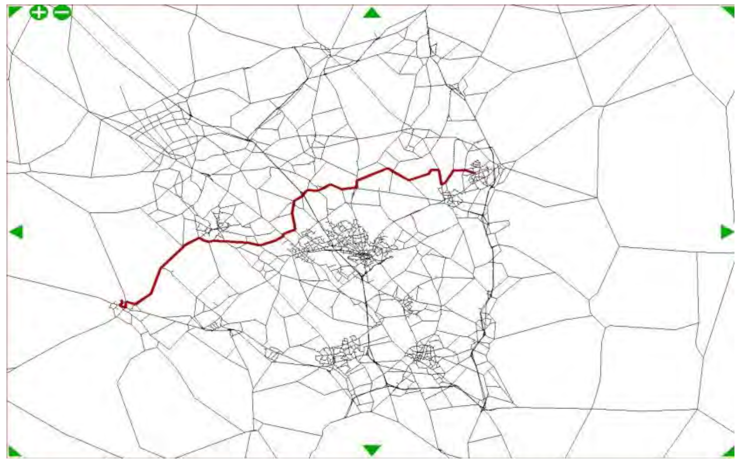
External North-West to External South-West



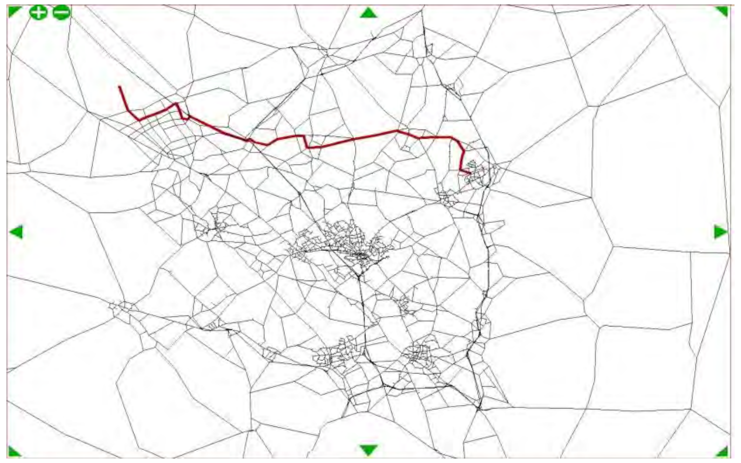
External Letchworth to South-East



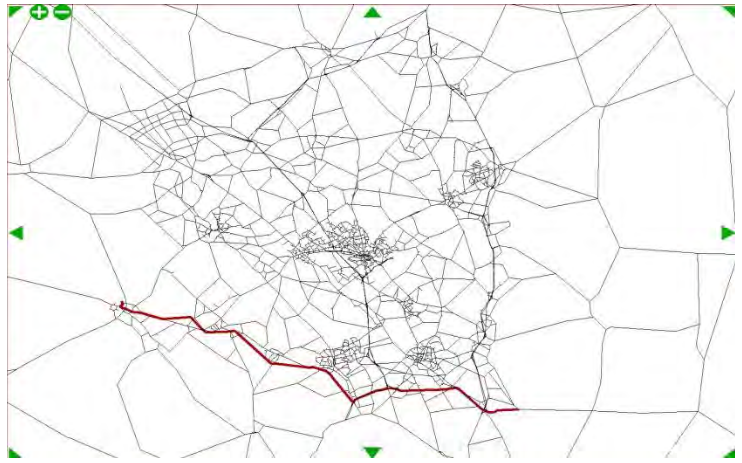
External Letchworth to South-West



External Letchworth to North-West



External South-East to South-West



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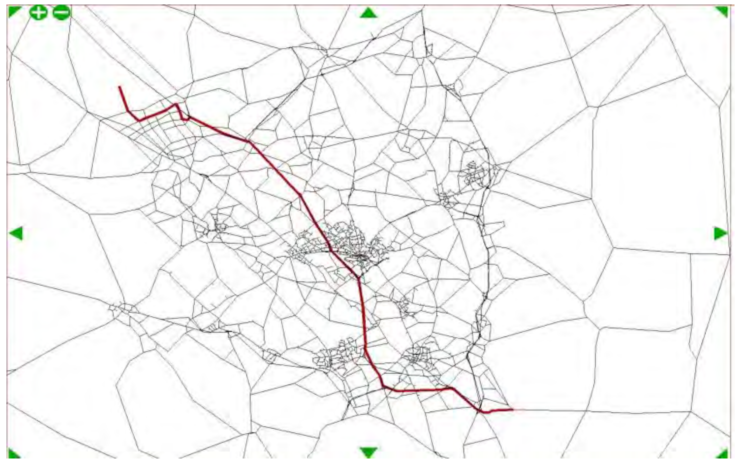

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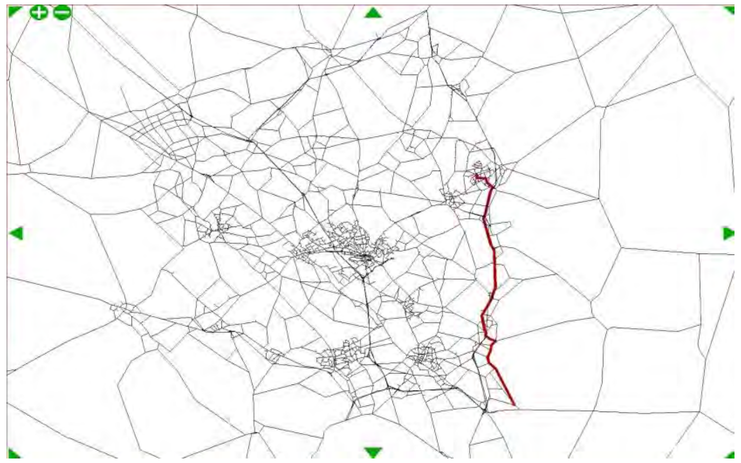

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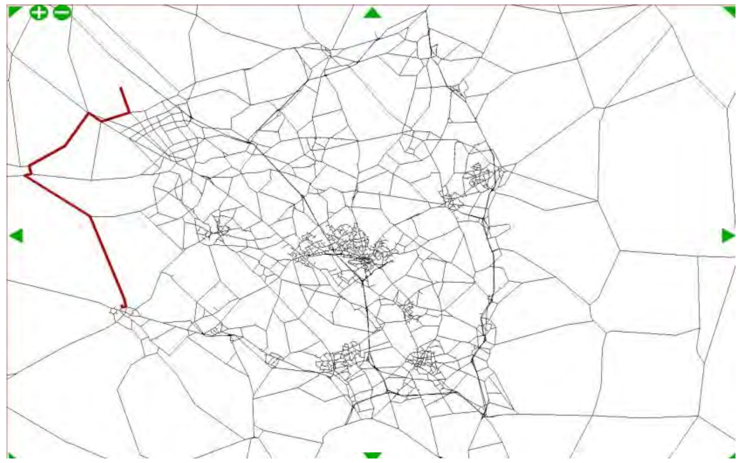
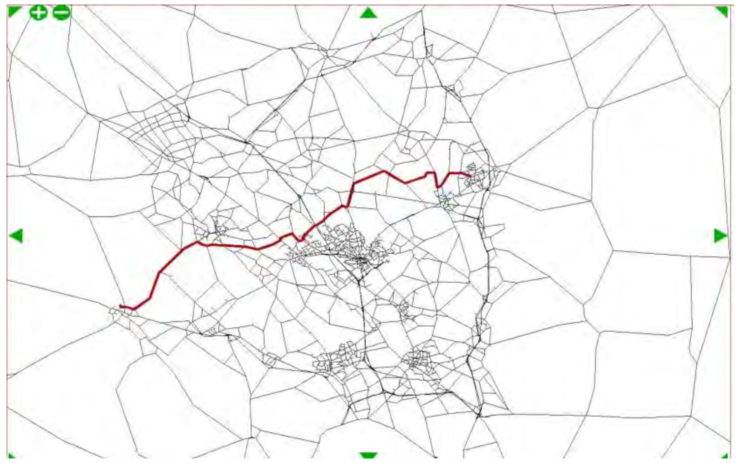
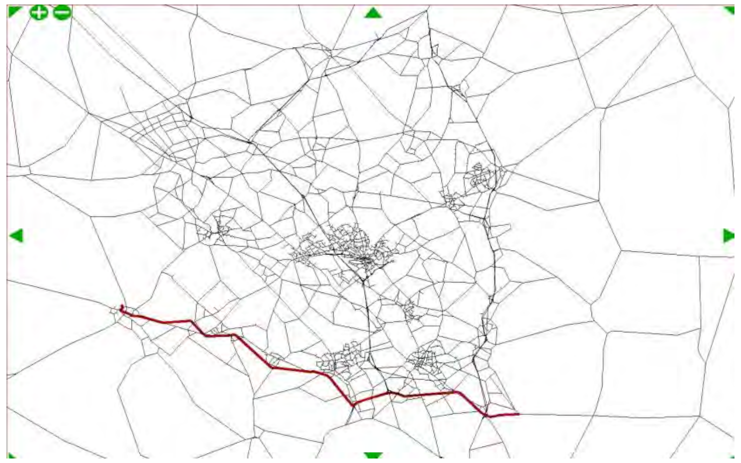


External South-West to Letchworth

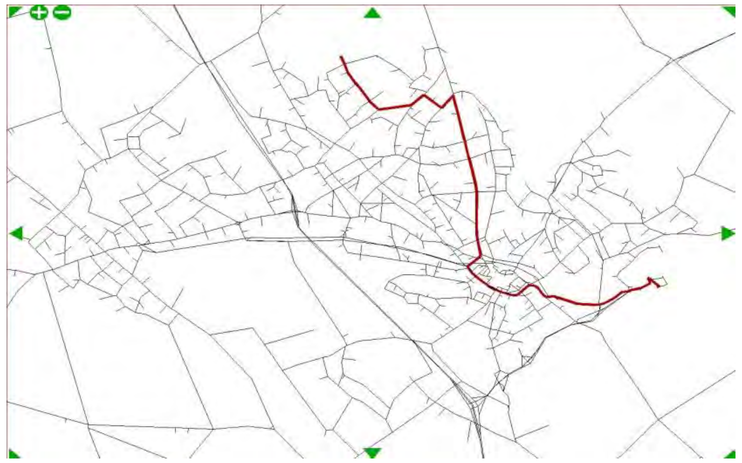


External South-West to South-East

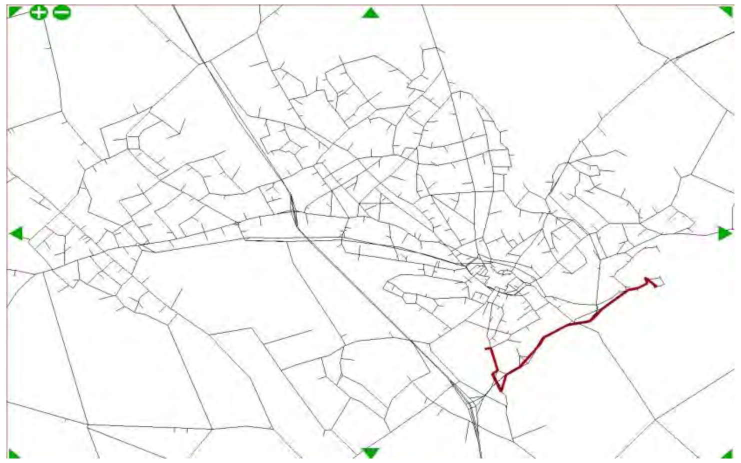


E2 AM Route Choice Analysis: HGV

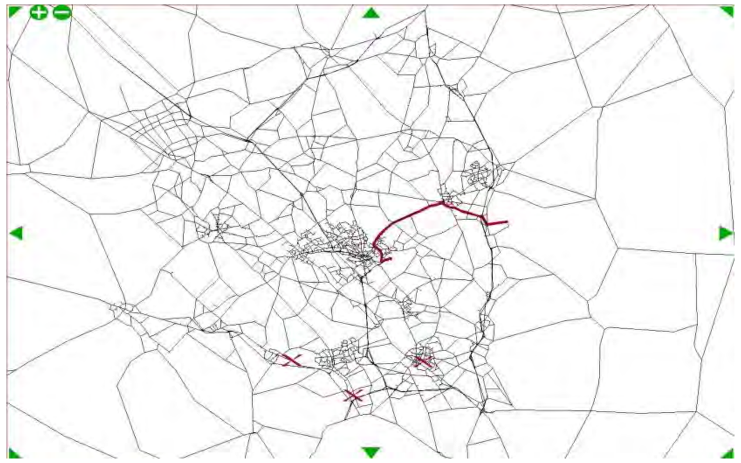
Luton Airport to Luton North



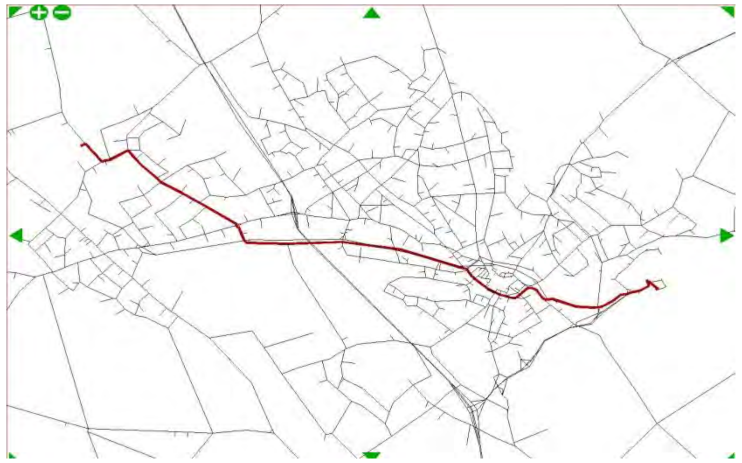
Luton Airport to Luton South



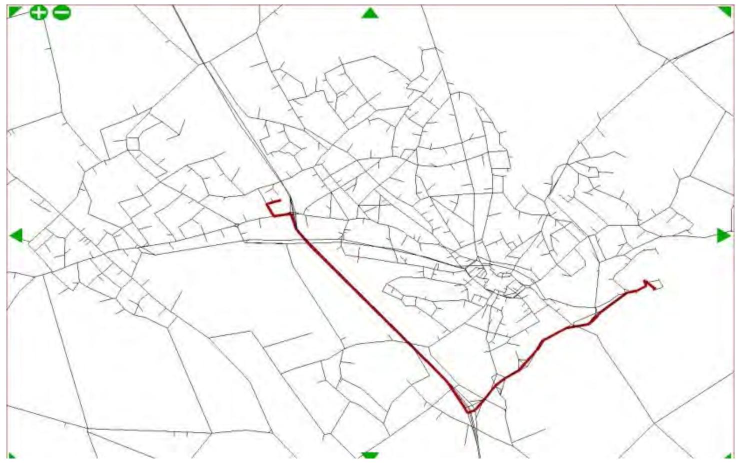
Luton Airport to External East



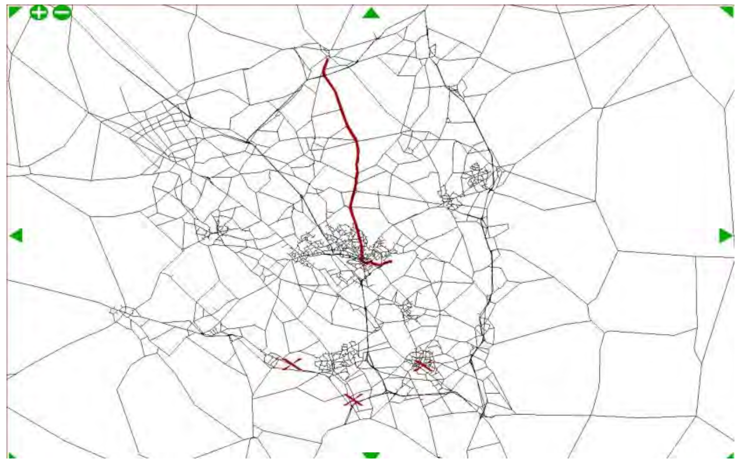
Luton Airport to Luton West



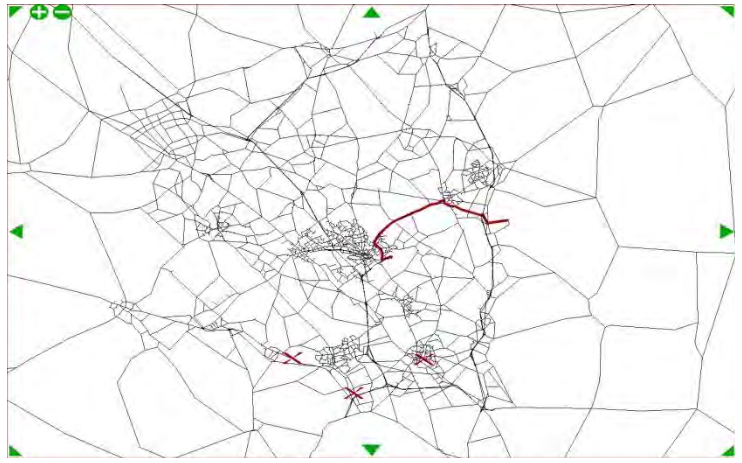
Luton Airport to M1 J11



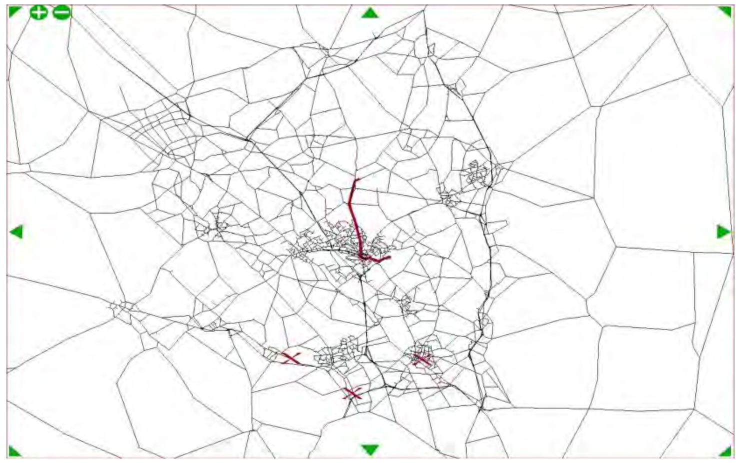
Luton Airport to Bedford



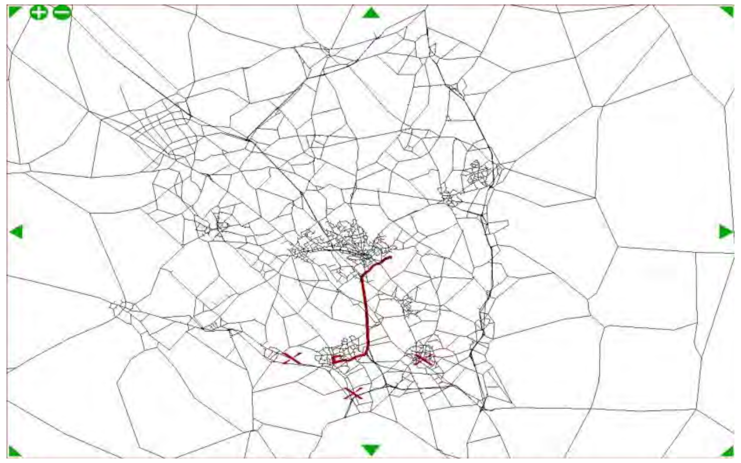
Luton Airport to External East



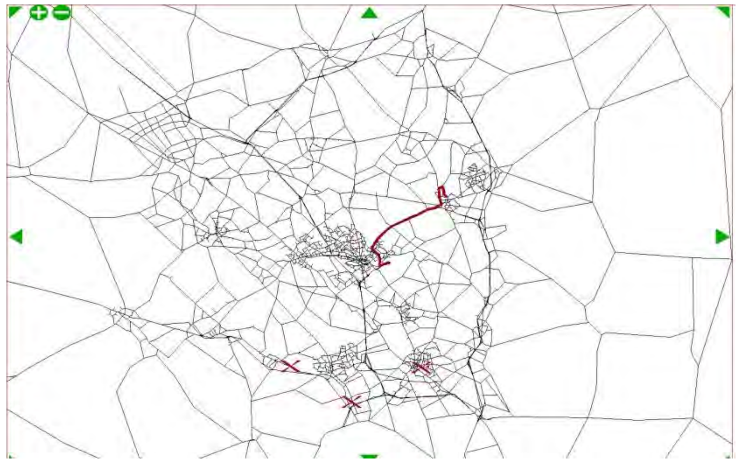
Luton Airport to A6



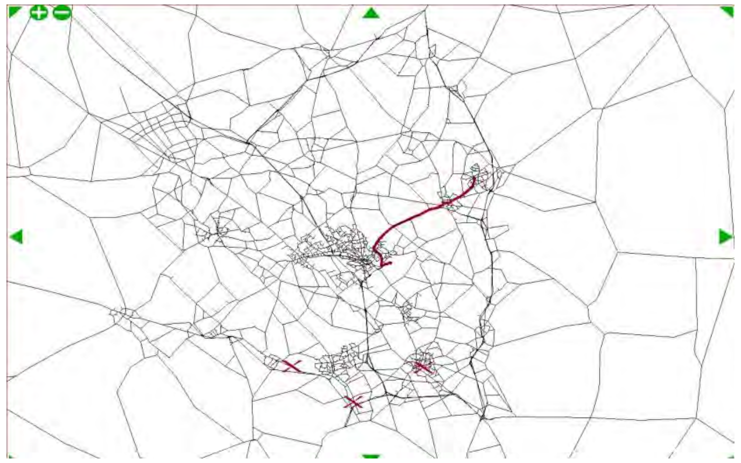
Luton Airport to Hemel Hampstead



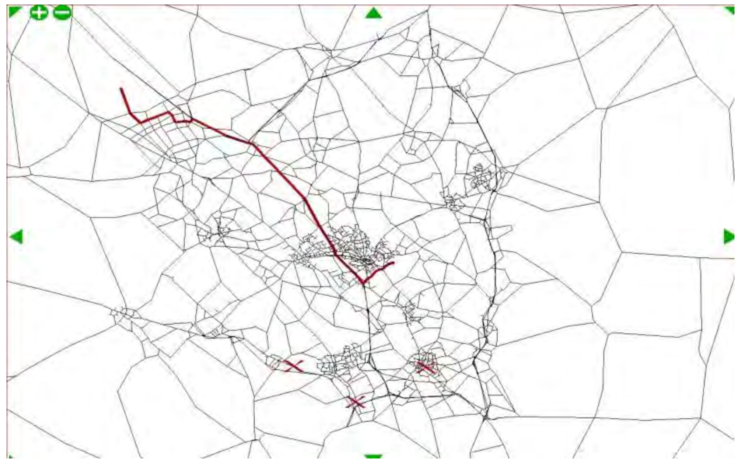
Luton Airport to Hitchin



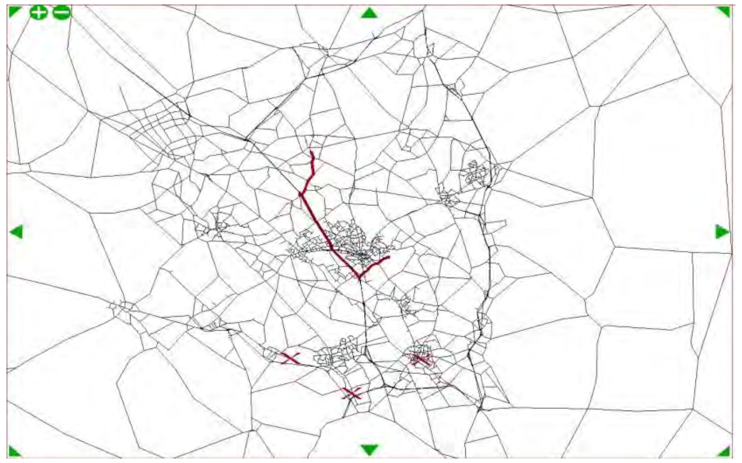
Luton Airport to Letchworth



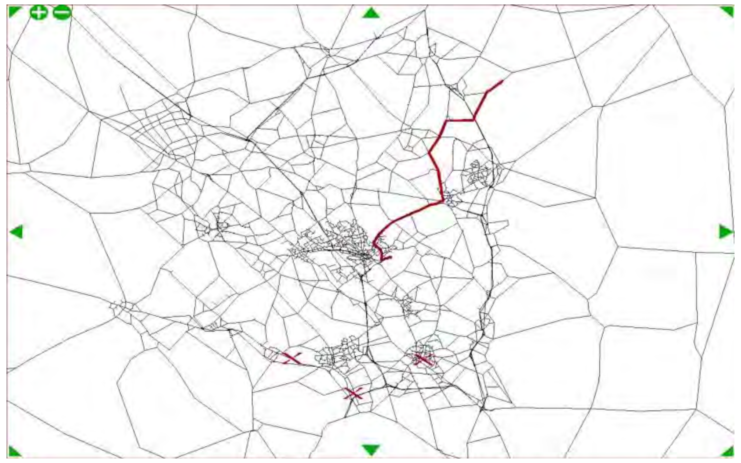
Luton Airport to External North-West



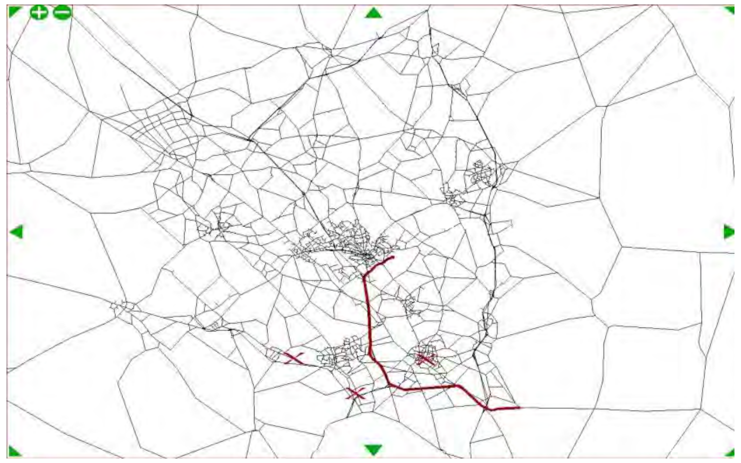
Luton Airport to External North



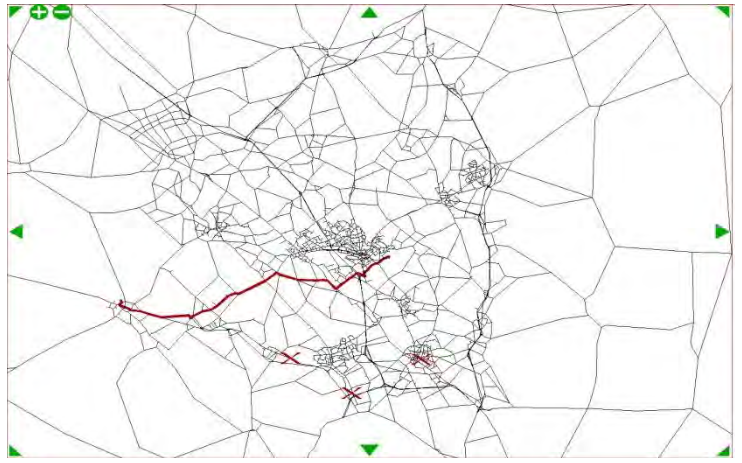
Luton Airport to External North-East



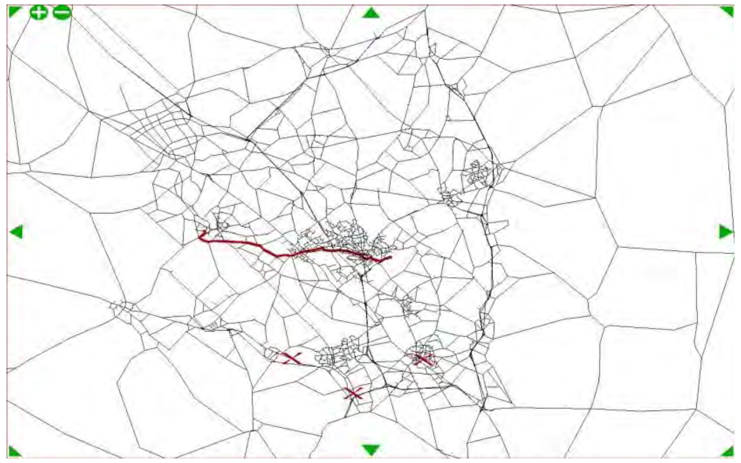
Luton Airport to External South-East



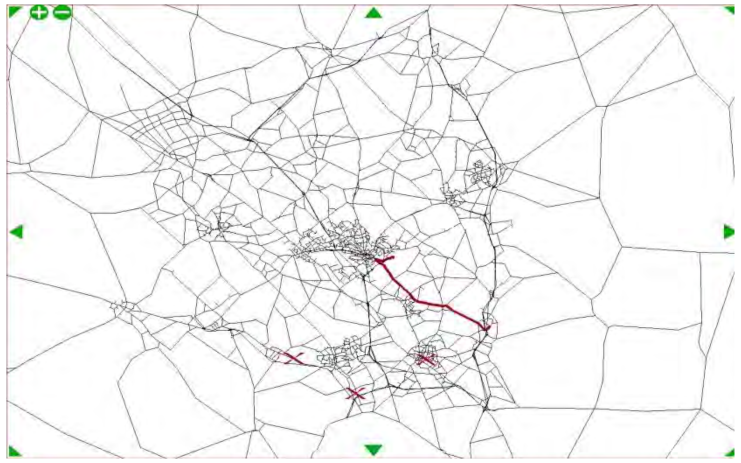
Luton Airport to External South-West



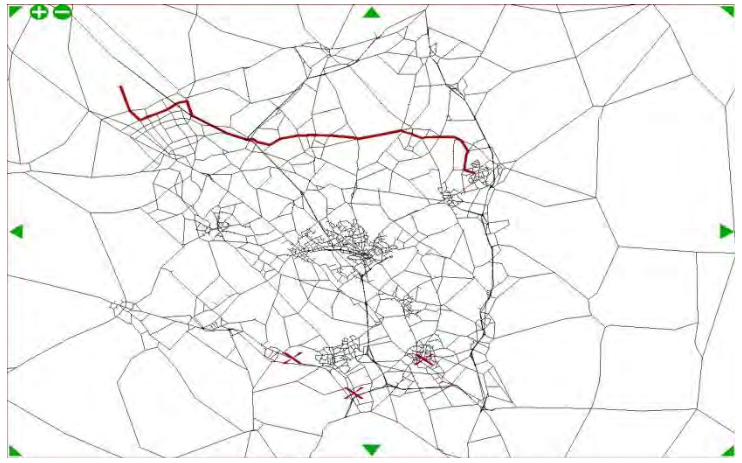
Luton Airport to External West



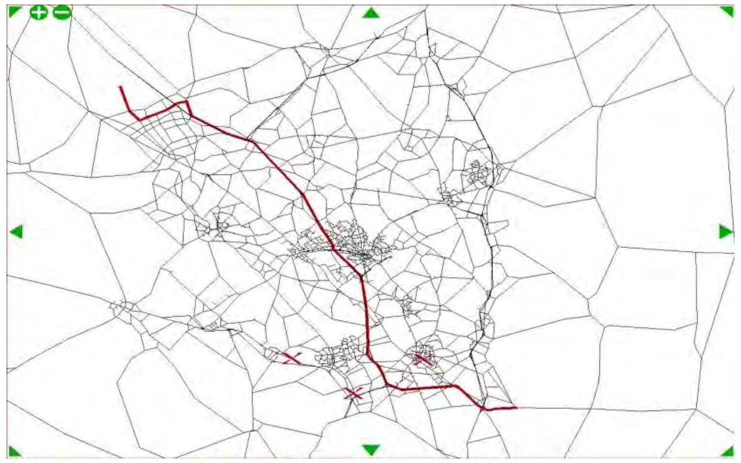
Luton Airport to Welwyn Garden City



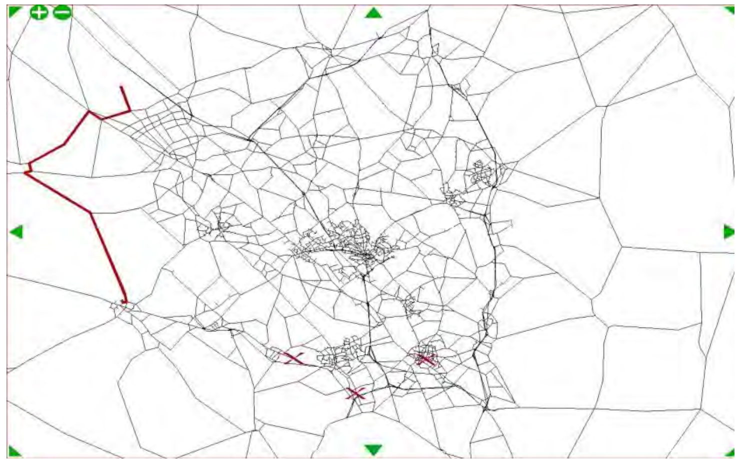
External North-West to Letchworth



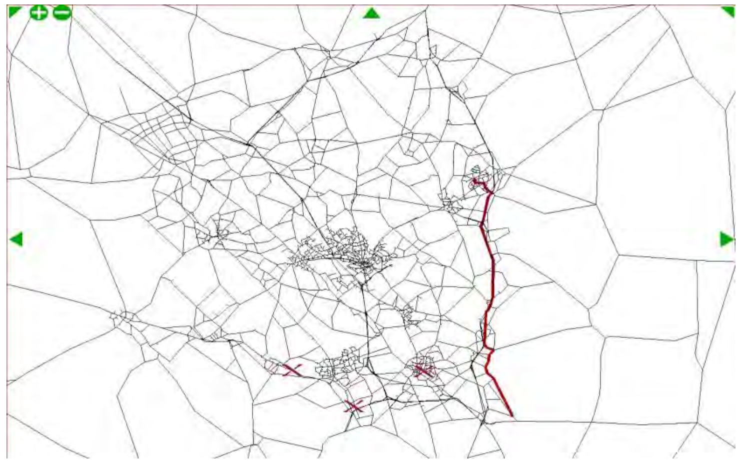
External North-West to External South East



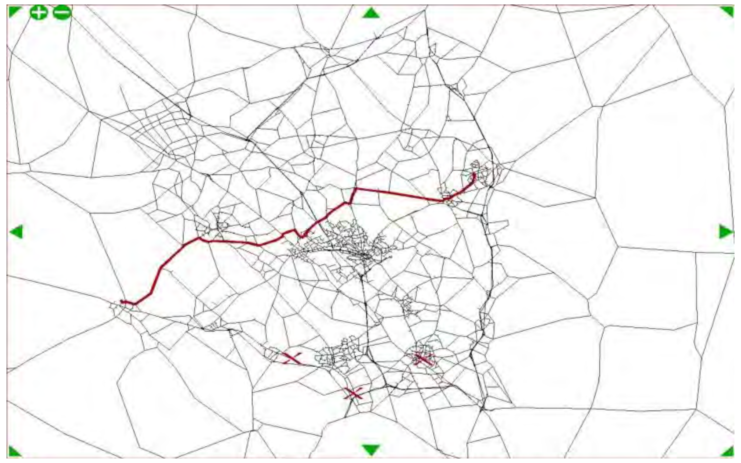
External North-West to External South-West



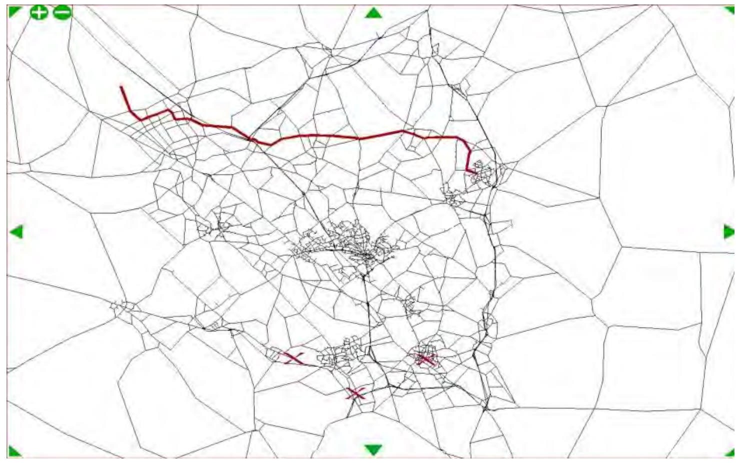
External Letchworth to South-East



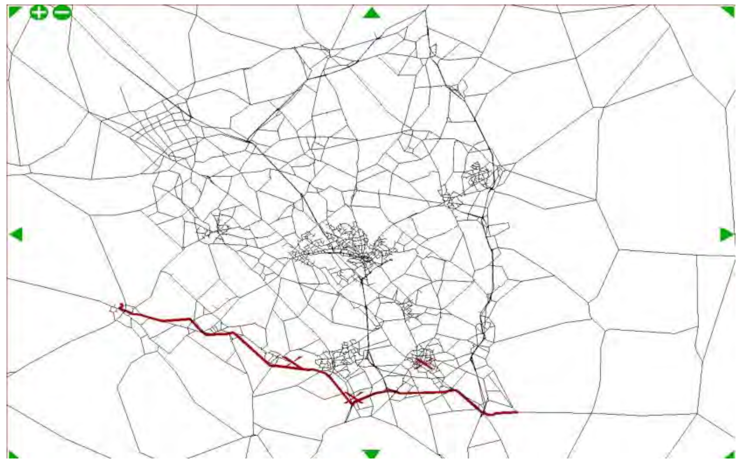
External Letchworth to South-West



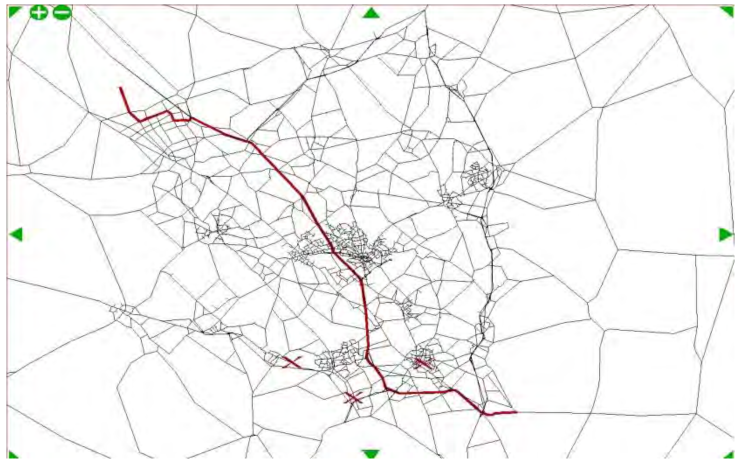
External Letchworth to North-West



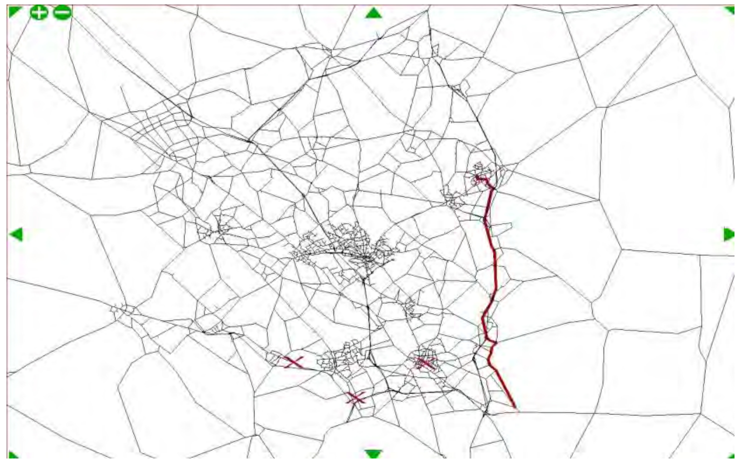
External South-East to South-West



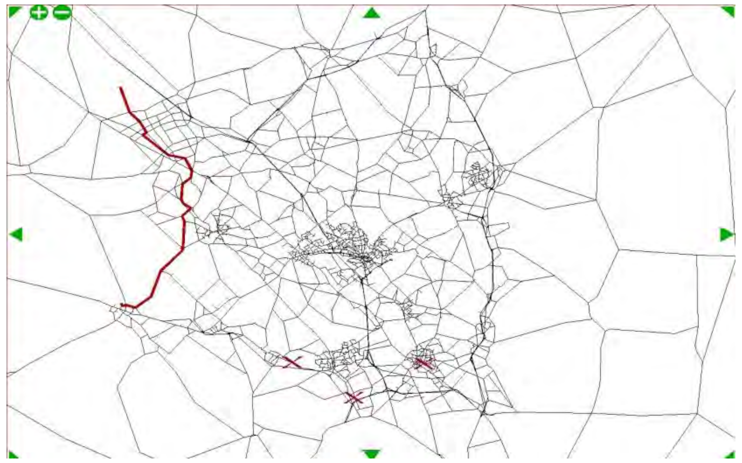
External South-East to North-West



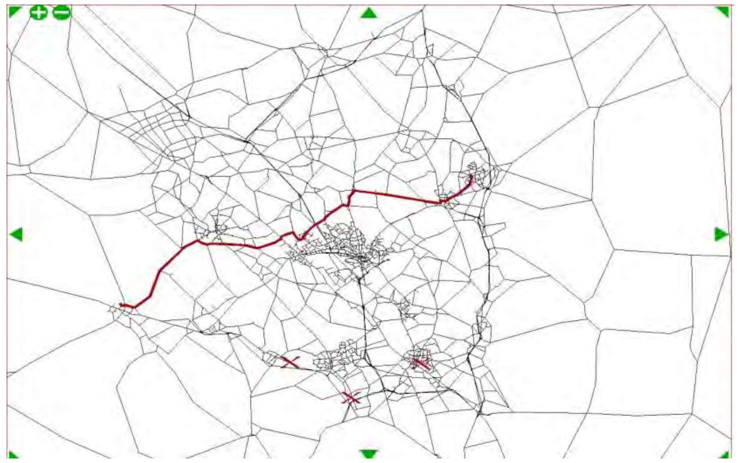
External South-East to Letchworth



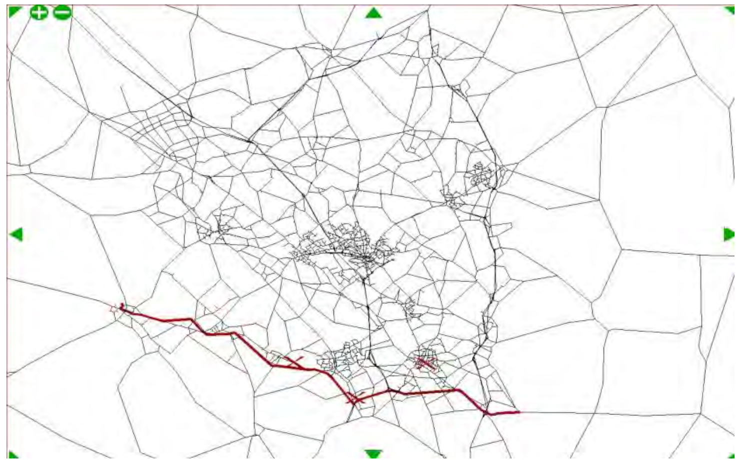
External South-West to North-West



External South-West to Letchworth

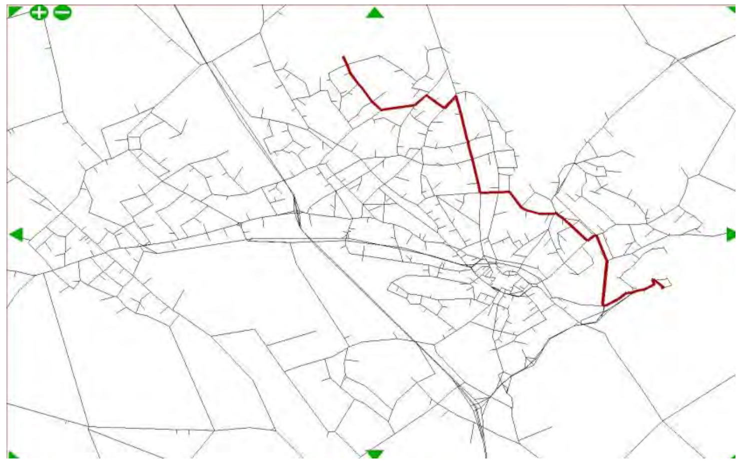


External South-West to South-East

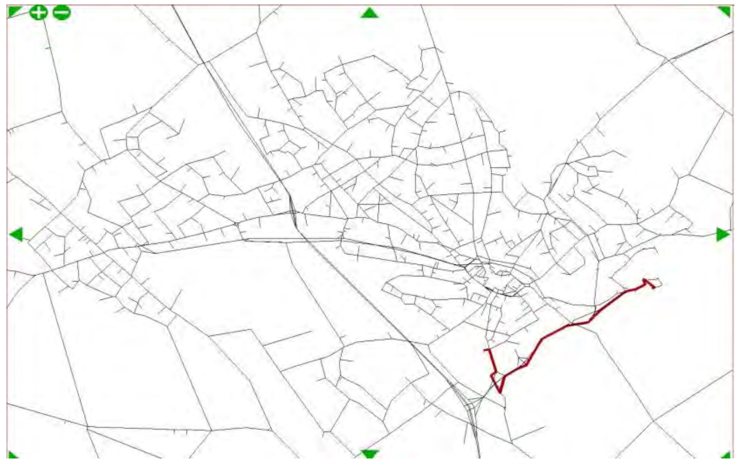


E3 PM Route Choice Analysis: Car (Commute)

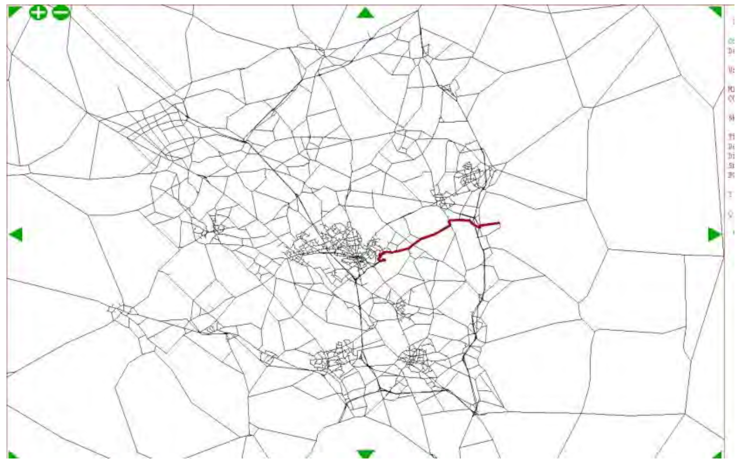
Luton Airport to Luton North



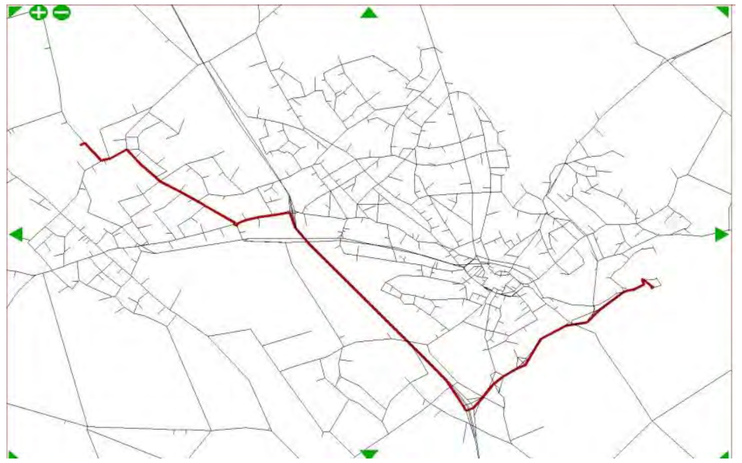
Luton Airport to Luton South



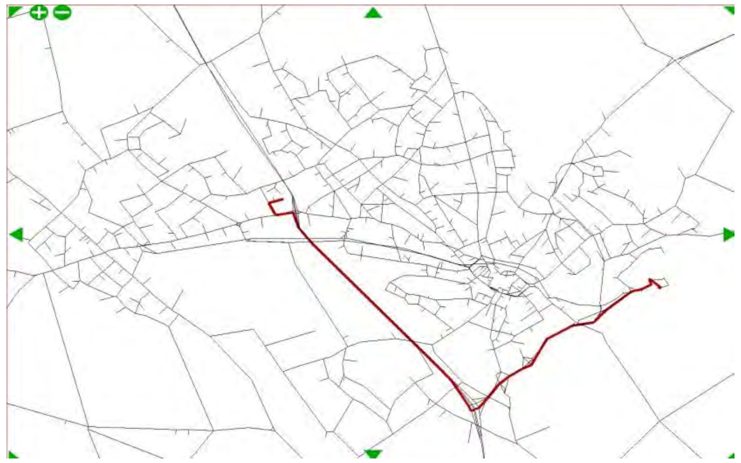
Luton Airport to External East



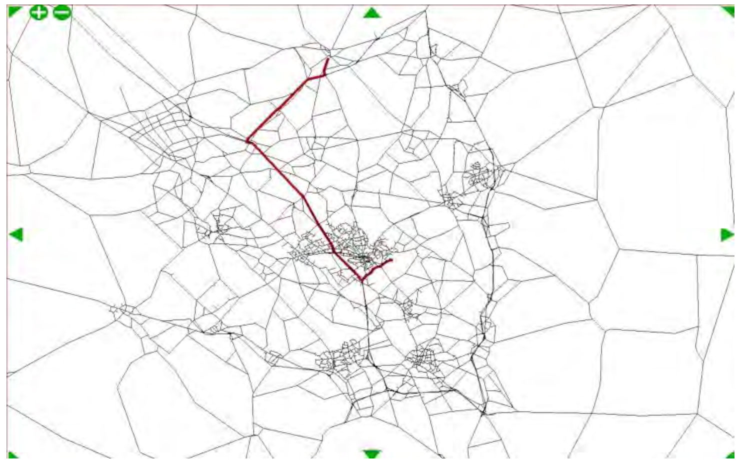
Luton Airport to Luton West



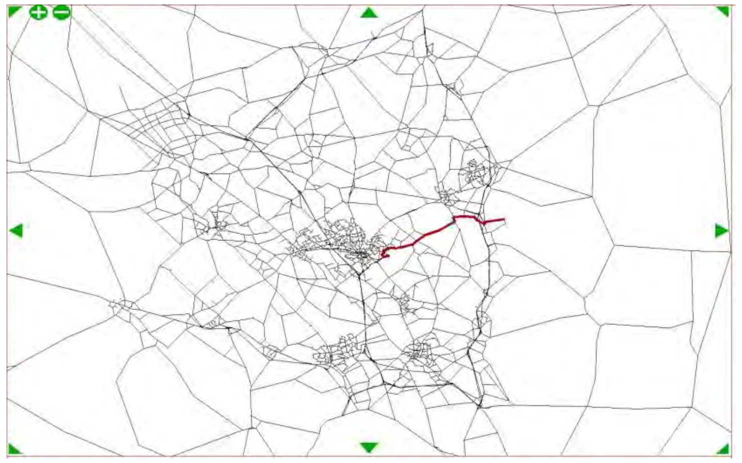
Luton Airport to M1 J11



Luton Airport to Bedford



Luton Airport to External East



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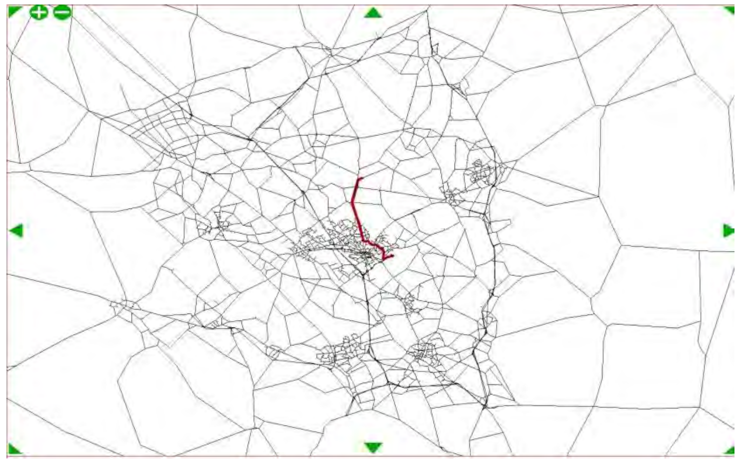

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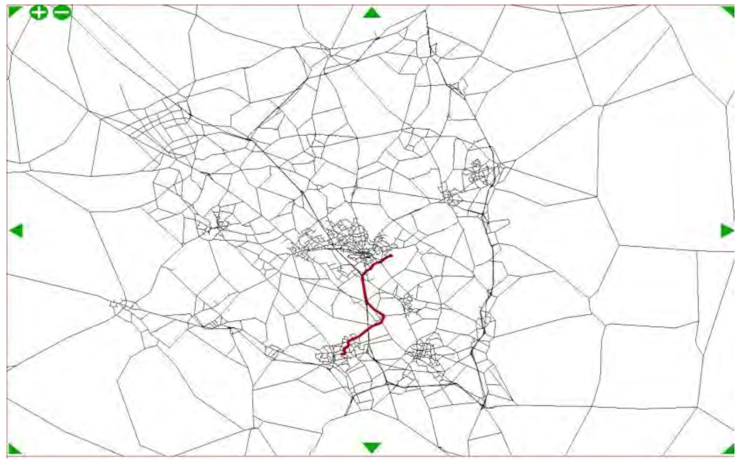

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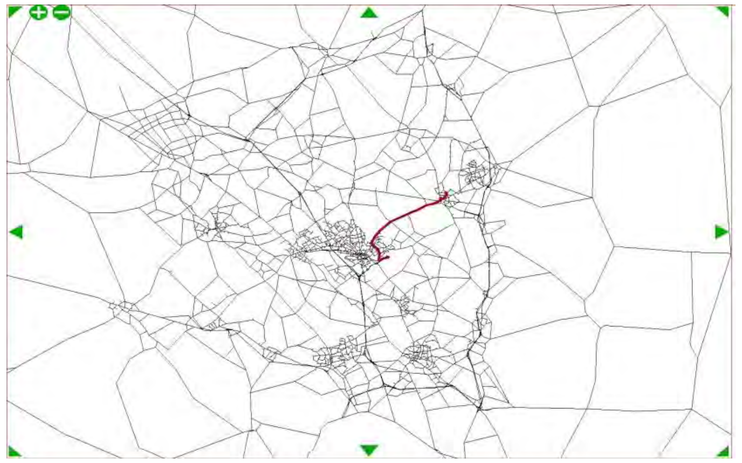

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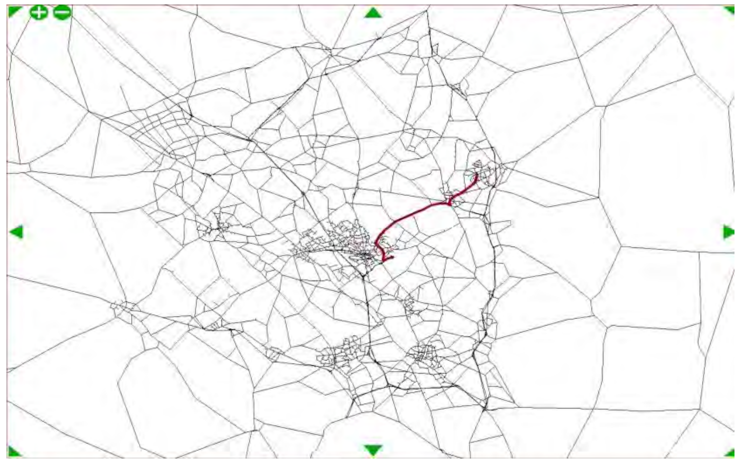

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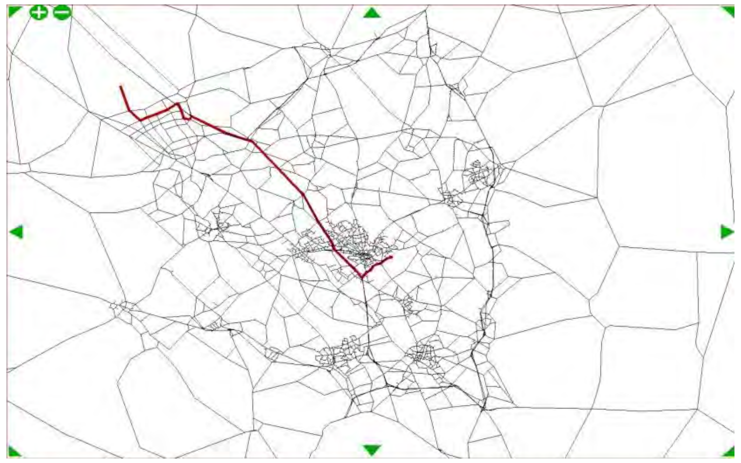

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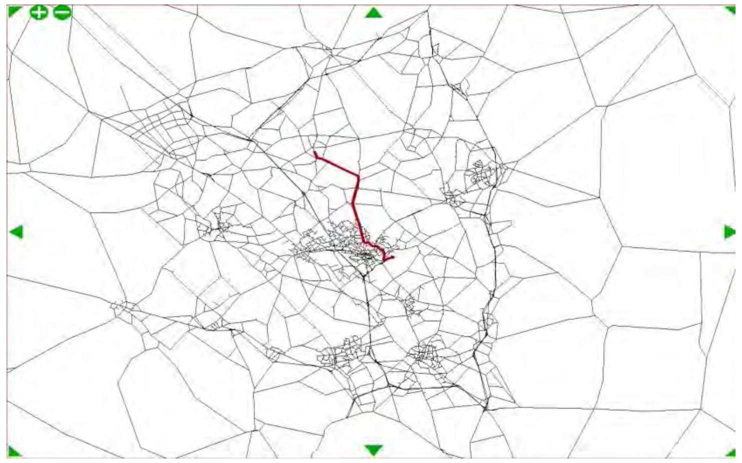

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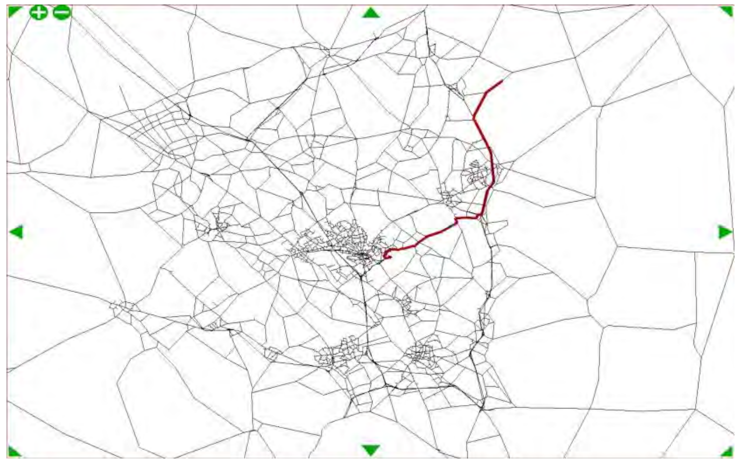

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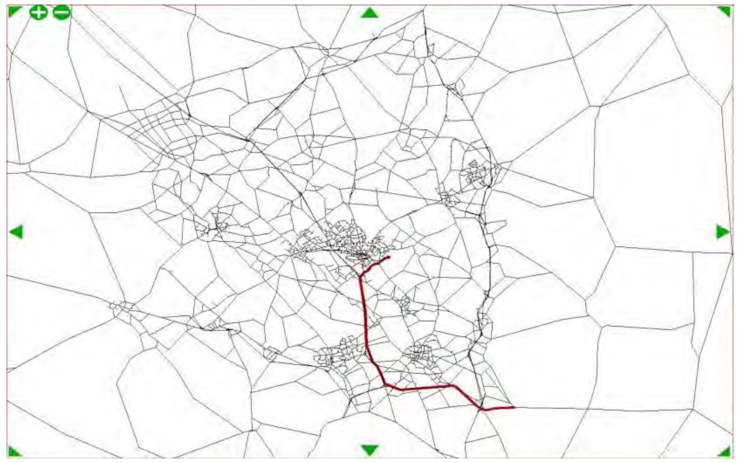

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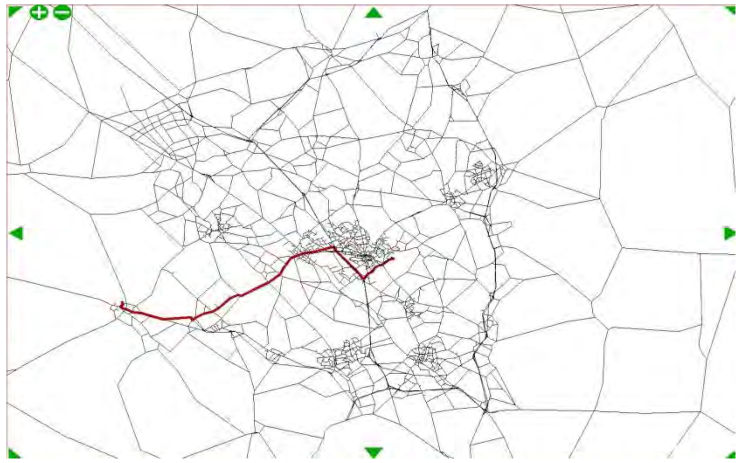

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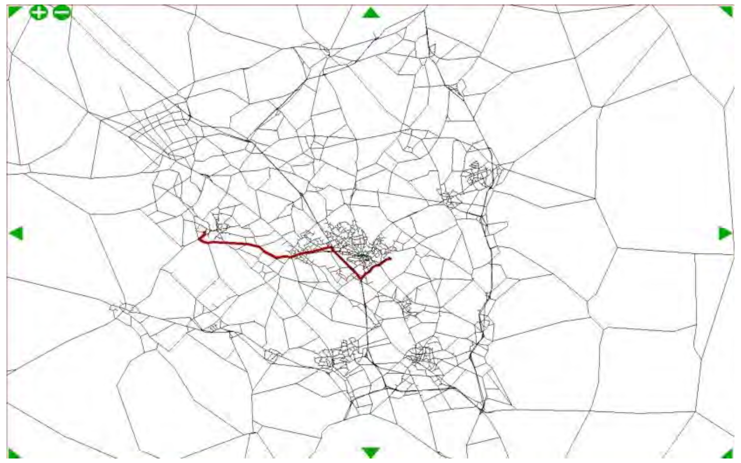

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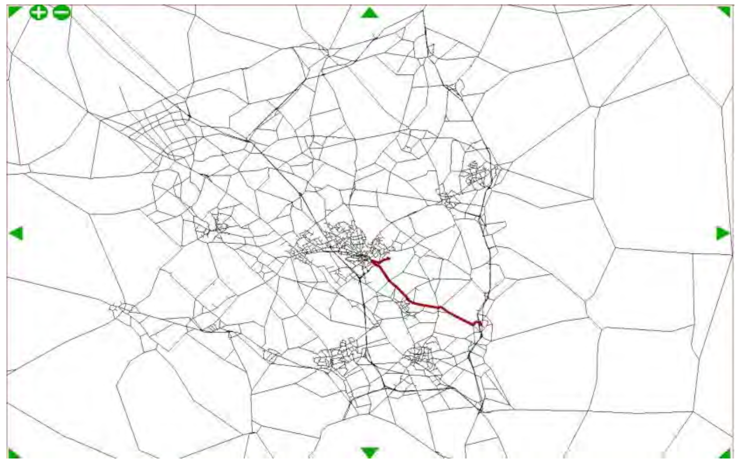

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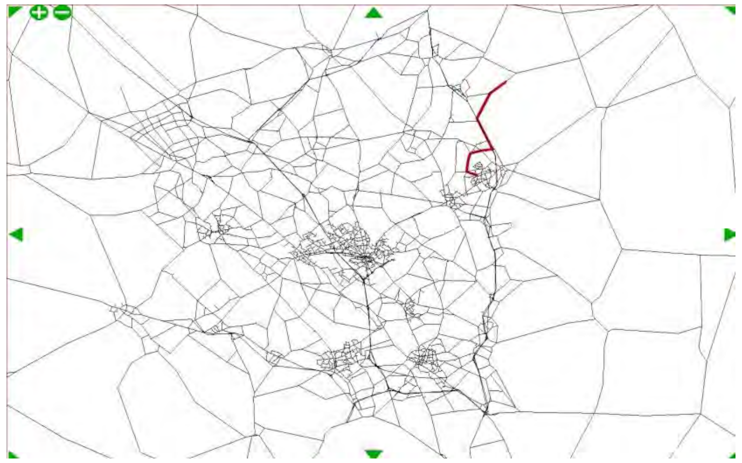

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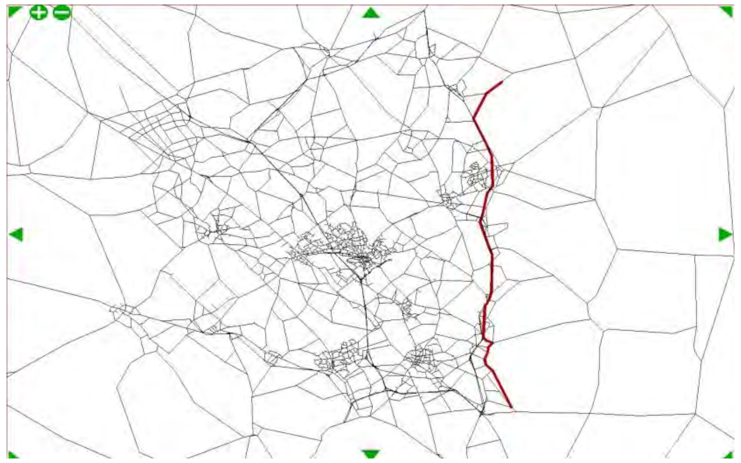

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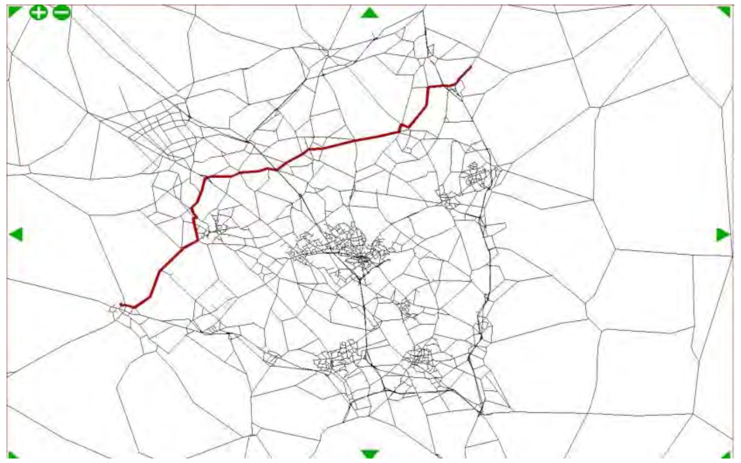

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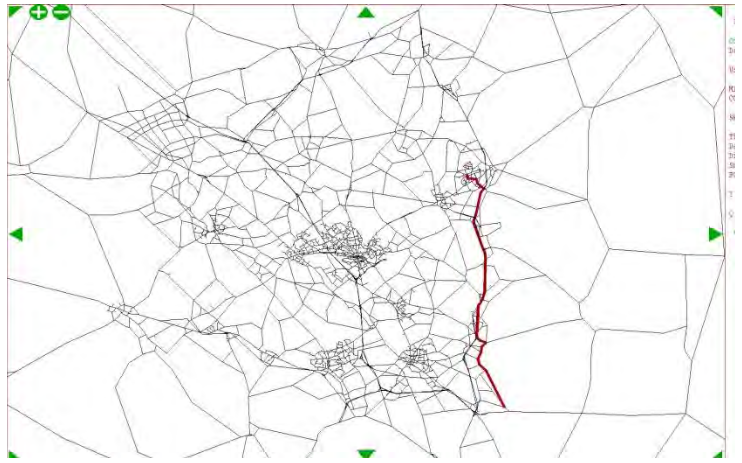

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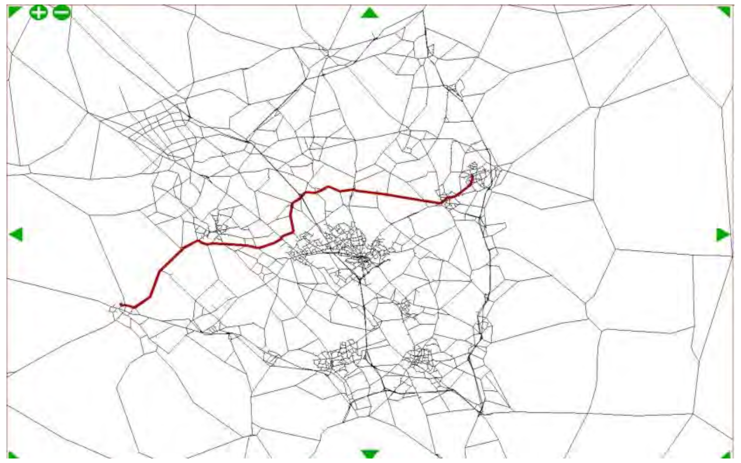

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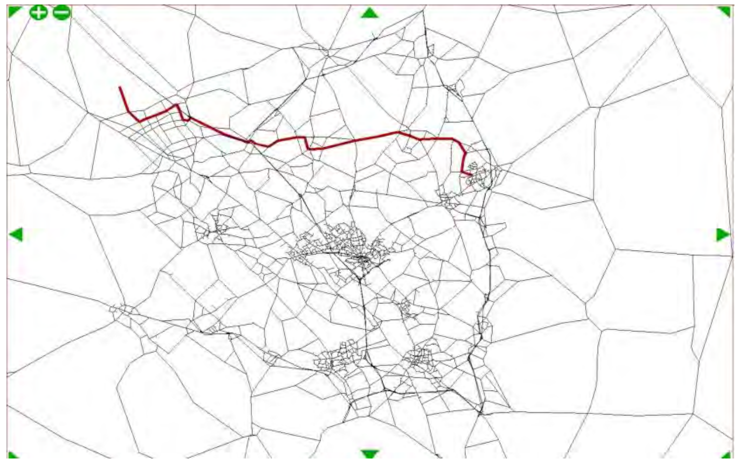

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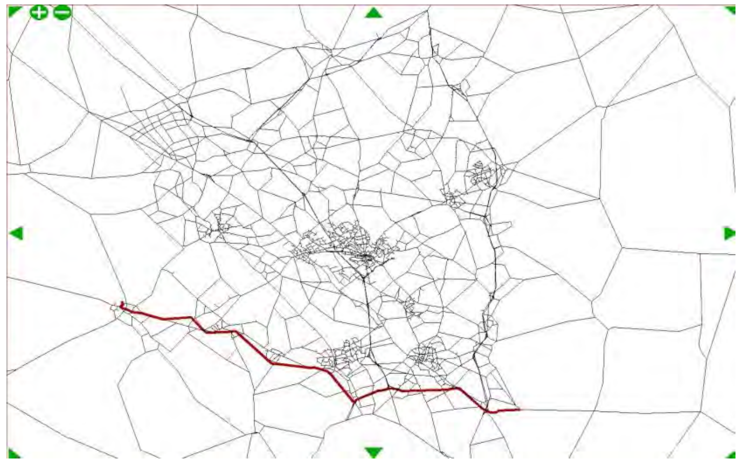

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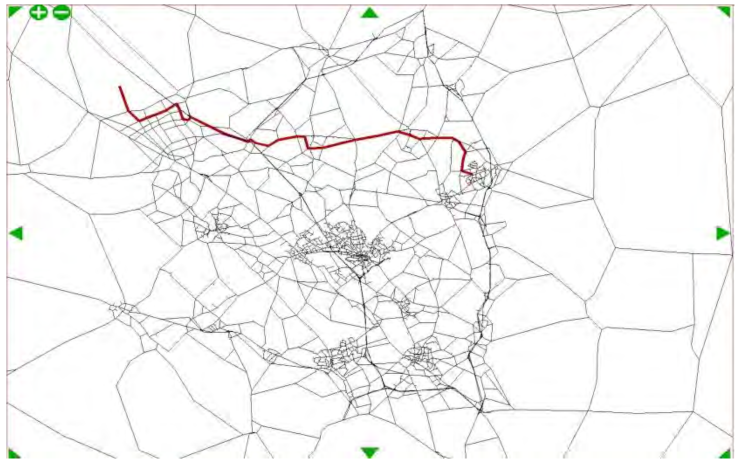

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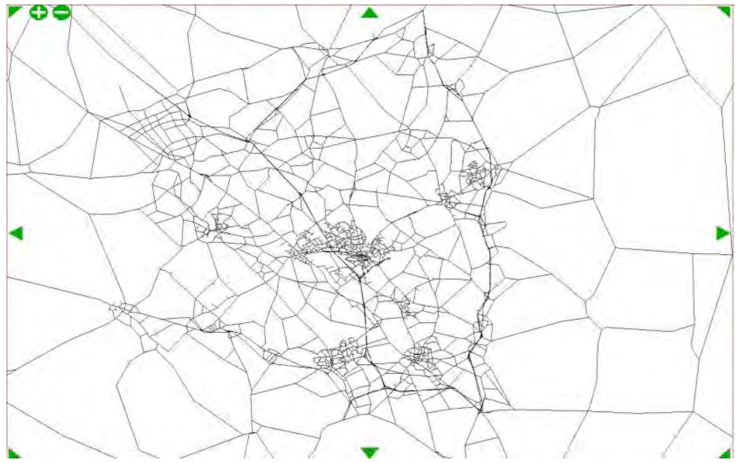

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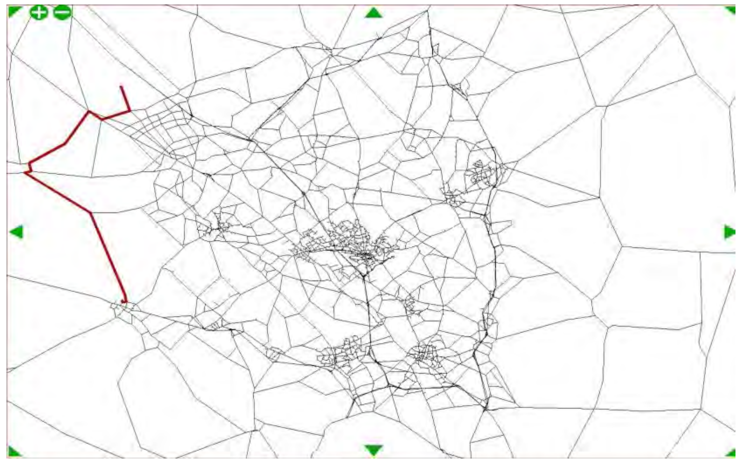

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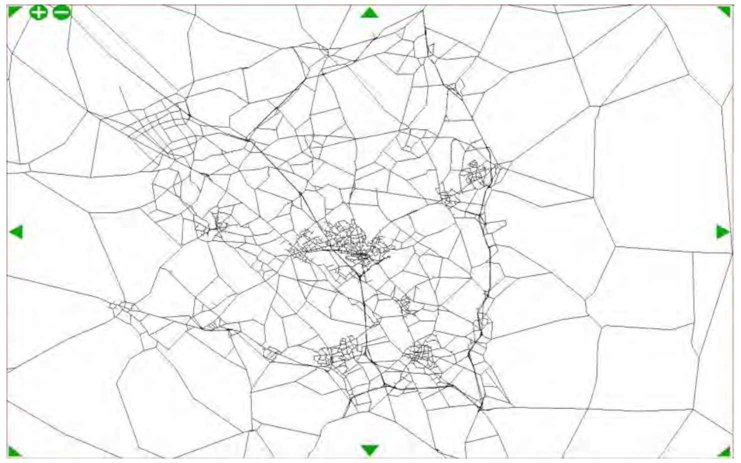

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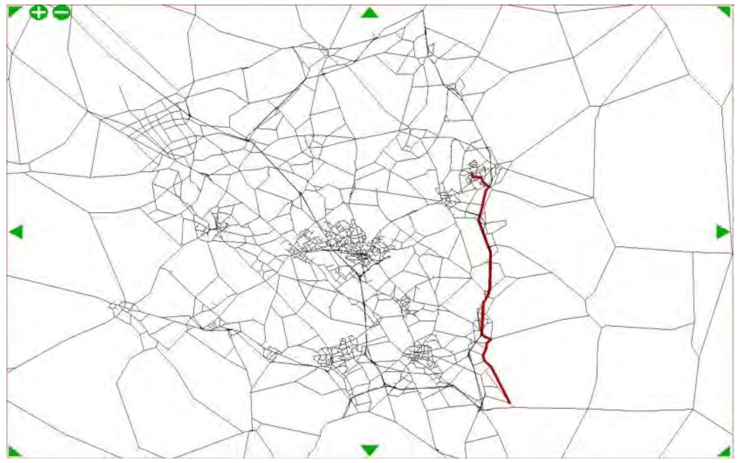
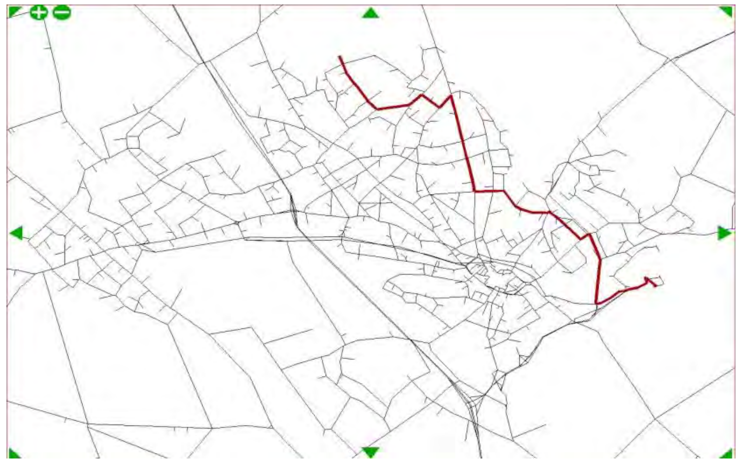


E4 PM Route Choice Analysis: HGV

Luton Airport to Luton North



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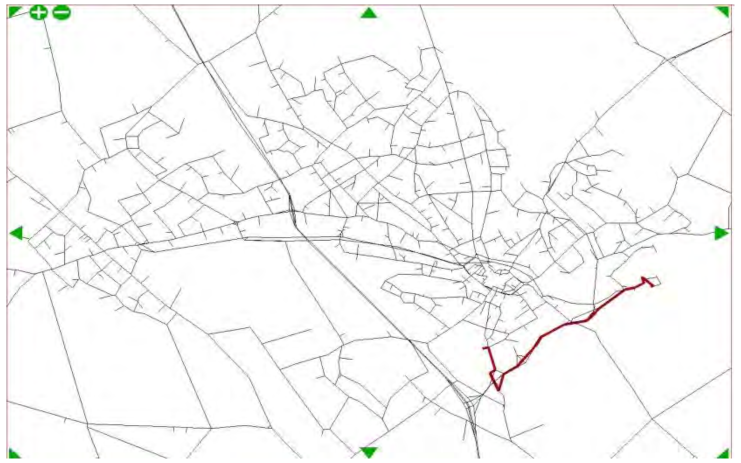

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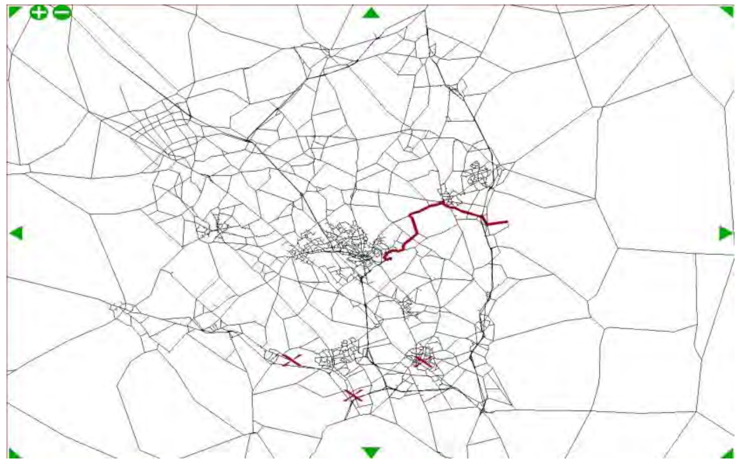

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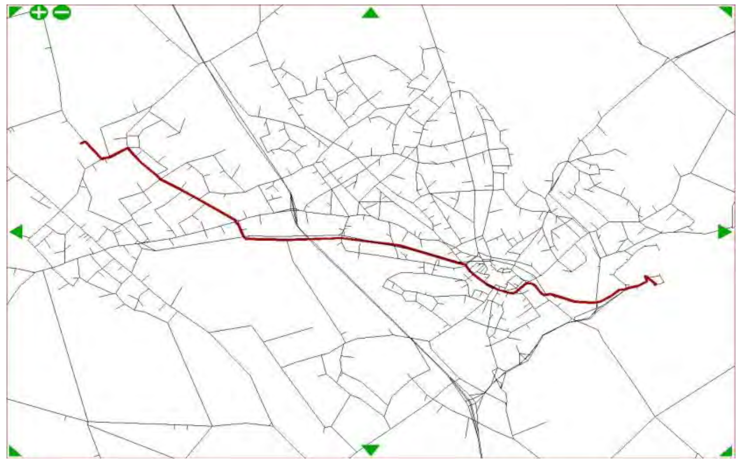

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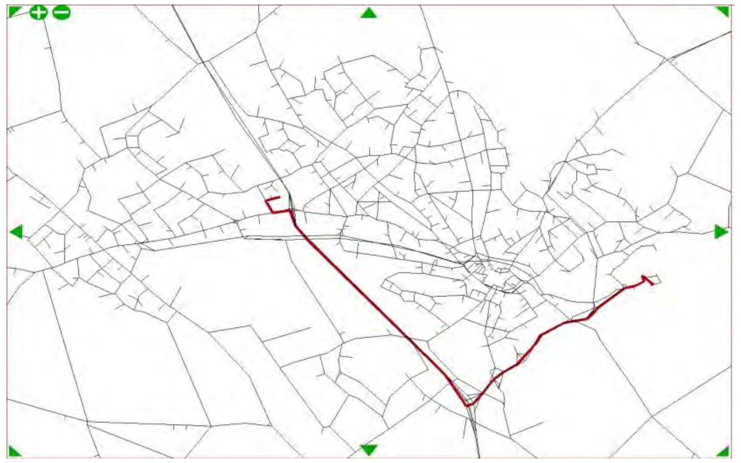

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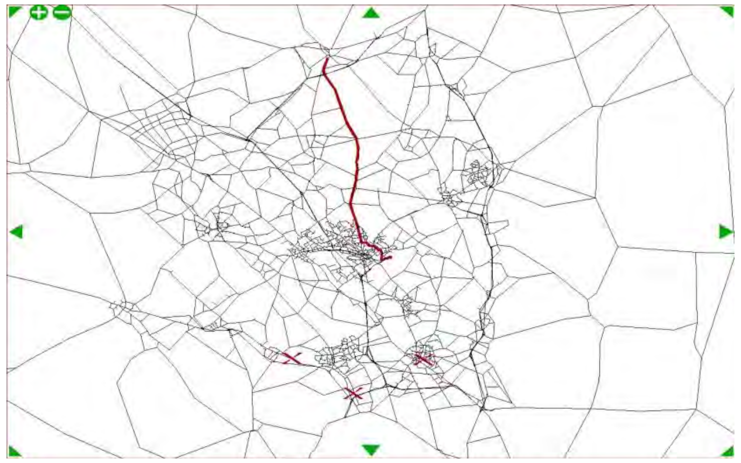

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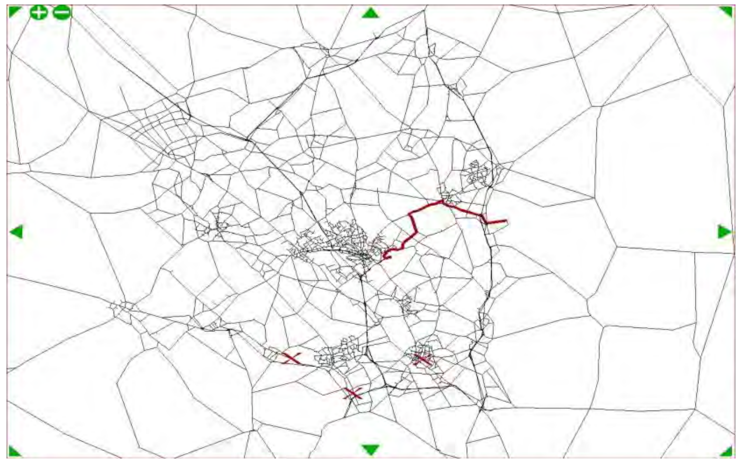

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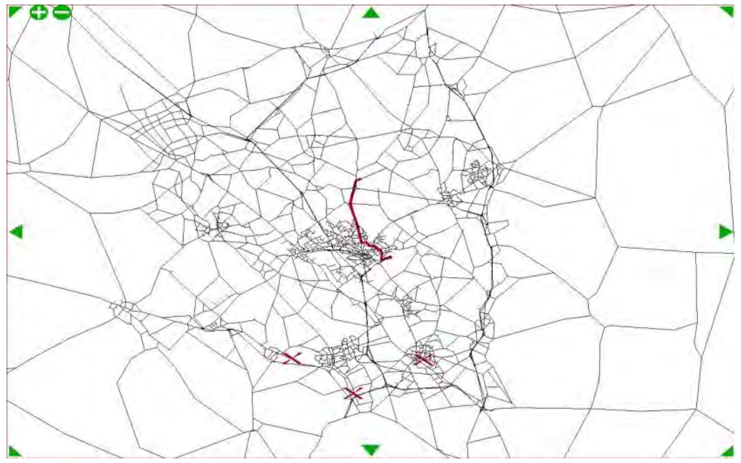

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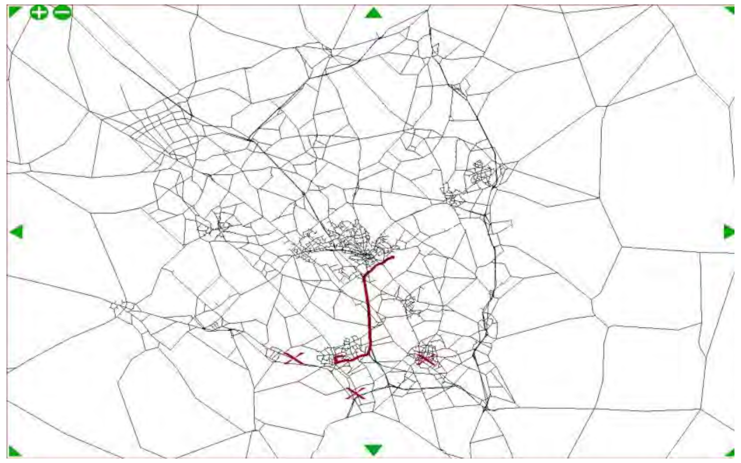

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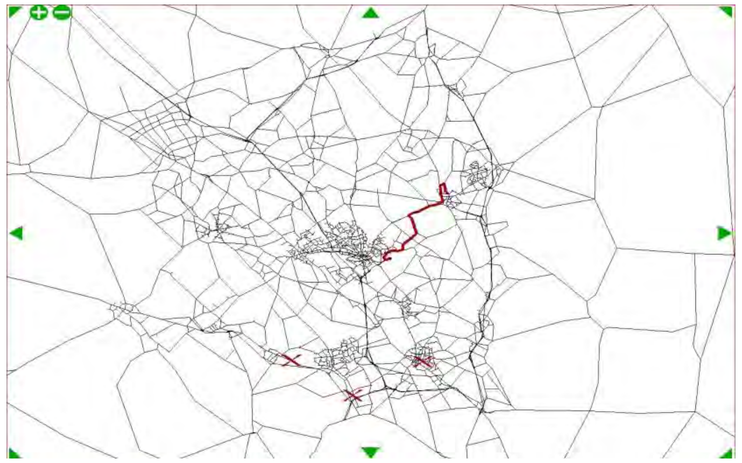

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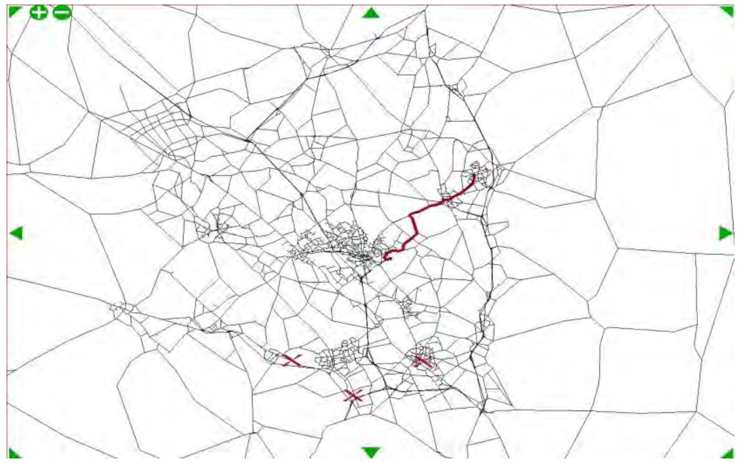
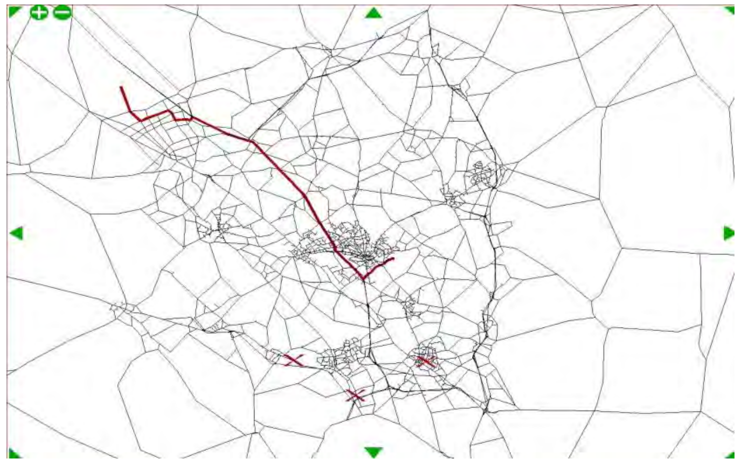


Luton Airport to External North-West



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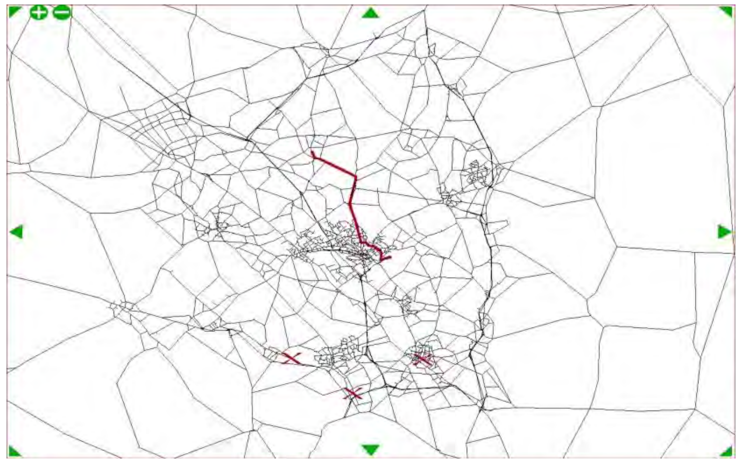

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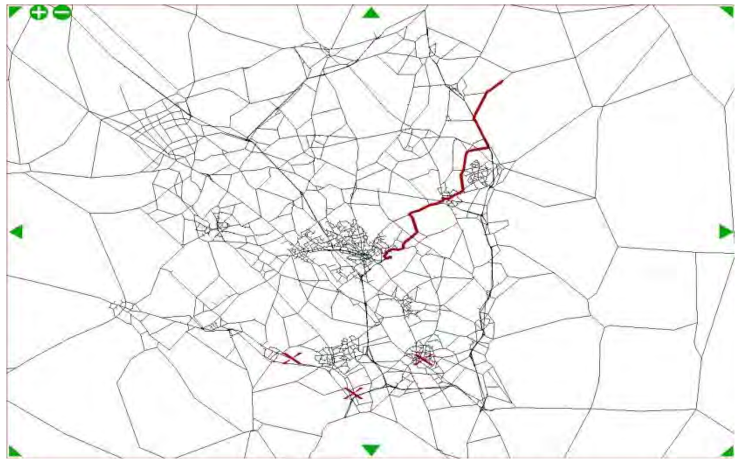

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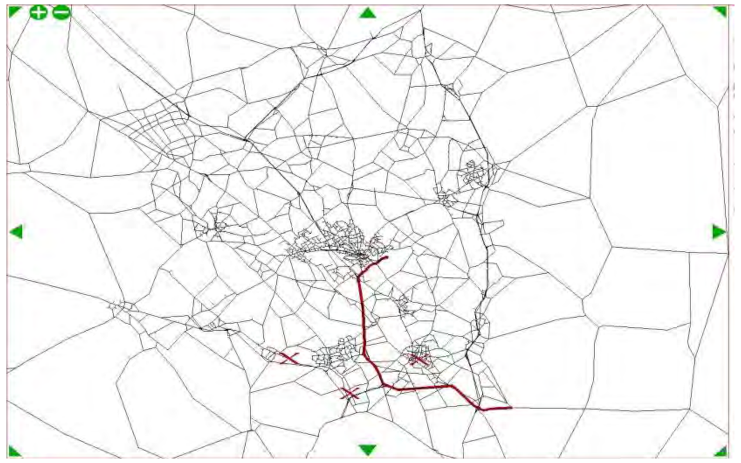

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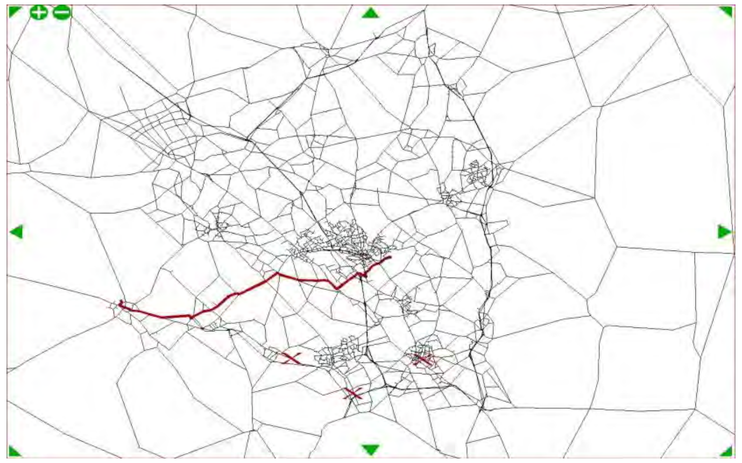

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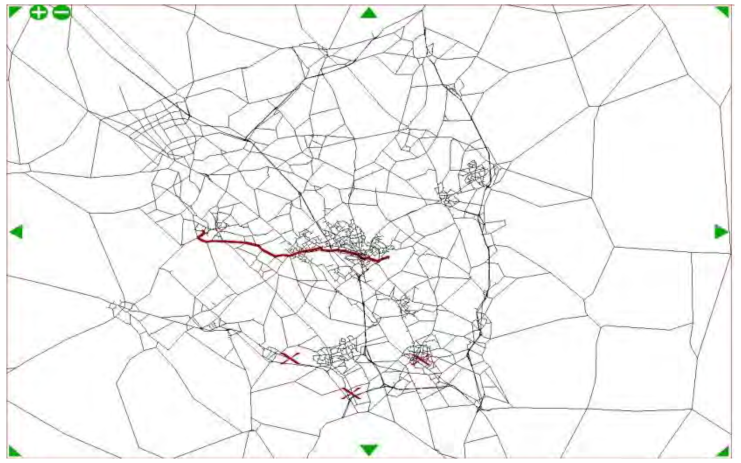

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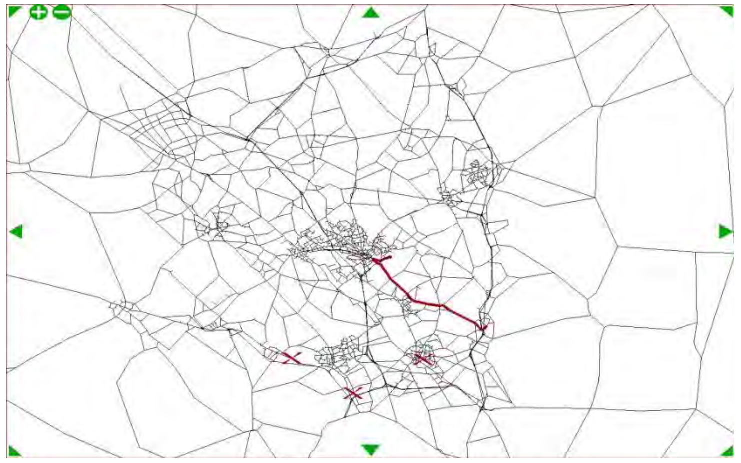

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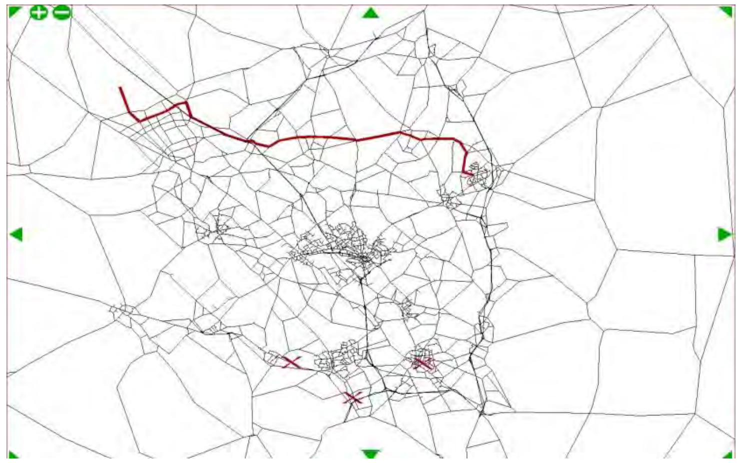

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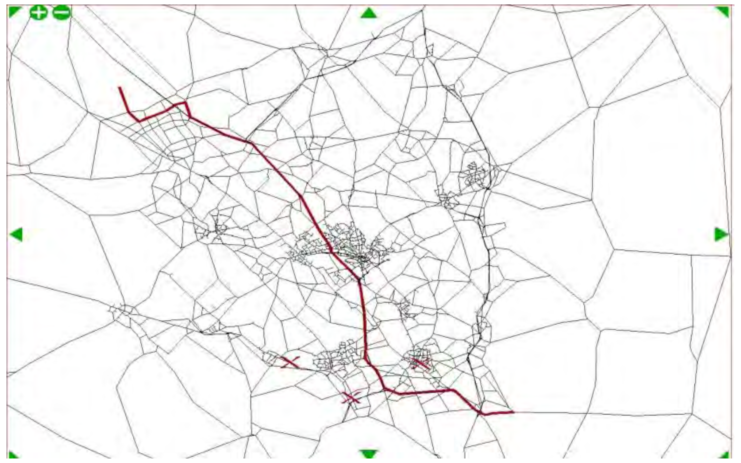

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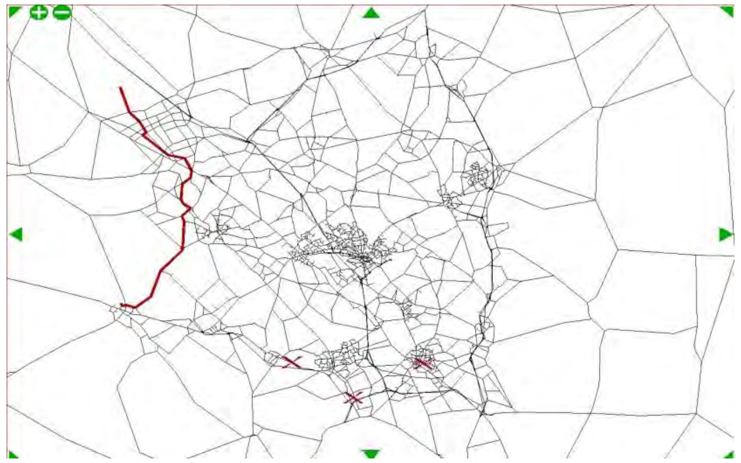

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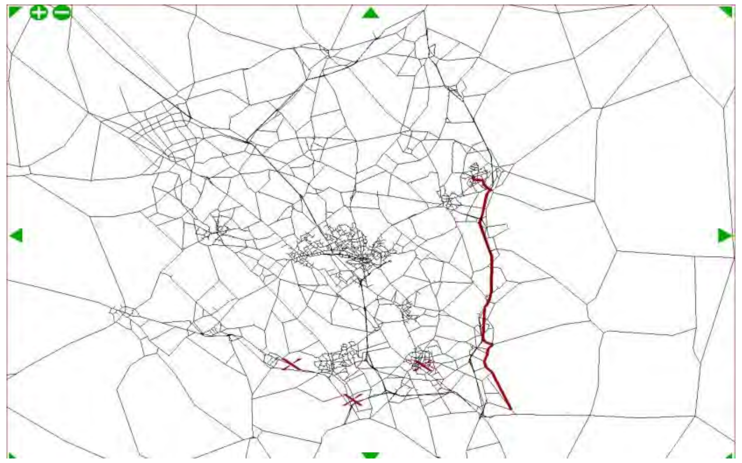

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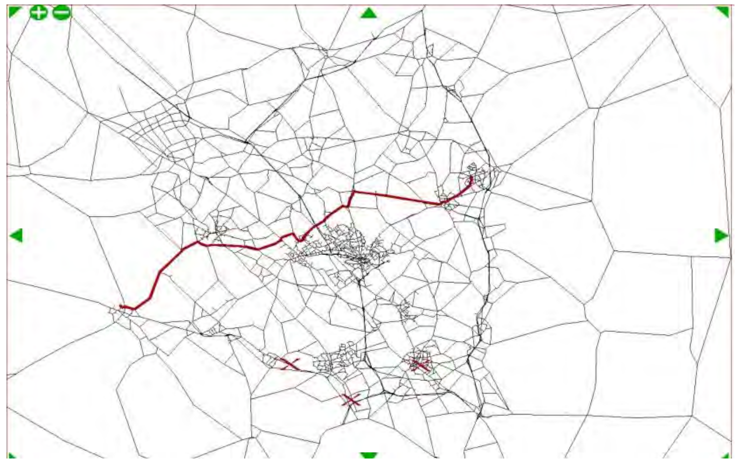

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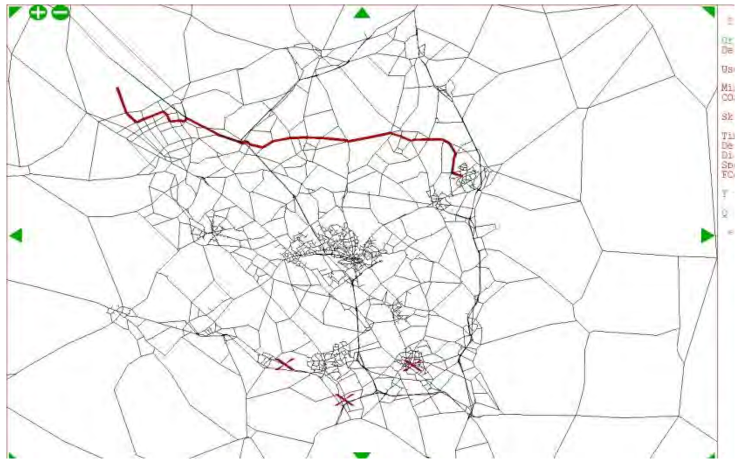

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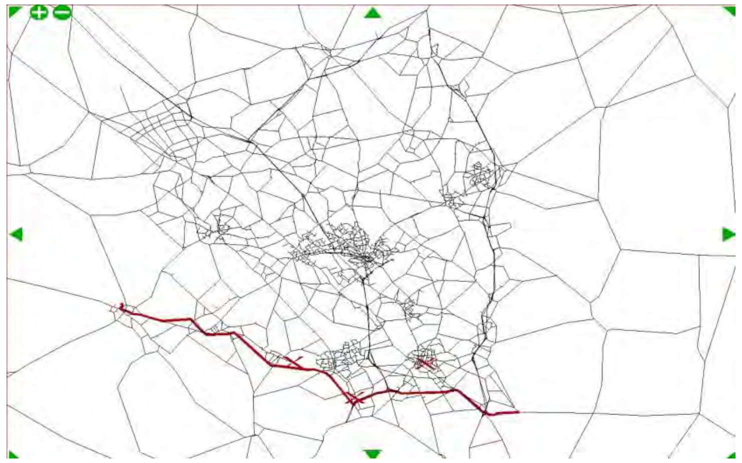

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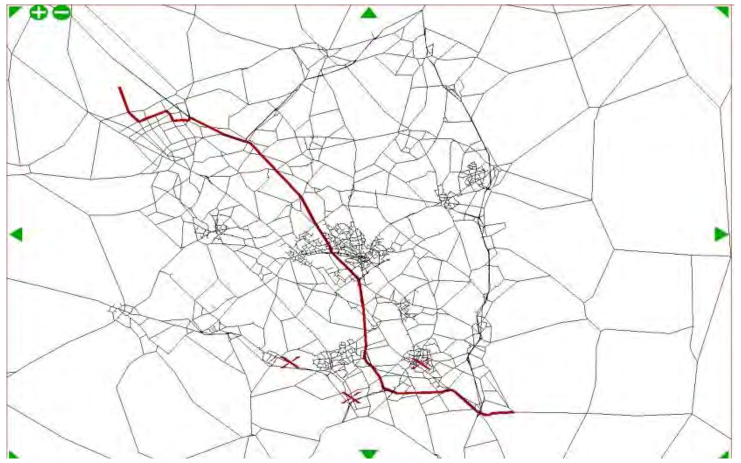

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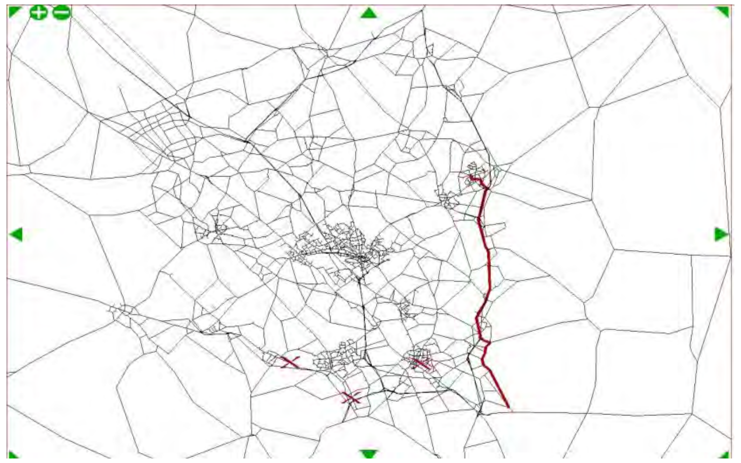

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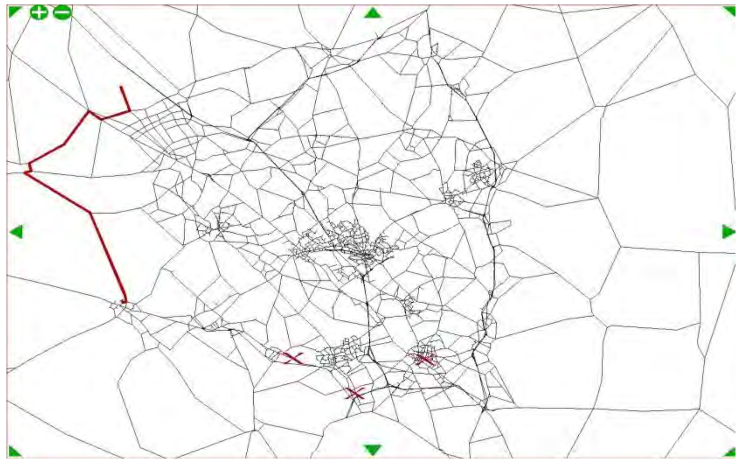

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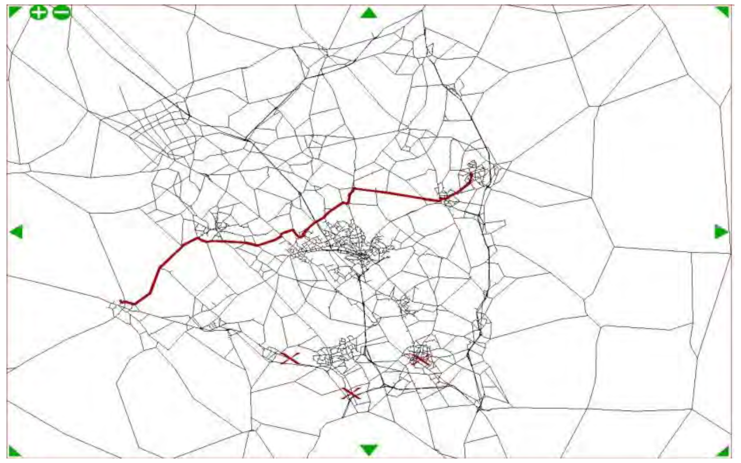

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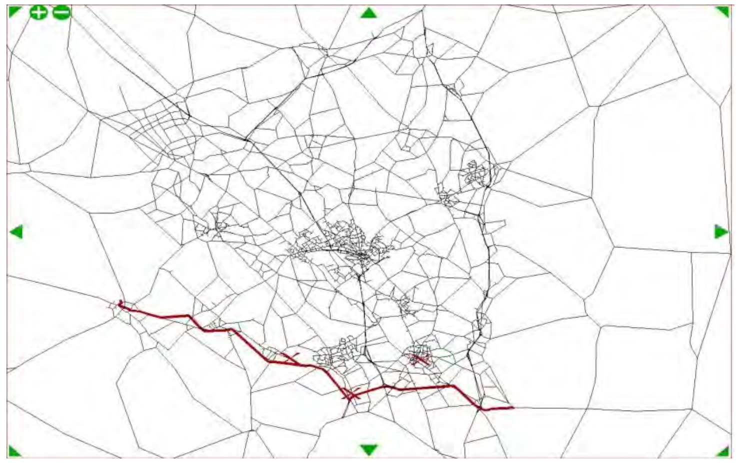

Appendix E2: Public Transport LMVR

London Luton Airport Expansion Development Consent Order

Strategic Modelling: Public Transport Model Validation Report

29 May 2019

Report ref: LLADCO-3B-AEC-00-00-RP-CH-0002

Contents

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Appendices

1 INTRODUCTION

1.1 Context

1.1.1 London Luton Airport Limited is preparing to secure the necessary consents to allow London Luton Airport to grow beyond the current permitted capacity of 18 million passengers per annum (mppa).

1.1.2 The Surface Access Strategy Position paper (July 2017) discusses the existing strategic transport modelling tools developed in and around the Luton Airport area which can potentially be used to first understand the existing transport provision and constraints, secondly to understand the impact of growth on the highway and public transport network, and finally to develop and examine multi-modal interventions required to deliver the airport expansion as part of the Airport Masterplan.

1.1.3 In order to assess the strategic impacts of the proposed expansion, the existing Central Bedfordshire and Luton Transport Model (CBLTM) has been identified as the best available tool.

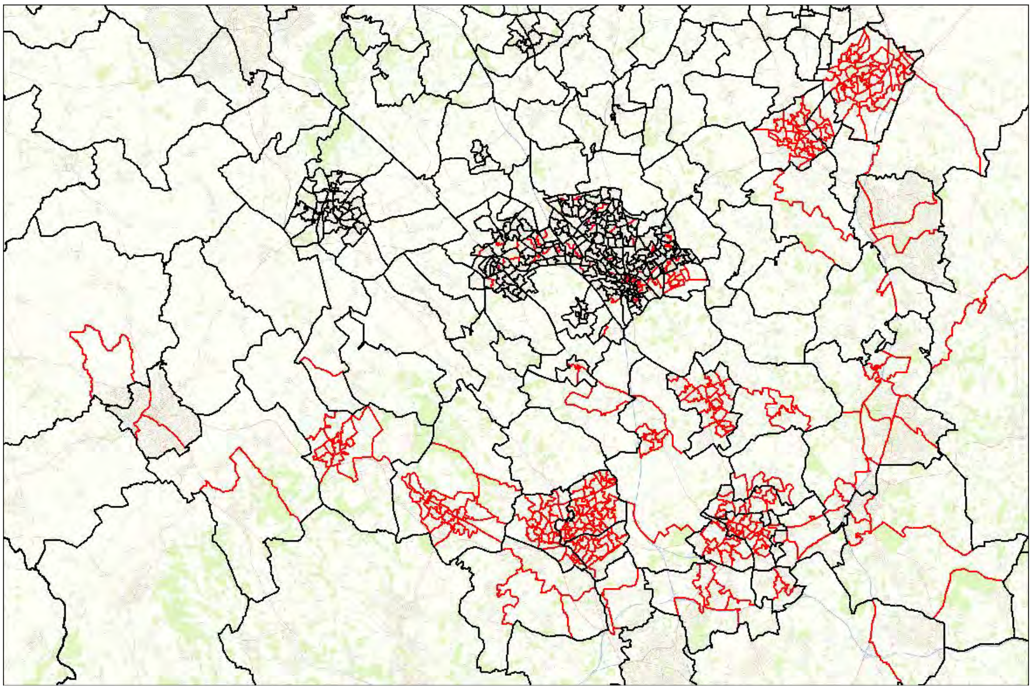
1.1.4 The original version of the CBLTM was developed in 2009 by Halcrow (now CH2M) with a base year of 2009. In 2016 AECOM was commissioned to update this model to reflect a 2016 base year, which included the collection of new travel demand data (mobile network data and public transport ticket data).

1.1.5 As part of the assessment of the proposed Luton Airport expansion, a Model Specification Report (September 2018) has been produced detailing the updates to be implemented to the CBLTM for the purposes of assessing the proposed development.

1.1.6 This report discusses the development of the existing CBLTM public transport model, the updates implemented as part of this model update, and the revised validation of the public transport model. This report therefore builds on the previous validation report for the public transport model, dated August 2017.

1.1.7 One component of the model suite which has been updated to create the updated version of CBLTM (hereafter referred to as CBLTM-LTN) is the model zoning. The previous model zone system has been disaggregated, increasing the number of zones from 643 to 991, adding zone detail at Luton Airport, within Luton Borough, and within Hertfordshire to the east and south of Luton Airport. Figure 1.1 provides an overview of the zone disaggregation within CBLTM-LTN, with Figure 1.2 and Figure 1.3 providing further detail of the revised zone system within Luton / Dunstable and Luton Town Centre respectively.

Figure 1.1 CBLTM-LTN Zone Disaggregation (shown in red) – Overview



Map contains Ordnance Survey data © Crown copyright and database right 2019

Figure 1.2 CBLTM-LTN Zone Disaggregation (shown in red) – Luton and Dunstable

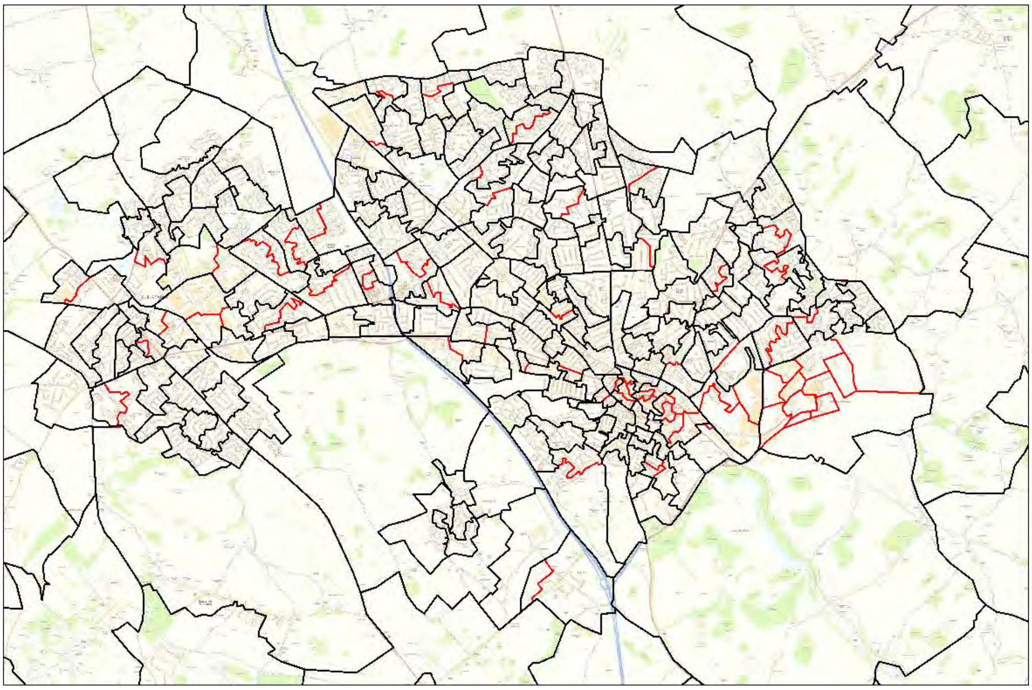


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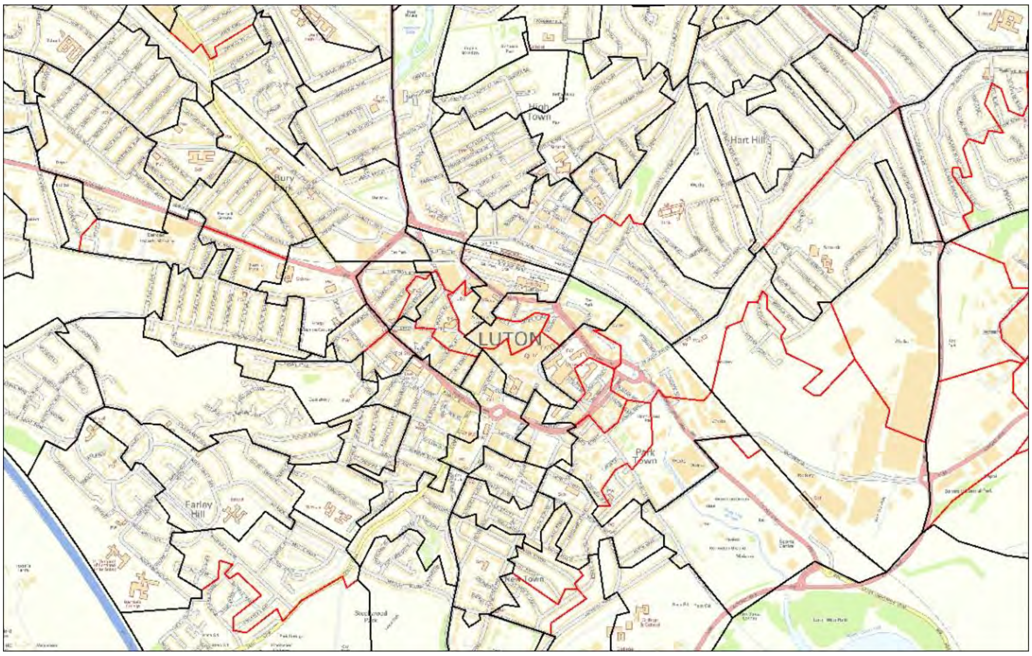
Figure 1.3 CBLTM-LTN Zone Disaggregation (shown in red) – Luton Town Centre



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1.1.8 Detailed discussion on the updates applied to the public transport model within CBLTM-LTN is detailed within the following sections of this report; however, the following provides a summary of these updates:

- The use of new airport demand data, covering both passengers and employees, with air passenger demand based on analysis of the Civil Aviation Authority (CAA) passenger survey data for Luton Airport.
- Additional network added in the vicinity of Luton Airport in response to the increased zone detail in this part of the model.
- A review of the bus and coach services, routes and journey times for services to / from Luton Airport, including the shuttle bus between Luton Airport and Luton Airport Parkway station.
- The addition of new centroid connectors to reflect the disaggregation of the model zone system, primarily within Luton and Hertfordshire to the east and south of the airport.

1.2 Structure of Public Transport Model Validation Report

1.2.1 Following this introduction, this Public Transport Model Validation Report contains the following sections:

- Section 2: Key Features of the Public Transport Model;
- Section 3: Public Transport Demand Data;
- Section 4: Public Transport Calibration and Validation Data;
- Section 5: Public Transport Matrix Development;
- Section 6: Public Transport Matrix Validation;
- Section 7: Public Transport Network Development;
- Section 8: Public Transport Network Validation;
- Section 9: Public Transport Assignment Validation; and
- Section 10: Conclusions.

2 KEY FEATURES OF THE PUBLIC TRANSPORT MODEL

2.1 Introduction

2.1.1 The CBLTM-LTN public transport model has been developed in INRO’s Emme software and covers bus, coach and rail modes. It is designed to model public transport in the districts of Central Bedfordshire and Luton. Rail services and demand extend across the whole of Great Britain, but in decreasing detail beyond Central Bedfordshire and Luton. Bus and coach services and demand cover only trips from, to and within Central Bedfordshire and Luton.

2.1.2 CBLTM-LTN is a strategic model designed to forecast effects upon broad travel patterns and the viability of corridors for investment. It is not a detailed operational model, and cannot produce results down to the level of individual bus stops, for example.

2.1.3 The public transport model uses the same zoning system as the highway and variable demand models. An overview of the CBLTM-LTN zone system is given in Figure 1.1 and Figure 1.2.

2.2 Modes of Travel

2.2.1 Table 2.1 shows the transport modes represented in the CBLTM-LTN public transport model.

2.2.2 The access modes ‘e’ and ‘m’ do not represent the speed of a specific mode of travel, but have speeds calibrated to broadly reproduce traveller behaviour. The mode ‘e’ is used outside Central Bedfordshire and Luton only, and represents access to external rail stations (by a combination of car, walk, and bus modes).

2.2.3 The mode ‘m’ has a similar role within Central Bedfordshire and Luton; however it has a lower speed due to the zone system containing more detail within these districts and thus a greater proportion of interzonal trips are likely to walk.

Table 2.1: Public Transport Model Modes

ID	Name	Type	Speed	Description
a	Auto	Auto	-	Car mode for traffic assignment; used only to enable turning data; actual car travel is modelled in the highway assignment model
b	Bus	Transit	-	Bus services derived from Traveline National Data Set (TNDS)
c	Coach	Transit	-	Coach services derived from the National Coach Services Data set (NCSD)
r	Rail	Transit	-	National rail services
s	Shuttle	Transit	-	Shuttle services derived from Luton Airport and Luton Airport Parkway
w	Walk	Aux	4 kph	Walk used for access to bus and pure walk trips
m	Mixed	Aux	10 kph	Access to rail stations within Central Bedfordshire and Luton
e	External	Aux	22 kph	External connectors to railway stations at motorised speed

2.3 Time Periods

2.3.1 The public transport assignment model represents an average hour within the AM Peak, interpeak and PM Peak periods. The public transport model therefore represents:

- an average AM Period hour (between 07:00 and 10:00);
- an average interpeak hour (between 10:00 and 16:00); and
- an average PM Period hour (between 16:00 and 19:00).

2.4 User Classes

2.4.1 As shown in Table 2.2, the model assigns three different user classes with different permitted modes. The demand model produces appropriate demand matrices for each of these user classes.

2.4.2 For the bus/coach and rail assignments, assigned link volumes are stored for each of the three modelled time periods. The walk assignment is only used to provide generalised costs to the demand model, and therefore assigned volumes are not saved as part of a model run.

Table 2.2: Public Transport Model User Classes

ID	Modes	Description
1	bwe	Bus/Coach travellers
2	rsmwe	Rail travellers
3	w	Walkers

2.4.3 The auto/car mode ('a') is not used in the assignment. It is used within the public transport model to enable information for turning movements should it be required. Without a car mode, Emme only allows for data to be represented within the public transport model at a link-level. Adding the car mode allows interventions for individual turns / movements at junctions (e.g. for a bus priority scheme) to be tested.

2.4.4 Mixed-mode bus/rail trips are not explicitly modelled, although travellers making such trips will be included in the ticket data on which the demand matrices are based. They will not, however, be linked within the model suite.

2.4.5 Only around 5% of rail access/egress legs in the East of England use a bus (source: National Travel Survey), and a smaller proportion of rail trips are used to access bus as a main-mode. This approximation of excluding mixed-mode trips from the public transport model is therefore considered to be appropriate.

2.4.6 For the purposes of assessing the proposed expansion at Luton Airport, the shuttle bus service between the airport and the parkway station has been coded as a 'shuttle' service within the assignment. This mode has been included in the rail assignment to allow trips with rail as their main-mode to use the shuttle service to / from Luton Airport.

2.5 Assignment Method

2.5.1 The CBLTM-LTN public transport model maintains the frequency-based deterministic assignment method in which each desired destination is assigned a single optimal strategy. A strategy consists of a decision of what to do at every node in the model network, which may be to take an access/walk mode along a specific link, wait for the first service to arrive from a defined set of services calling at the node, or alight from a service.

2.5.2 The frequency-based nature of the model is suitable for strategic assessment in relatively high-frequency situations. This describes most local/urban coach and bus services, and rail services to and from London fairly well. As actual timetables are not represented (only the average interval between buses, coaches or trains on a service), nor are passengers' desired departure times represented in detail below the three or six hour periods, this approach is not suitable for detailed operational or timetable planning, nor is it suitable for assessing relatively low frequency services (such as those operating less than once an hour) where interchanges may occur.

2.5.3 The CBLTM-LTN model suite includes an absolute logit choice model to split passengers between rail and bus/coach. Although rail and bus/coach demand was developed separately from different sources of data, the demand for public transport was combined and is split within the model using an absolute choice model.

2.5.4 This absolute sub-mode choice for public transport demand is applied to all movements except those to / from Luton Airport. As discussed in Section 5.6, demand for Luton Airport is an input to the model by public transport mode, and is not subject to the sub-mode choice.

2.5.5 The absolute choice model reproduces the observed split between rail and bus/coach well, largely due to the movements served by the two modes tending to be distinct, with limited direct competition between modes. The adoption of an absolute choice model for public transport makes certain kinds of intervention (particularly new rail routes) easier to model, compared with the incremental model generally favoured by WebTAG[1].

2.6 Generalised Cost Formulations and Parameter Values

2.6.1 The assignment seeks to minimise a public transport traveller's "generalised cost", a combination of their travel time and fare. Defining the generalised cost requires appropriate weights for different components of travel time. The values within the previous CBLTM public transport model were derived initially from WebTAG and PDFH (Passenger Demand Forecasting Handbook) advice and other models. Many of these weights have been adjusted to improve the routeing behaviour, and these parameters have

[1] Note that the remaining choice models within the variable demand model (trip distribution, time period choice, mode choice and trip frequency) use an incremental model approach as preferred by WebTAG. Further discussion on the variable demand model can be found in the 'Demand Model Development' Report.

been retained within the CBLTM-LTN public transport model.

2.6.2 The exception to this is the value of time assumed within the public transport assignment, which has been updated to reflect the latest available WebTAG data book (November 2018). As the public transport model does not represent trip purpose within the assignment, a demand-weighted average value of time has been derived. This demand-weighted average assumes that 39.6% of public transport demand is commuting, 1.6% is business and 58.7% are 'other' trips.

2.6.3 The final values adopted in the public transport model are shown in Table 2.3. Time weights are defined as factors of bus in-vehicle travel. The "value of time" is used to convert monetary elements, fares, into time equivalents.

Table 2.3: Public Transport Model Parameters, 2016 Base Year

Name	Value	Description
Fares	-	Set as functions of boardings and distance by vehicle type
Value of Time	12.328	Derived by model year from WebTAG advice (p/min, 2010 prices)
Walk time weight	2.5	Relative perception of walking time compared with public transport in-vehicle time.
Wait time weight	2	Relative perception of waiting time compared with public transport in-vehicle time.
Rail in-vehicle time	1	Relative perception of rail travel compared with bus travel.
Walk speed	4 kph	Average walking speed.
Rail Access Speed	10 kph	Average rail access speed.
Boarding, bus/coach	6 min	Time penalty (mins) applied to each bus vehicle boarding.
Boarding, rail	2 min	Time penalty (mins) applied to each rail vehicle boarding.
Wait factor, threshold (w_t)	5 min	Expected wait time below which travellers turn up at random.
Wait factor (w_w)	0.25	Factor applied to half-headway to derive wait time beyond the threshold
Mode Choice Sensitivity	-0.14	Generalised cost factor for logit choice utility between rail and bus (min^{-1})
Rail ASC[2]	-5 min	Mode constant for rail travel relative to bus

2.6.4 The function used to calculate wait time is as follows:

[2] Alternative-Specific Constant: this represents elements of passengers' choice between rail and bus which are not represented within the assignment model, such as comfort, reliability, and access to other services such as onboard Wi-Fi.

$$w(h) = \frac{h}{2}\left(\frac{min(\bar{h}, w_t) + w_w max(\bar{h} - w_t, 0)}{\bar{h}}\right)$$

where:

- w is the wait time in minutes;
- h is the headway in minutes for services the traveller might board;
- $\bar{h}$ is the average headway in minutes for a service calling at the stop; and
- w_t and w_w are parameters as described in Table 2.3

2.6.5 Public transport fares are used within both the assignment and the mode choice model between rail and bus models. Rail, coach, bus and shuttle bus fares for the 2016 base year are calculated as follows:

- Bus / shuttle fares (pence): $76 + 4.3 * Distance_{km}$
- Coach fares (pence): $60 + 6.5 * Distance_{km}$
- Rail fares (pence): $136 + 14.6 * Distance_{km}$

2.6.6 All fares are intended to represent average fares actually paid (including all discounts and concessions), rather than the advertised full single fare. Fare functions were derived from ticket sales data in all cases.

2.6.7 Crowding on public transport services is not represented within the calculation of generalised costs. As stated within WebTAG Unit M3.2 §3.5.4, the introduction of crowding within a public transport assignment model has significant practical implications, primarily in terms of runtimes and the need to calibrate crowding functions. WebTAG goes on to state that *"crowding should only be modelled where it is likely to have a significant effect on traveller behaviour or where an effect on crowding is one of the objectives of the scheme"*.

2.6.8 Within the context of the CBLTM-LTN public transport model and the assessment of the proposed expansion of Luton Airport, crowding on public transport services is not considered to be a significant element of traveller behaviour. There are no known issues of bus crowding within Luton, and whilst there are known capacity constraints on rail services between Luton and London at peak times, these are not considered to be a key driver of traveller choice due to the lack of alternative modes for these movements.

2.7 Relationship between Public Transport Model and Highway Assignment Model

2.7.1 Highway congestion is not modelled at a link level in the public transport assignment, which uses timetabled travel times. However, increases in highway congestion over time are added to bus and coach travel times for variable demand modelling in forecasting, to ensure that congestion increases are taken into account, and hence bus or coach travel is not perceived to be unreasonably attractive.

2.7.2 It is possible to model bus priority schemes at a corridor level using this mechanism, although detailed assessment of operation at a junction level is too detailed for the model scope.

2.7.3 Bus and coach vehicle flows have been transferred from the public transport model to the highway model to ensure their impact on congestion is fully represented in the base year. There is no direct link between the two models in forecasting. If a bus or coach scheme is considered likely to affect highway congestion, this is required to be coded separately in the highway model.

2.8 WebTAG Validation Criteria

2.8.1 WebTAG Unit M3.2, Section 7 details guidance on the recommended differences between observed and modelled flows within a public transport model.

2.8.2 For screenlines and cordons, WebTAG recommends that the modelled flows across screenlines and cordons are within ±15% of the observed passenger flows in at least 95% of cases. As detailed in Section 4, count data are not available to construct watertight screenlines or cordons, and therefore this criterion cannot be applied.

2.8.3 For individual link counts, WebTAG states that modelled flows should be within ±25% of the observed passenger flows, except where observed hourly passenger flows are below 150 passengers per hour. Within the CBLTM-LTN public transport model, this criterion has been applied (where hourly flows are above 150 passengers) to both individual bus link counts and rail station boardings.

3 PUBLIC TRANSPORT DEMAND DATA

3.1 Bus Electronic Ticket Machine (ETM) Data

3.1.1 Electronic ticket machine (ETM) data have been collected from two bus operators (Arriva and Centrebus) in Central Bedfordshire and Luton. Between them, they cover around 73% of bus services that operate in Central Bedfordshire and Luton. The collected data are summarised by the bus operator in Table 3.1.

Table 3.1: Bus Electronic Ticket Machine Data

Operator	Services	Journeys (March to May 2016)	Operating Area
Arriva	54	2,963,582	Luton, Dunstable, Leighton Buzzard, Milton Keynes, Aylesbury, Stevenage, Watford, Letchworth, Arlesey, Hitchin, Hemel Hempstead, London.
Centrebus	26	579,417	Luton, Hitchin, Stevenage, Dunstable, Markyate, St Albans, Sandy, Caddington, Leighton Buzzard, Biggleswade, Toddington, Stotfold, Hemel Hempstead, Hatfield, Harpenden, Welwyn Garden City.

3.1.2 Although there is some variation in the format of data provided, the bus operators have both provided record-based data, containing one passenger boarding (or another event) per record. This covers the following:

- bus service number;
- bus journey departure time;
- boarding event time;
- ticket type;
- fare paid (Arriva only);
- boarding stage identifier; and
- alighting stage identifier (certain ticket types only).

3.1.3 The data in principle cover all passenger boardings, including concessions, use of return tickets, and use of smartcards and other passes, as well as actual ticket sales.

3.1.4 The operators provided boarding information at a fare stage level, with each fare stage often covering a group of bus stops in the same general area (such as "Luton Town

Centre"). The number of trips associated with each fare stage has been used to inform the suitable allocation of zones to stages. For example, where a stage has a high number of trips and is located close to a number of residential or shopping zones, then multiple zones have been allocated to a single stage.

3.1.5 All ETM data have been provided for three months from March to May 2016.

3.2 Rail LENNON Data

3.2.1 The rail demand matrices were developed using LENNON (Latest Earnings Nationally Networked Over-Night) rail ticket data obtained from the Association of Train Operating Companies (ATOC) for the whole country. This information is a complete representation of all rail tickets sold, and was therefore used as the starting point for the development of a rail matrix.

3.2.2 LENNON data contain tickets (including season tickets) sold by type, issuing station, origin station and destination station. They lack a considerable amount of information required to construct rail matrices, which had to be estimated, including:

- trip purpose;
- car availability;
- time periods of outgoing and return trips; and
- actual origin/destination as opposed to merely the origin and destination stations, which may be some distance from ultimate trip-ends.

3.2.3 The LENNON data were provided for the month of March 2016.

3.3 Household Interview Data

3.3.1 As the primary data sources for public transport demand are largely ticket-based, they lack many travel attributes that are required for transport modelling, such as trip purpose. These missing elements have been added with the help of household interview data from the National Travel Survey (NTS, 2002-2014).

3.3.2 The NTS has large samples overall, with robust bias-correction and data validation; however, sample sizes at a local level are smaller and have been considered when making use of the data.

3.4 Trip-End Model

3.4.1 A trip-end model is used to convert planning data (population, households and employment) at a zonal level into trips made by each mode of transport, by purpose and direction of travel. The trip-end model is based on version 7.2 of the National Trip-End Model (NTEM), with the zoning altered to represent CBLTM-LTN zones inside and around Central Bedfordshire and Luton.

3.4.2 Whilst accepting that the mode-split in the trip-end model is approximate, in the absence of a better data set (NTS samples were too small at a local level), we have made extensive use of these trip-ends in developing public transport matrices. This is of particular value, as the trip-end model will be used to calculate forecast changes in demand over time, and it is highly desirable that these forecasts are reasonably consistent with the base year demand.

4 PUBLIC TRANSPORT CALIBRATION AND VALIDATION DATA

4.1 Office of Rail and Road (ORR) Station Usage

4.1.1 The Office of Rail and Road (ORR) (formerly the Office of Rail Regulation) publishes annual statistics on usage of all stations in Great Britain[3]. These data are based primarily on LENNON ticket sales data, and have been used to validate and confirm our processing of the LENNON data.

4.2 Bus Passenger Flow Count Data

4.2.1 One set of single on-board counts along four links in four different locations within the model area was carried out in September 2016. Those locations are:

- Ampthill Road (Flitwick), shown in Figure 4.1;
- Stanbridge Road (Leighton Buzzard), shown in Figure 4.2;
- Biscot Road (Luton), shown in Figure 4.3; and
- Barton Road (Luton), shown in Figure 4.4.

Figure 4.1 Ampthill Road, Survey Site Plan

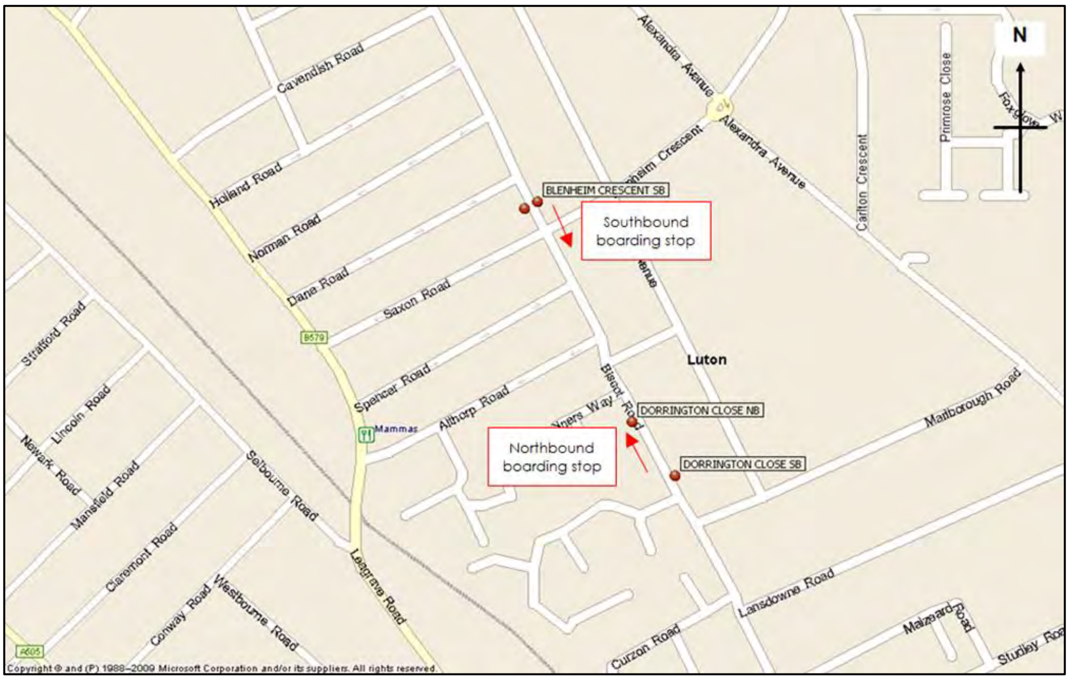
Map contains Ordnance Survey data © Crown copyright and database right 2019

[3] http://orr.gov.uk/statistics/published-stats/station-usage-estimates

Figure 4.2 Stanbridge Road, Survey Site Plan

Map contains Ordnance Survey data © Crown copyright and database right 2019

Figure 4.3 Biscot Road, Survey Site Plan



Map contains Ordnance Survey data © Crown copyright and database right 2019

Figure 4.4 Barton Road, Survey Site Plan

Map contains Ordnance Survey data © Crown copyright and database right 2019

5 PUBLIC TRANSPORT MATRIX DEVELOPMENT

5.1 Introduction

5.1.1 Public transport travel demand has been generated for an average weekday in a neutral week (a week without bank holidays) in Spring 2016. Demand includes both bus/coach and rail travel. Taxi travel is not included in the CBLTM-LTN public transport model, nor is travel by air.

5.1.2 The demand represents travel on scheduled public bus services, the airport shuttle bus, coach services and national rail. It does not include all education travel on dedicated school buses (though some buses that primarily serve schoolchildren were included in the ETM data), travel on non-scheduled coaches.

5.1.3 For rail travel, the LENNON ticket data captures travel at all stations within Great Britain, and therefore the rail demand matrices are a complete representation of rail travel within the country. For bus travel, the matrices represent passengers on services which start, end or pass through Luton and Central Bedfordshire. This will include bus travel by residents of neighbouring districts which enter Luton or Central Bedfordshire; however bus travel within or between neighbouring districts (which does not pass through Luton or Central Bedfordshire) is not included within the model.

5.1.4 Origin-destination (OD) matrices, which represent person trips made between CBLTM-LTN geographic zones, have been generated. Each matrix contains an estimate of numbers of trips between every pair of zones, except external-external bus and coach trips, which have not been estimated. Rail external-external trips are included.

5.1.5 Matrices have been segmented in several ways: by time period, by purpose and direction of travel (from-home / to-home for home-based trips), by rail or bus/coach, and car-availability of travellers. Each valid combination of these dimensions has resulted in a separate matrix.

5.1.6 The demand matrices have been developed as trip matrices (stored in OD format) for home-based purposes and non-home-based purposes. The model does not consider tours of linked trips (for example, from home to work and from work to home) or chaining of successive trips across different modes or routes/services.

5.1.7 Demand matrices have been constructed for the four time periods:

- AM Period: 07:00 – 10:00;

- Interpeak Period: 10:00 – 16:00;
- PM Period: 16:00 – 19:00; and
- Off-Peak Period: 19:00 – 07:00.

5.1.8 In addition, the demand matrices have been developed for the journey purposes shown in Table 5.1.

Table 5.1: Public Transport Purposes of Travel

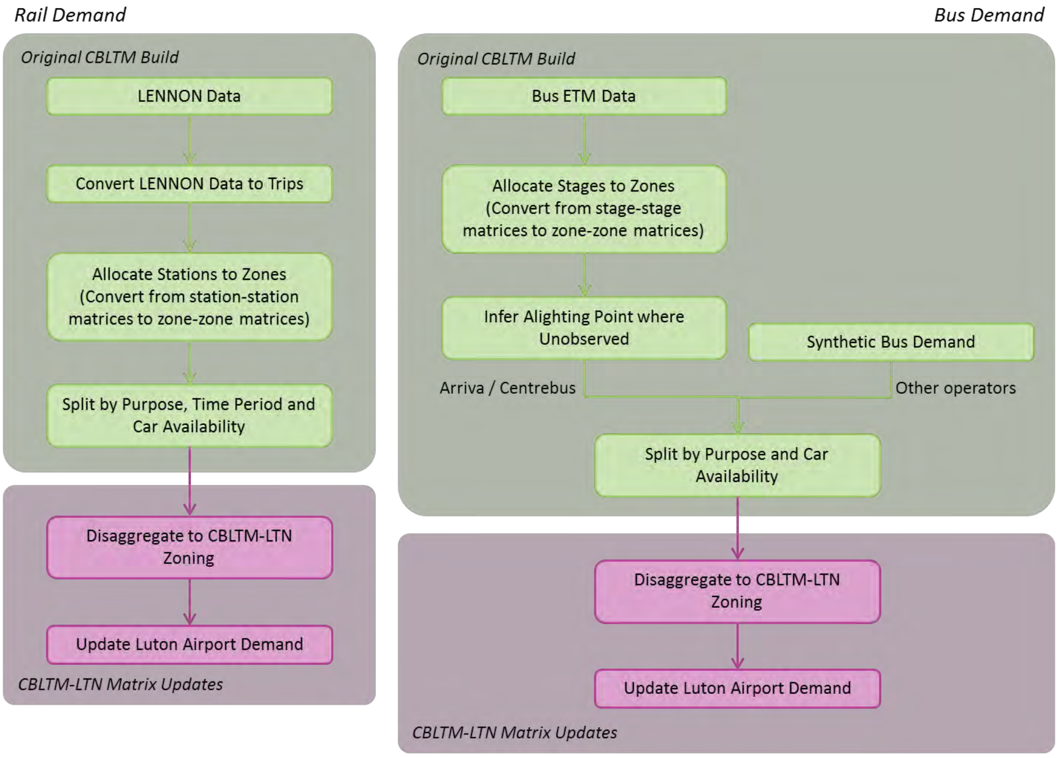
Representation	Purpose
Home-Based Trips	Commuting
	Employers' Business
	Other
Non-Home-Based Trips	Employers' Business
	Other

5.1.9 Matrices have been further segmented by car ownership using household car ownership data from the National Trip-end Model (NTEM) and the National Travel Survey (NTS).

5.1.10 The processing of bus and rail ticketing data to generate demand matrices has not been repeated as part of the update to produce CBLTM-LTN. The public transport matrices developed for the previous CBLTM have been disaggregated to correspond with the revised model zone system and the demand to / from Luton Airport has been updated. These updates to the public transport matrices are discussed in Section 5.6.

5.1.11 Further details on the matrix development are contained within the remainder of this section; however, Figure 5.1 provides an overview of the processes adopted for developing the rail and bus travel demand matrices.

Figure 5.1 Overview of Rail and Bus Demand Matrix Development



5.2 Rail Demand

5.2.1 LENNON data contain tickets sold by type, issuing station, origin station and destination station for Great Britain. They lack a considerable amount of information required to construct rail matrices, including:

- trip purpose;
- car availability;
- time periods of outgoing and return trips; and
- actual origin/destination zones as opposed to the origin and destination stations.

5.2.2 With regard to the last point, this is more an issue when developing demand internal to Central Bedfordshire and Luton. It is considerably less of a problem for external demand, partly because the accurate representation of external demand is less crucial, but principally, as zones are much larger in the external area, it can be reasonably assumed that the majority of travellers' ultimate trip-ends are contained within the same zone as the corresponding station.

5.2.3 It has been assumed that the LENNON trip-ends represent the actual trip-ends of the trips at most stations outside Central Bedfordshire and Luton.

5.2.4 Generation of ultimate trip-ends (as opposed to station trip-ends) was performed by a combination of estimating access/egress distance distributions by trip-length of actual rail journey, and by considering proportional levels of total rail demand originating in/destined for each modelled zone.

5.2.5 Estimates of total trips made per ticket issued, by ticket type, were required to create the rail matrices from the LENNON data. Each ticket type has been classified into either a single trip or a tour, and the number of trips that an average customer makes on the ticket was estimated. Most of these estimates were acquired from databases that are already at AECOM's disposal but some had to be estimated logically.

5.2.6 Table 5.2 shows the number of trips that were assigned to the most frequent ticket types in the LENNON data set in Central Bedfordshire and Luton. The ticket types in this table account for 92% of ticket sales within the model area.

Table 5.2: Sales from LENNON by Ticket Type

Ticket Name, LENNON Database	Tickets Sold (C. Beds and Luton)	Trip / Tour?	Implied Trips / Tours
CHEAP DY RTN HI 2BDY	70,929	Tour	1
STANDARD DY RTN 2BAF	62,098	Tour	1
STANDARD SINGLE 2AAA	48,766	Trip	1
STD CHEAP SNGL 2ADA	16,546	Trip	1
O CIRCULAR 2AGB	7,624	Trip	1
7 DAY SEASON 2MQA	6,959	Tour	4.5
ANYTIME RETURN STANDARD 2BUA	6,679	Tour	1
SAVER RETURN HI 2BFP	5,693	Tour	1
AI SEAT RESVTNS 2ZYM	4,908	Trip	0
PROMO RETURN 2BLD	3,481	Tour	1
PROMO RETURN 2BLC	3,274	Tour	1
SEASONS VB 1 2MTA	2,286	Tour	20

5.2.7 The distance-distribution of access and egress trips was extracted from the National Rail Travel Survey (NRTS), 2005. This is an old source of data, but other data sources (such as the National Travel Survey) do not contain reliable information on access distances due to reporting biases and omissions.

5.2.8 In addition to a distance-distribution, weightings were also required to reflect levels of rail travel to/from each model zone. These were derived from the CBLTM base year trip-end model.

5.2.9 The zone weights and distance-distributions were used to create a function to allocate demand by access/egress zone, of the form:

$$D_{ijab} = D_{ab} k_{ab} P_i A_j d_{ia}^{(\lambda_{l1}-1)} e^{\mu_{l1} d_{ia}} d_{bj}^{(\lambda_{l2}-1)} e^{\mu_{l2} d_{bj}}$$

where:

- i is the production zone;
- j is the attraction zone;
- a is the production station zone (from LENNON data);
- b is the attraction station zone (from LENNON data);
- D_{ab} is the demand (from LENNON data);
- P_i and A_j are the production and attraction factors, from the trip-end model;
- d_{ia} and d_{bj} are the (crow-fly) distances from origin zone i to origin station a, and from destination station b to destination zone j;
- λ_{l1} and μ_{l1} are calibrated parameters for access, by trip length band l (from a to b);
- λ_{l2} and μ_{l2} are calibrated parameters for egress, by trip length band l (from a to b); and
- k_{ab} is a factor to control total demand from a to b to the total in the LENNON matrix.

5.2.10 The λ and μ parameters were calibrated using Excel's "Solver" function to maximise the fit of the output data to the distance distributions observed in the NRTS data.

5.2.11 Demand was then aggregated over ultimate production and attraction zones i and j. The final demand matrices were not stored by station production and attraction, so that:

$$D_{ij} = \sum_{ab} D_{ijab}$$

5.2.12 Station origin and destination zones (i and j) were considered for a given set of modelled zones (a and b) only if they fell into a defined "catchment area" for each station. In the case of zones within Central Bedfordshire and Luton and in the immediate vicinity of these zones (Milton Keynes and Bedford), the catchment area was a larger area around the station. In total, catchment areas were defined for 24 national rail stations in and around Central Bedfordshire and Luton.

5.2.13 The LENNON data do not contain any indication of travel purpose or of time of day. It is possible that time of day information can in principle be obtained, but in any case, this would be based on the purchase time of the ticket, which in the case of return and season tickets would not identify the time of travel.

5.2.14 These characteristics have therefore been inferred using the trip-end model. The NTS data do not contain enough geographic detail to enable reliable purpose/period splits to be obtained across the districts. However, overall purpose splits have been compared with the NTS proportions to validate the approach adopted.

5.3 Bus Observed Demand

5.3.1 The initial task in processing Electronic Ticket Machine (ETM) data was the allocation of the stages provided by operators (usually related to fares) to model zones. Stage information is generally in the form of a numeric ID, and a corresponding text description, for example, "*4 – Luton Airport*". Where provided, the alighting stage has also been used to ensure that all possible stages have been allocated.

5.3.2 This allocation was carried out by service, using GIS software. Bus service route maps and timetables were used to map service routes into GIS, along with a base street map and the model zone system. Boarding stage numbers and descriptions were used to identify the order and general location of each stage on the route.

5.3.3 The zone system was used to allocate zones to stages. These were chosen on the assumption that travellers will generally not walk much more than 250m to a bus stop, that they will choose the closest bus stop on the service in question and will choose the most convenient bus corridor where there is a choice. More zones were required for urban centres where zones are smaller. The number of trips associated with each stage has been used to inform the selection of multiple zones in more populous areas, such as residential or shopping zones.

5.3.4 Although most of the ETM data contain alighting stage information, these data are accurate only for certain kinds of ticket; generally singles and returns. For concessionary fares, multi-day tickets, season tickets and other passes, the alighting stage were generally either missing or coded arbitrarily (either to the same point as the boarding or to the last calling point of the service). From analysis of the ETM data, around 25% of records have associated alighting information which can be used directly.

5.3.5 As a result, it was necessary to estimate alighting points where these data were not available. Analysis has also been undertaken to identify records with "unobserved" alighting points. The assumption has been made that for all trips whose boarding and alighting points are the same, the alighting stage is "unobserved". This will not be true for all trips, but there should be relatively few trips short enough to remain within a single stage for their entire journey.

5.3.6 In order to estimate alighting points, those ETM records with "observed" alighting points were used as a basis for distribution of trips within the same service, for the same boarding point and time of day. This has been carried out at a stage level for all operators.

5.3.7 The ETM alighting points are likely to be biased towards journey patterns for less frequent travel (which are more likely to use singles and returns). It is considered that this is not a major inaccuracy.

5.3.8 A number of spot checks by service were carried out to check the plausibility of demand matrices after alighting points had been estimated. The matrices by stop-to-stop movement were extracted for around 10 services selected at random. Checks were made to inspect the patterns of travel to ensure broad tidality and symmetry across the day, and that the key boarding points appeared plausible.

5.3.9 Zone-based matrices were created by distributing each ETM record among the zones allocated to the boarding and alighting stages, using the base year trip-end model estimates as weights. Given the relatively short distances involved, it was not deemed necessary to construct a full gravity model to take account of the relative distances to the bus stops from model zones.

5.3.10 Records not referring to passenger boardings were ignored as part of this process. These include bus start times, fare stage changes, incidents and refunds. Not all operators use each or any of these. Records referring to a cancellation of a ticket issued in error were considered as negative trips, as these should cancel out an earlier (mis-sold) ticket within the data set.

5.3.11 Data were aggregated by origin to destination movement following this process. Checks were undertaken on the output demand matrices by studying demand desired lines derived from the matrices. This provided confidence that the demand matrices reflected a pattern of travel that would be expected when considering the service routes.

5.3.12 The above process used an implicit assumption that a bus boarding and a bus/public transport trip are identical concepts. This suggests that the multi-leg trips, either using more than one bus service or using both bus, coach and rail, are not explicitly considered. A small proportion of multi-leg trips will have been correctly captured, because some of the ticket data includes through tickets that involve interchanging onto another bus, but this occurs only where the journey can be made using a single ticket and the same operator runs either services, or when passengers are using the shuttle bus from Luton Airport Parkway.

5.3.13 NTS data suggest that approximately 9% of bus trips in the East of England involve more than one bus boarding. This is sufficiently low that it is not expected that any significant forecasting or demand interaction issues will arise through treating each bus journey as a separate trip, as the above matrix development process has done.

5.4 Bus Synthetic Demand

5.4.1 With the ETM data being provided for approximately 73% of services within Central Bedfordshire and Luton, albeit for most of the services in the key areas of the model, it was necessary to develop synthetic demand matrices to account for trips on the remaining bus services.

5.4.2 Using the ticket data for Arriva and Centrebus detailed in Table 3.1, an estimate of annual passengers for these two operators of approximately 12.6 million has been derived. Whilst not directly comparable, the Department for Transport publishes annual bus patronage statistics by district, with the total for Luton and Central Bedfordshire being 13.8 million in the period April 2016 to March 2017[4]. This suggests that whilst around 73% of services have been captured within the ETM data, around 91% of trips have been observed.

[4] https://www.gov.uk/government/statistics/annual-bus-statistics-year-ending-march-2017

5.4.3 A significant proportion of the unobserved bus services operate between Milton Keynes and Bedford. These services are located at the northern edge of the study area, and are not considered to have a significant impact on the assessment of the proposed expansion of Luton Airport.

5.4.4 All Central Bedfordshire and Luton bus services were identified from the Traveline National Data Set (TNDS). These were compared against the services for which ETM data had been provided to establish for which services data were missing. Demand for these services has been synthesised based on those services with observed ETM data and the relationship between observed trips and service frequency has been used to control the total number of trips in the synthetic matrix.

5.4.5 The daily frequencies of all services and the length of bus routes were extracted from the TNDS for those services with ETM data, and the number of passenger trips on an average modelled weekday was fitted as a function of the frequency and length of the route. Figure 5.2 shows the fitted estimates of total trips against the actual ETM data trips for those services for which ETM data are available.

5.4.6 The function used is shown below:

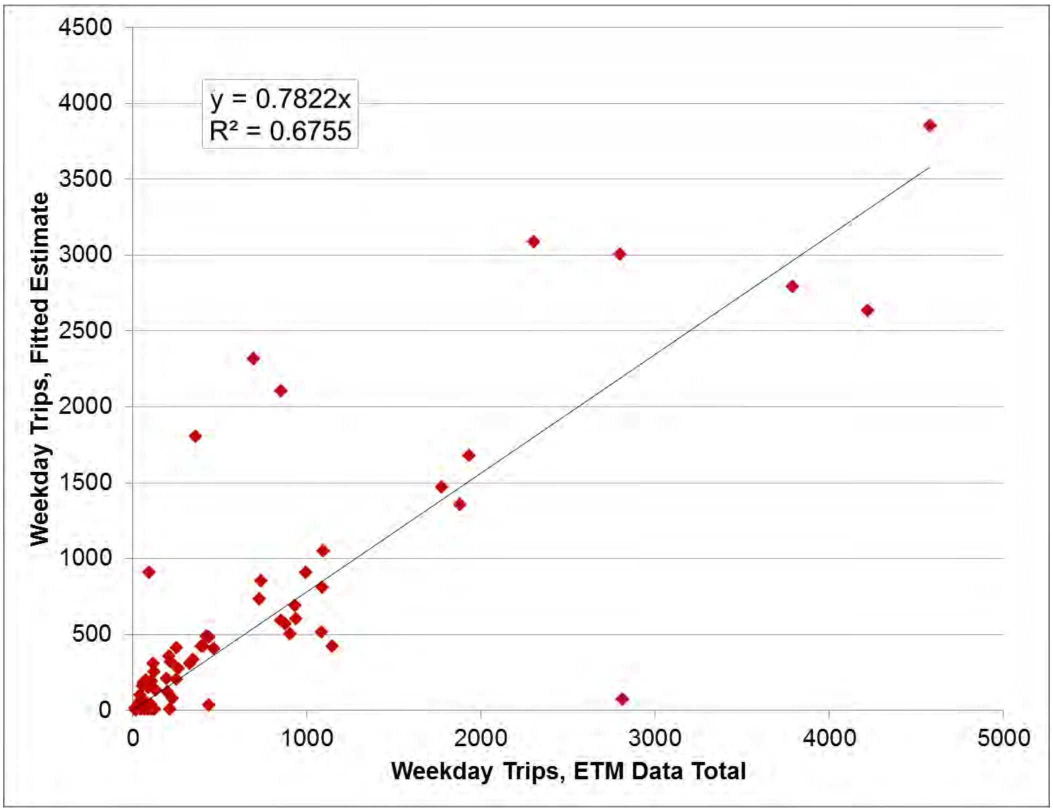
$$T = 1.429 * F^{1.252} * L^{0.555}$$

where:

- T is the number of trips on the service in an average weekday;
- F is the total of bus journeys made per day by the service; and
- L is the route length of the service in kilometres.

5.4.7 The total population of zones within the bus route catchment area was also considered for informing the estimated function, but this was not used, as the comparison showed a weaker correlation.

Figure 5.2 Synthetic Bus, Fit of Estimated Function



5.4.8 In addition to the parameters derived from the length versus trip relationship, it was necessary to calculate a trip-length distribution for services with ETM data. The trip-length distribution was calculated at 1km bands up to 50 km using the observed data from both operators across all time periods.

5.4.9 The expression for the fitted curve of the trip-length distribution was used as the basis of the alpha (α) and beta (β) parameters of the following equation, which was used to influence the distribution of trips within the synthetic matrix.

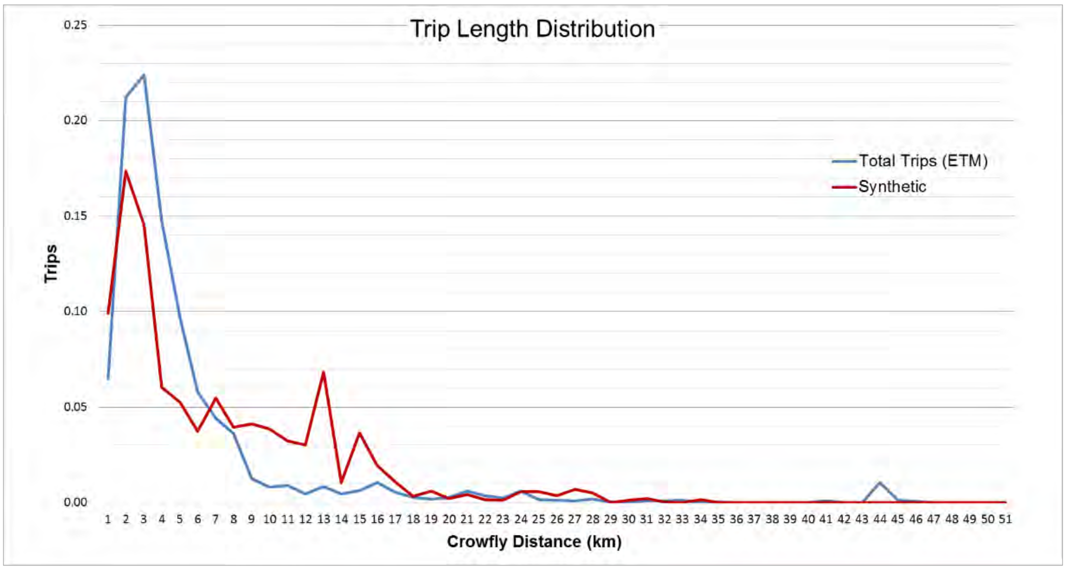
$$ABe^{-\alpha D}D^{\beta}$$

where:

- A and B are land-use weights of model zones, taken from the base year trip-end model (estimates of zonal origin and destination trips); and
- D is the crow-fly distance in kilometres between zones.

5.4.10 After a number of iterations, the trip-length distribution (α and β parameters) of the synthetic matrices was calibrated to correspond with that of the observed ETM demand matrices, as shown in Figure 5.3.

Figure 5.3 Synthetic Trip-Length Distribution



5.4.11 Synthetic trips have a lower proportion of short distance trips and there is also a peak between 12 and 15 km, which do not match the ETM data. A large proportion of bus services with synthetic demand run between Milton Keynes and Bedford (both located between 10 and 15 km from the edges of the model area), and this can explain this discrepancy.

5.4.12 The final synthetic matrices were then combined with the observed demand matrices to create total OD demand matrices for each time period.

5.5 Bus Demand Disaggregation

5.5.1 Following the above process, trip-based zonal matrices were split by travel purpose and direction in addition to time period. The direction of travel refers to whether the trip is from-home, to-home, or non-home based.

5.5.2 This was achieved by taking land-use weights according to these directions/purposes for each zone from the base year trip-end model. Proportions for each were then applied over the total demand matrices. The proportions used for purpose splits are presented in Table 5.3 along with the outturn purpose splits in the model bus demand matrices.

Table 5.3: Purpose Proportions, Bus Demand, Central Bedfordshire and Luton

Purpose	Trip-end Model	Bus Matrices
HB Commuting	17%	17%
HB Employers' Business	1%	1%
HB Other	75%	78%
NHB Employers' Business	0%	0%
NHB Other	7%	4%

5.5.3 Household car ownership splits have also been applied across the demand matrices once split by purpose. These used data from the NTS. The car ownership split has been applied across purpose and direction. Table 5.4 details the proportion of bus trips undertaken by residents of car owning households by trip purpose.

Table 5.4: Car Ownership Proportions, Bus Demand, Central Bedfordshire and Luton

Purpose	Proportion of Bus Travellers from Car Owning Households
HB Commuting	68%
HB Employers' Business	73%
HB Other	59%
NHB Employers' Business	84%
NHB Other	62%

5.6 CBLTM-LTN Matrix Updates

5.6.1 The public transport model within the CBLTM-LTN uses the rail and bus demand matrices developed for the previous CBLTM using the methodology described above. Using these matrices, two updates have been applied: zone disaggregation; and replacement of Luton Airport demand.

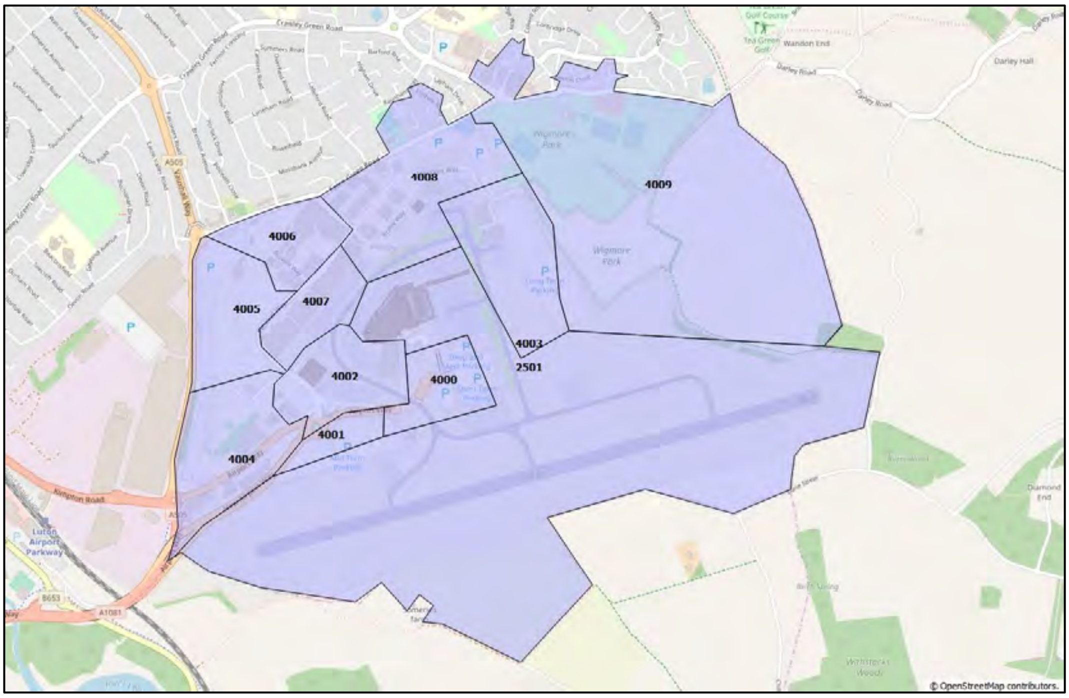
5.6.2 As detailed within Section 1.1, additional zone detail has been included in the CBLTM-LTN, largely within Luton and areas of Hertfordshire to the south and east of Luton Airport. To convert the existing base year rail and bus/coach matrices to this revised zone system, trip-ends from the updated base year trip-end model were used to disaggregate trip productions and attractions.

5.6.3 In terms of Luton Airport public transport demand, base year demand estimates have been provided for both bus and rail, for airport passengers and employees, and for all modelled time periods. This data cover trips to / from the zones highlighted in Figure 5.3.

5.6.4 This demand data for trips to / from the zones highlighted in Figure 5.4 have replaced those derived from the processes implemented in the previous CBLTM public transport model, and described in Section 5.2 to 5.5.

5.6.5 As discussed, these trips to / from Luton Airport are provided by public transport mode (i.e. bus / coach and rail), and are therefore not subject to the sub-mode choice component of the public transport model.

Figure 5.4 Luton Airport Model Zones



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5.6.6 Following the disaggregation of the bus and rail assignment demand to the CBLTM-LTN zone system and the updating of trips to / from Luton Airport, Table 5.5 and Table 5.6 summarise the assignment trip matrix totals by assignment hour and mode for trips originating within Luton and Central Bedfordshire, and those with a destination in these two districts.

Table 5.5: Base Year Assignment Matrix Origin Totals, Passengers

Hour	Trips from…	Mode	Non-Airport	Airport Passengers	Airport Employees	Total
AM	Luton Borough	Bus	2,584	202	69	**2,856**
		Rail	1,252	199	36	**1,487**
	Central Bedfordshire	Bus	1,170	2	4	**1,175**
		Rail	1,445	3	4	**1,452**
IP	Luton Borough	Bus	2,836	189	62	**3,087**
		Rail	358	186	39	**582**
	Central Bedfordshire	Bus	1,174	2	2	**1,178**
		Rail	342	3	2	**348**
PM	Luton Borough	Bus	2,236	214	78	**2,528**
		Rail	467	210	54	**732**
	Central Bedfordshire	Bus	896	2	1	**899**
		Rail	289	4	1	**295**

Table 5.6: Base Year Assignment Matrix Destination Totals, Passengers

Hour	Trips to…	Mode	Non-Airport	Airport Passengers	Airport Employees	Total
AM	Luton Borough	Bus	2,595	205	77	**2,878**
		Rail	529	202	54	**785**
	Central Bedfordshire	Bus	1,005	2	1	**1,008**
		Rail	327	3	1	**331**
IP	Luton Borough	Bus	2,855	219	61	**3,135**
		Rail	330	216	36	**583**
	Central Bedfordshire	Bus	1,167	2	2	**1,171**
		Rail	273	3	3	**279**
PM	Luton Borough	Bus	2,381	290	69	**2,740**
		Rail	1,034	286	35	**1,356**
	Central Bedfordshire	Bus	1,078	2	4	**1,084**
		Rail	1,341	3	5	**1,348**

6 PUBLIC TRANSPORT MATRIX VALIDATION

6.1 Introduction

6.1.1 This section details the validation of the base year rail and bus/coach demand matrices against available independent sources of data, and the results of this comparison.

6.1.2 Due to the nature of the updates to the public transport demand matrices applied within the CBLTM-LTN (zone disaggregation and replacement of Luton Airport trips), these would not significantly alter the analysis presented in this section. Therefore the analysis presented within this section is largely based on the matrix validation undertaken for the previous CBLTM public transport model.

6.2 Purpose Splits

6.2.1 For bus, a series of checks were undertaken to ensure that purposes derived from the base year trip-end model were in-line with local and regional statistics from other sources. This involved extracting bus trip purpose data from the NTS and NTEM and comparing proportions with that of the model, and is shown in Table 6.1.

Table 6.1: Validation of Purpose Splits, Bus

Purpose	CBLTM	NTS (East of England)	NTEM (C. Beds and Luton)
HB Commuting	17%	21%	23%
HB Employers' Business	1%	1%	1%
HB Other	78%	70%	65%
NHB Employers' Business	0%	0%	1%
NHB Other	4%	8%	10%

6.2.2 The bus purpose split within the model agrees fairly well with the NTS data, and almost as well with NTEM (which is a model itself, and thus a less direct source than the NTS). However, we have notably less commuting bus demand in the modelled bus matrices. This may partly be genuine as commuting demand in Central Bedfordshire and Luton is quite heavily dominated by rail when compared with the wider East of England region.

6.2.3 NTS data are generally a very reliable source; however, their only significant weakness here is that the data relate to the whole East of England (Hertfordshire, Bedfordshire, Cambridgeshire, Norfolk, Suffolk, and Essex), rather than just Central Bedfordshire and Luton.

6.2.4 For rail demand, the CBLTM agrees fairly well with NTS for the East of England, and slightly less well with both of the trip-end models (CBLTM and NTEM), as shown in Table 6.2.

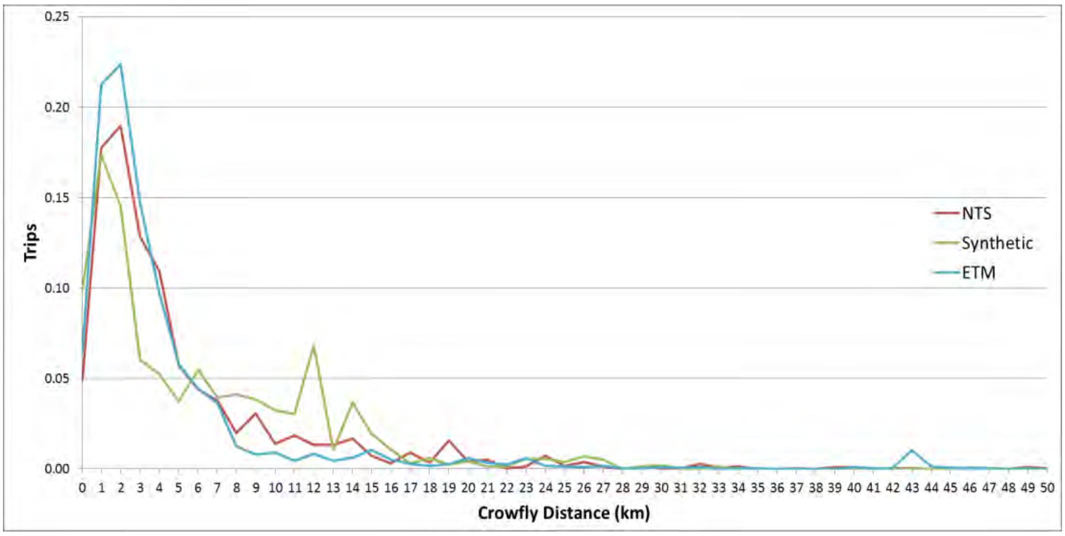
Table 6.2: Validation of Purpose Splits, Rail

Segment	CBLTM (C. Beds and Luton)	CBLTM (GB)	NTS (East England)	CBLTM Trip-End Model (C. Beds and Luton)	NTEM (C. Beds and Luton)
HB Work	57%	66%	57%	49%	39%
HB Business	10%	7%	7%	2%	7%
HB Other	28%	20%	28%	41%	27%
NHB Business	1%	2%	2%	1%	3%
NHB Other	5%	6%	6%	6%	24%

6.3 Trip-Length Distributions

6.3.1 Trip-length distributions were derived for bus/coach trips from both the household surveys and compared against the trip-length distribution of the CBLTM demand matrices, shown in Figure 6.1. This was carried out in order to verify the quality of the total demand matrix.

Figure 6.1 Bus Trip-Length Distributions, Validation



6.3.2 The overall shape of the trip-length distribution from the model fits well with that of the NTS, with the exception of some peaks at longer distances and a higher proportion of short distance trips. This could partly be explained by the fact that trip chaining has not been considered when developing the demand matrices, so a small number of journeys which change mode or route have not been picked up as a single trip. This should not have an impact on overall demand.

6.3.3 The difference between the actual observed demand and the synthetic demand can be explained by the fact that a significant proportion of the services from the operators which did not provide any data require a longer in-vehicle distance (travelling to / from places such as Bedford or Milton Keynes, on the outskirts of the model area).

6.3.4 The modelled 'in-vehicle' average trip-length was also calculated after demand had been assigned to the network and was found to be 5.3 km. This is broadly in-line with trip-lengths expected according to NTS data.

6.3.5 The modelled trip-length distribution for rail is heavily dominated by the distance between Luton and London (which represents the substantial majority of rail demand in the area). It is therefore difficult to compare this meaningfully with any other source.

6.4 Rail Demand Data Processing

6.4.1 The rail demand matrices were developed from LENNON ticket sales data through AECOM's own established process and assumptions. It is desirable to check this by comparing the results with the official ORR station usage statistics, also derived largely from LENNON data.

6.4.2 Unfortunately, the ORR data provide only annual station usage. Factors were derived from the National Travel Survey to estimate average weekday patronage from the annual data, and the conversion factor applied to all stations. This introduces some uncertainty, as some stations may have slightly different weekly and annual profiles from others.

6.4.3 The largest stations in Central Bedfordshire and Luton, and in the immediate vicinity of the model area, have services running 7 days a week, but there are also a considerable number of stations which have no Sunday (or even Saturday) services. Therefore, the variability at these smaller stations will be more than at the larger stations within the model.

6.4.4 Table 6.3 compares the estimated daily station usage from the ORR data with the processed LENNON data. The CBLTM data are derived from the assignment matrix, using the zone(s) associated with each rail station, and is not a result of an assignment.

6.4.5 As shown in Table 6.3, the processed LENNON data compare well with the estimated daily passenger usage, particularly at the larger stations within the model. The largest percentage differences generally occur at smaller stations, such as Aspley Guise and Lidlington where passenger numbers are low. Overall, the modelled trips for these stations are within 0.5% of the ORR data.

Table 6.3: Validation of Rail Demand Data Processing

Station	ORR Daily Entry	CBLTM-LTN Matrix	Difference
Luton	5,519	5,047	-9%
Luton Airport Parkway	4,285	5,091	19%
Leighton Buzzard	2,687	2,739	2
Leagrave	2,947	2,594	-12%
Flitwick	2,257	1,939	-14%
Biggleswade	1,467	1,401	-5%
Arlesey	976	934	-4%
Sandy	780	821	5%
Harlington	506	443	-12%
Ridgmont	55	52	-5%
Lidlington	45	31	-31%
Millbrook (Bedfordshire)	25	17	-33%
Aspley Guise	16	9	-42%
Milton Keynes Central	10,343	10,159	-2%
Bedford Midland	5,776	5,913	2%
Bletchley	1,538	1,516	-1%
Wolverton	639	626	-2%
St. Albans City	11,626	11,877	2%
Harpenden	5,158	5,186	1%
Total	**56,645**	**56,395**	**-0.4%**

6.4.6 All stations compare well in order-of-magnitude terms, and only three stations fail the WebTAG-suggested criterion of ±25% (as detailed in Section 2.8). These are all very small stations, namely Lidlington, Millbrook and Aspley Guise.

6.4.7 In addition, it should be noted that there are a number of assumptions inherent to the comparison of ticket data with the CBLTM-LTN matrix which may contribute to higher differences, including:

- the ticket-to-journey ratio;
- the conversion between annual and weekday factors, which could be expected to vary significantly for the airport; and
- background assumptions within the ORR data.

6.4.8 It is perhaps worth acknowledging here that the use of LENNON data as a source of demand implies that ticketless (i.e. illegal) passengers on rail will not be included in the matrices. The ORR data also explicitly exclude ticketless travel for the same reason. This is not likely to be a significant issue at major Central Bedfordshire and Luton stations as ticket gates are in operation during the day. However, most the smaller stations do not have ticket gates. It is quite likely that total passengers are understated by the ORR data and by the model at these stations.

6.5 Trip Rates

6.5.1 Although bus data processing has not been validated in the same way as the rail, the matrix totals have been compared with plausible trip rates and knowledge of the population of Central Bedfordshire and Luton. Trip rates have been taken from the National Travel Survey and applied to the population of Central Bedfordshire and Luton, and compared with the base model results. NTS data and the model have also been compared against two other sources:

- Office of National Statistics (ONS) data for bus trip rates (see Table 6.4); and
- the Office of Road and Rail (ORR) for rail trip rates (see Table 6.5).

6.5.2 Note that although NTS (and the trip-end model, which indirectly uses NTS data) was used for a number of purposes in building both the bus and rail matrices, it was only used to disaggregate demand, and not to inform an overall matrix total. This is consequently an independent validation of the matrices.

Table 6.4: Bus Trip Rates Validation, Trips per person, on an average weekday

Source	Central Bedfordshire	Luton	Central Bedfordshire and Luton
CBLTM	0.052	0.157	0.101
ONS	0.038	0.112	0.073
NTS (East England)	-	-	0.100

Table 6.5: Rail Trip Rates Validation, Trips per person, on an average weekday

Source	Central Bedfordshire	Luton	Central Bedfordshire and Luton
CBLTM	0.032	0.053	0.042
ORR	0.031	0.052	0.041
NTS (East England)	-	-	0.042

6.5.3 For bus, the comparison is very good with the NTS data (although the NTS refers to the whole East of England), but is not as good when compared against the data from Office of National Statistics[5] (ONS).

6.5.4 The ONS data include all the passenger journeys on local bus services by local authority from 2009/10. The discrepancy between both sets of data (around 20%) may partly be caused by the model including some regular school bus services, which increases the number of total trips in Central Bedfordshire and Luton.

6.5.5 For rail, there is a close match against both independent data sources, ORR and NTS data. The Office of Rail and Road (ORR) trip rates are slightly lower than the model and the NTS data for the East of England, but not significantly.

[5] A link to the tables used to obtain this set of data can be found through the following link: https://www.gov.uk/government/statistics/annual-bus-statistics-year-ending-march-2016

7 PUBLIC TRANSPORT NETWORK DEVELOPMENT

7.1 Introduction

7.1.1 As with the development of the rail and bus demand matrices, the process of creating the base year public transport networks and service coding has not been repeated as part of the update for CBLTM-LTN.

7.1.2 This section details the development of the public transport for the existing CBLTM, and as part of the development of the CBLTM-LTN a review of the service coding for trips to / from Luton Airport has been undertaken.

7.2 Base Bus and Rail Network

7.2.1 The network used by the CBLTM-LTN public transport model consists of roads, railway lines and pedestrian access routes, as well as "centroid connectors" used to allocate model zones to suitable loading points on the road network.

7.2.2 The road network in the public transport model has been taken directly from highway model, converted from SATURN to Emme format using an established automated process. Additional network detail has been added around Luton Airport as part of the CBLTM-LTN update to reflect the greater level of zone detail in this area of the model.

7.2.3 To this has been added railway track, which has been coded manually with reference to GIS maps of UK railway lines. All lines within Central Bedfordshire and Luton have been coded in detail. With increasing distance outside the model area, fewer lines have been coded. In general the major station in each zone is represented, and sufficient railway track to correctly link up all coded stations has been added.

7.2.4 For example, branch lines outside Central Bedfordshire and Luton are generally not coded, railway lines in Scotland north of Edinburgh are not coded, nor the Underground in central London.

7.2.5 Walk links connecting railway stations to the road network have been added to this, and centroid connectors have been manually coded, one per zone, connecting each model zone to a suitable point on the road network representing the likely access point for demand to / from the zone.

7.2.6 Therefore, for bus passengers, trips walk along the highway network from their origin zone to reach their desired bus stop to join a service. Bus stops are mapped to the nearest node in the highway network (which are generally located at junctions), and therefore there is some approximation in the location of bus stops within the model. Checks undertaken on the routeing within the base year assignment have shown that this approximation of bus stop locations does not significant affect the assignment results.

7.2.7 Figure 7.1 and Figure 7.2 illustrate the extent of the rail and road networks in and around Central Bedfordshire and Luton. Internal links within the public transport highway network are in shown in blue with Figure 7.2, with external links shown in red.

7.2.8 The rail network is “shaped” within the model area such that each modelled link connecting two junctions or nodes follows the actual route of the railway line. This can be seen is Figure 7.1. This shaping has no effect on the model results, but is useful for analysis, plotting and reporting.

Figure 7.1 Rail Network in and around Central Bedfordshire and Luton

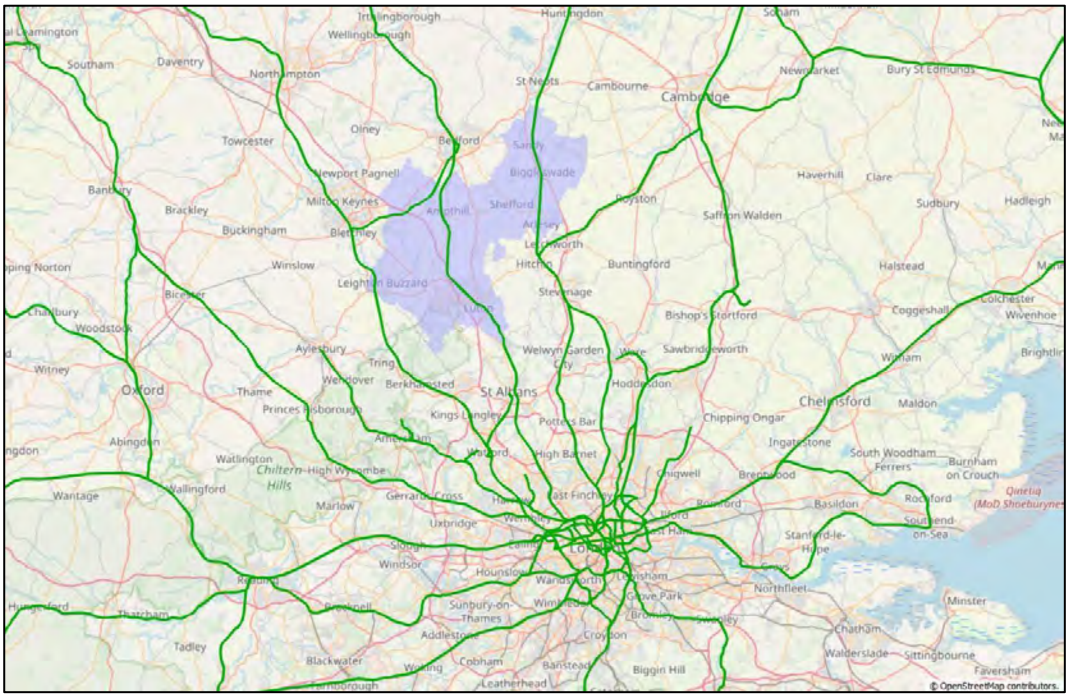


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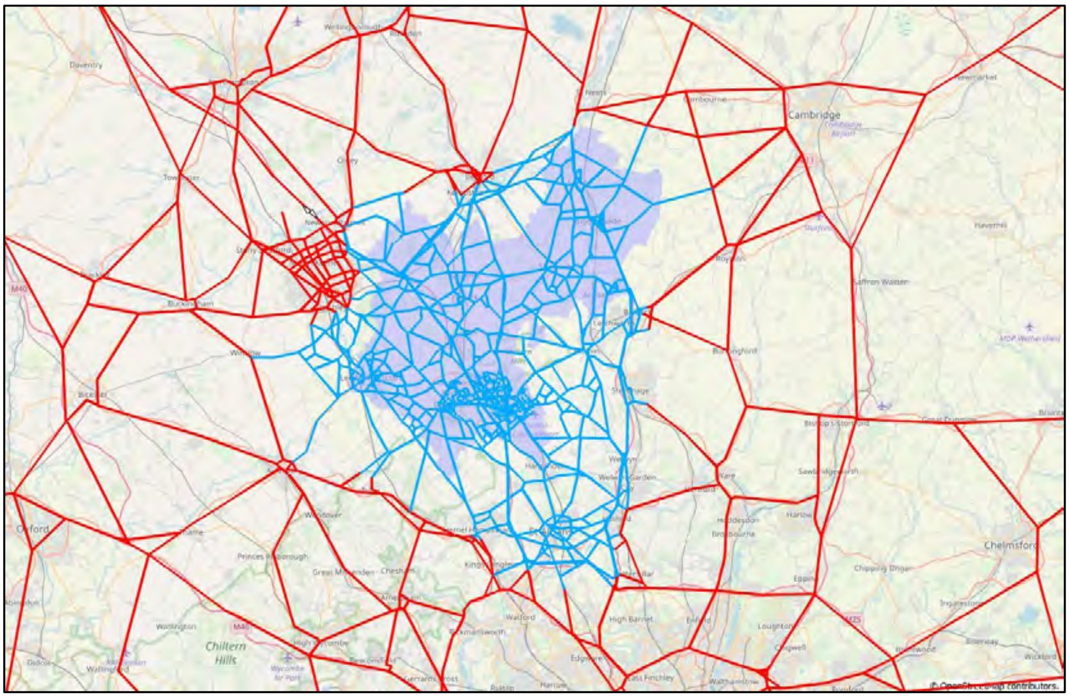
Figure 7.2 Road Network in and around Central Bedfordshire and Luton



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7.3 Bus and Coach Routes

7.3.1 The base network is only part of the specification of the public transport system. In addition to this, public transport passenger services need to be coded to allow the model to represent the routeing behaviour of passengers.

7.3.2 Bus, shuttle bus, coach, and rail services have been coded from different sources. Most of the input data are in TransXChange format, an xml-based format for sharing public transport service pattern information. These include service timetables in full detail, with all stops and stopping times throughout the year, including differences between weekdays, Saturdays, Sundays and bank holidays.

7.3.3 Bus data have been taken from the Traveline National Data Set (TNDS). This is updated weekly with information on all bus, tram, light rail and ferry services in Britain. It does not cover rail, coach or underground.

7.3.4 Coach service data have been developed using the National Coach Service Database (NCSD) available from the Department of Transport (DfT). NCSD contains information for all time periods, including:

- coach operators;

- coach services;
- coach journey data; and
- coach stop data.

7.3.5 It should be noted that the NCSD is not a nationally complete data set of the coach network but rather a collection of scheduled data for several mainland UK coach services, last updated in 2014. However, coach services to / from Luton Airport have been manually reviewed against online timetable information to ensure that the model replicates coach services in the base year. The following is a summary of the coded bus and coach services which include a stop at Luton Airport across the three modelled time periods:

- Luton Airport – Luton Airport Parkway Shuttle Bus
- Arriva Route 100 (Luton – Stevenage)
- Arriva Route A, Guided Busway (Luton Airport – Dunstable)
- National Express Route 230 (Gatwick – Derby)
- National Express Route 240 (Heathrow – Bradford)
- National Express Route 707 (Gatwick – Northampton)
- National Express Route 737 (Stansted – Oxford)
- National Express Route 777 (Stansted – Birmingham)
- National Express Route 787 (Heathrow – Cambridge)
- National Express / easyBus Route A1 (Luton Airport – Victoria)
- National Express Route A2 (Luton Airport – Paddington)
- Metroline Route 714 (New Barnet – Luton)
- Green Line Route 757 (Luton Airport – Victoria)
- Stagecoach Route 99 (Luton Airport – Milton Keynes)

7.3.6 A review of these converted bus service data has been undertaken as part of the development of the CBLTM-LTN public transport model. This includes adding additional detail to routes travelling to, from or through the Luton Airport area, where additional network detail has been added as part of the model update.

7.3.7 An example of the bus service coding in and around Luton is illustrated in Figure 7.3, and coach service coding shown in

Figure 7.4. Red circles within these figures indicate stops, while red arrows are service start and end points. Each service is illustrated by a single black line, following its route.

Figure 7.3 Bus Services within Luton in the AM Period

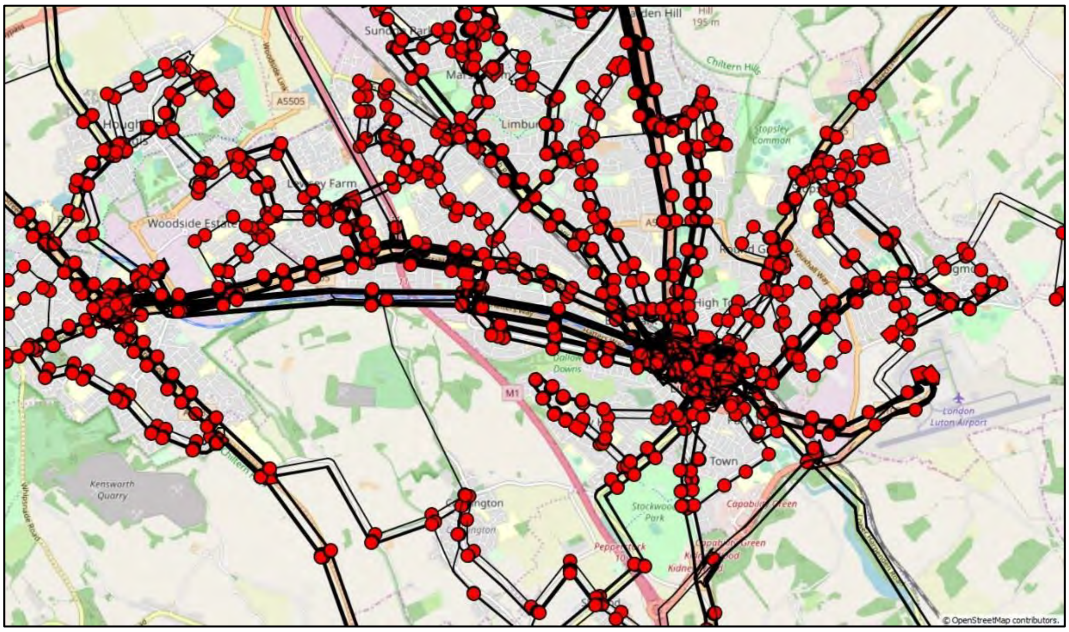

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Figure 7.4 Coach Services to / from Luton Airport in the AM Period

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7.4 Rail Services

7.4.1 Rail services within Central Bedfordshire and Luton have been coded manually with reference to online timetables.

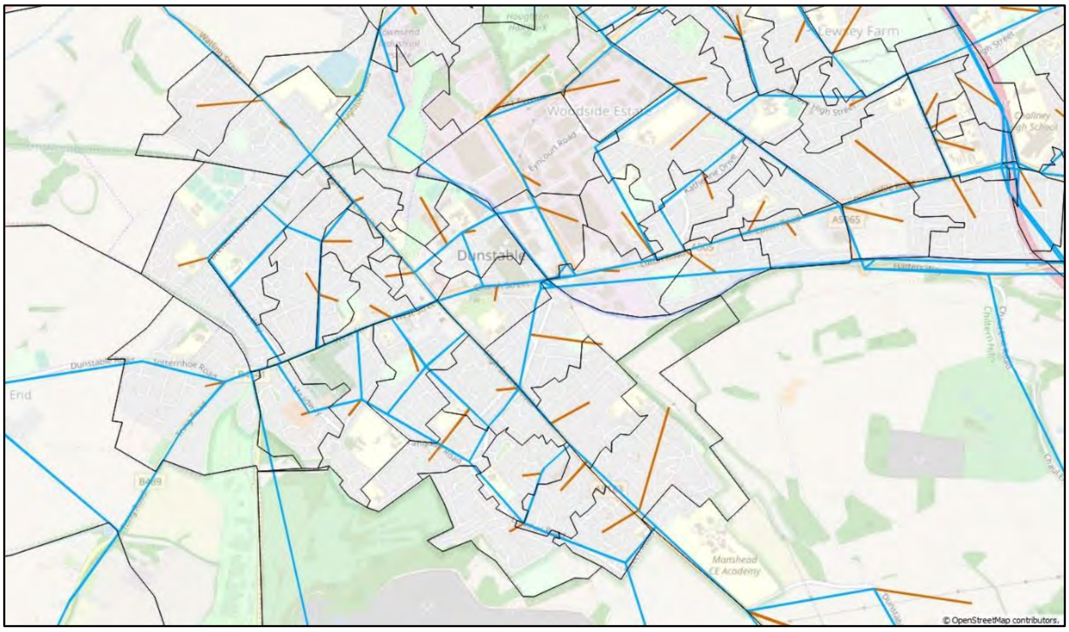
7.4.2 Rail services outside Central Bedfordshire and Luton were not coded in full detail as this would have generated excessively detailed services. Instead, line frequencies were manually coded in a simpler way to ensure broadly correct routes and frequencies, without including detailed representation of stopping patterns.

7.5 Centroid Connectors

7.5.1 Centroid connectors have been manually coded, one per zone, connecting each model zone to a suitable node on the road network representing the land-use access within the zone. An example of these is illustrated in Figure 7.5 (where centroid connectors are in brown and zones are outlined in black).

7.5.2 Where zone disaggregation has been implemented within CBLTM-LTN, the centroid connector coding has been reviewed and updated to represent the revised zone system.

Figure 7.5 Network with Centroid Connectors within Dunstable



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7.6 Fares

7.6.1 Public transport fare systems, especially on the national rail network, are complex, with fares varying by time of day, movement, person characteristics, degree of ticket flexibility required, and more. It is neither possible nor desirable to model all of these details, and so the fares used in the public transport model are approximations.

7.6.2 The approach adopted is to model fare functions whereby the fare paid is a function of distance, with longer trips paying more. The intent has been to model an average fare actually paid, including the effect of discounts and concessions.

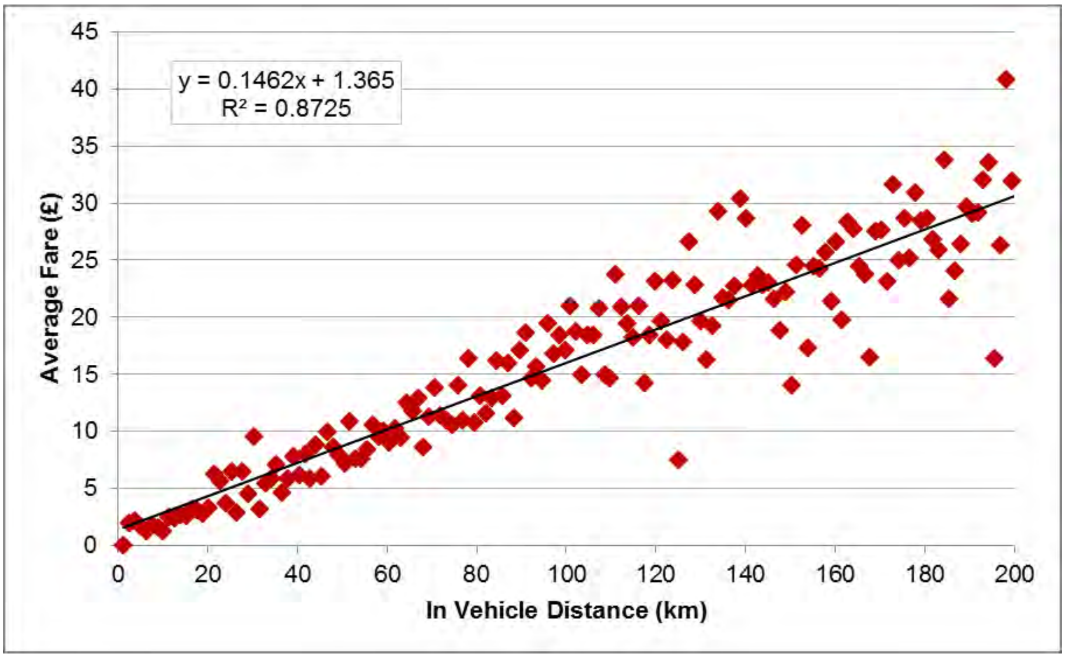
7.6.3 The preferred source for deriving such functions is complete ticket sales data with associated fares paid. For rail travel this approach has been adopted as the LENNON data contains revenue data.

7.6.4 For bus and coach, fare data were received from the operators and used in a similar way. We have not plotted the raw bus or coach fares data to protect the operators' commercial confidentiality, but the fitted function is quoted in Section 2.6.

7.6.5 The rail data used and the function fitted to the data are illustrated in Figure 7.6. Rail trips originating in Central Bedfordshire and Luton have been extracted from the LENNON data, and actual in-vehicle distances calculated using the model have been compared with the fare recorded in the LENNON data. These are plotted in Figure 7.6, along with the function (black line) fitted to the data and used in the model. This analysis ensures that the rail fares are appropriate for Central Bedfordshire and Luton specifically.

7.6.6 Fares have been converted to 2010 prices for consistency with WebTAG and other aspects of the model suite.

Figure 7.6 Rail Fare Data and Fitted Function, 2010 prices



8 PUBLIC TRANSPORT NETWORK VALIDATION

8.1 Service Pattern Validation

8.1.1 The automated process for converting TransXChange data to model format, discussed in Section 7 has been used in a number of other developed models by AECOM and is considered robust. However, it does have some weaknesses. One issue relates to allocating bus stops correctly to model network nodes; the process is over 99% accurate here, but a small proportion of bus stops had to be manually corrected. In addition, neither the TNDS data nor NCSD data are themselves perfectly accurate, though it is in general very good.

8.1.2 Consequently, the service coding was thoroughly checked as part of the development of the existing CBLTM public transport model, with additional detailed checks undertaken as part of this update in and around Luton Airport. This involved checking the following for all services:

- There were no strategically odd routes; in particular services travelling long loops around motorways or major roads. This generally indicates a severe misallocation of a bus stop to the model network.
- There were no highly implausible speeds (either too low or too high) on any service. All bus service speeds average between 10 kph and 55 kph (note that this includes time for stopping and picking up/setting down passengers), and all rail service speeds between 35 kph and 165 kph.
- There were no implausible service frequencies. All services operate between once per day and once every 5 minutes.

8.1.3 All extreme values on these measures have been independently checked to ensure the high / low speeds or high / low frequencies were correct.

8.1.4 In addition, a random sample of services has been checked in detail within the development of the existing CBLTM for the full route, stopping pattern and travel times against published online timetables. The total travel time and frequency results of this check are presented in Figure 8.1 and Figure 8.2. Both comparisons show a good correlation between the modelled and online timetable data.

Figure 8.1 Bus Service Validation, Travel Times

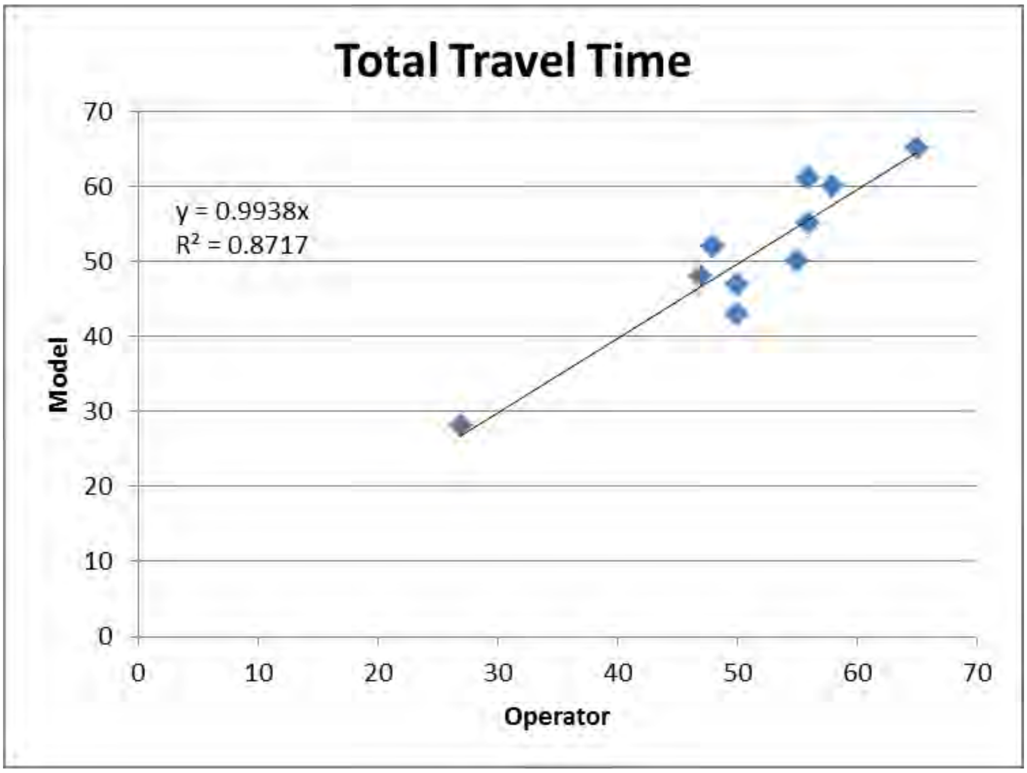
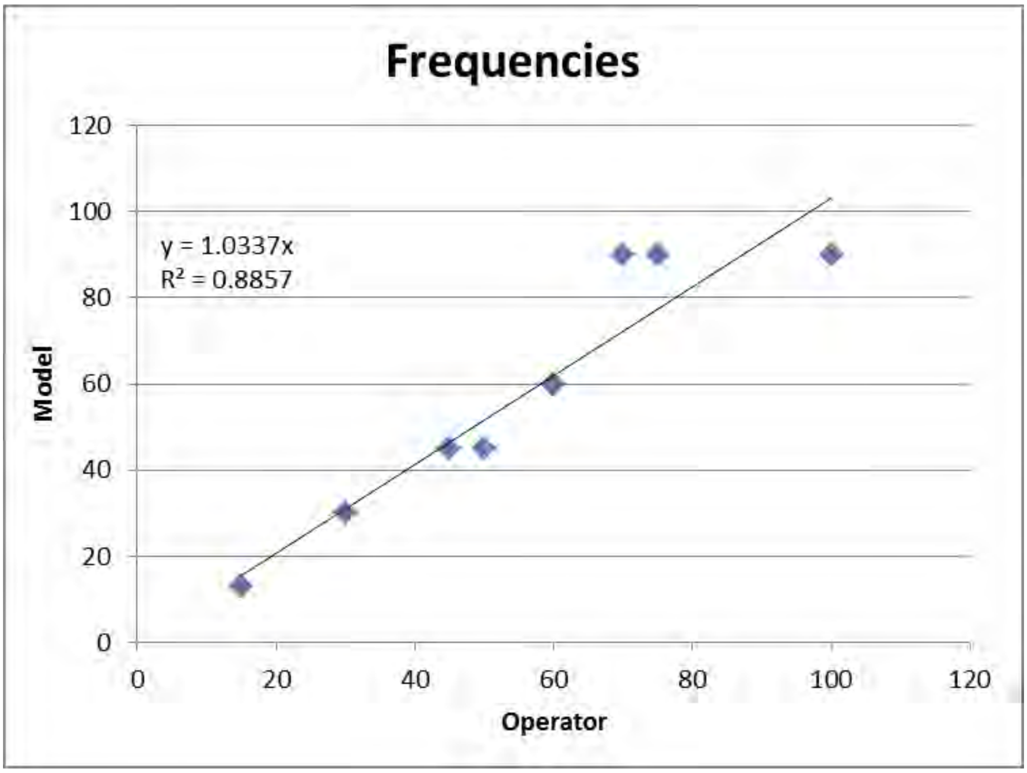


Figure 8.2 Bus Service Validation, Service Frequencies



8.2 Route Choice Validation

8.2.1 A randomly selected set of 20 potential passenger journeys within the model region was reviewed as part of the development of the existing CBLTM. These journeys were run through the public transport model, and the outputs were compared with the recommendations given by online journey planners for the corresponding trip.

8.2.2 The model gave realistic routes and services used for each origin-destination pair, with largely accurate in-vehicle journey time estimates compared with estimates given by journey planners. A small representative set of these comparisons is shown in Table 8.1 to Table 8.4, for rail and bus journeys.

Table 8.1: Modelled versus Journey Planner, Journey Travel Times and Routes, Bus

Origin	Destination	Transit Time (Min) Model	Transit Time (Min) Journey Planner
Dunstable	Marsh Farm (Luton)	30.9	32.5
Central Luton	St Albans	46.5	38.1
Tin Town (Luton)	Central Luton	22.7	23.7
Central Luton	Leighton Buzzard	43.5	44.4
Arlesey	Biggleswade	17.3	16
Dunstable	Leighton Buzzard	22.4	25.3

Table 8.2: Modelled versus Journey Planner, Journey Headways and Routes, Bus

Origin	Destination	Headway (Min) Model	Headway (Min) Journey Planner
Dunstable	Marsh Farm (Luton)	9.7	10
Central Luton	St Albans	15.7	15
Tin Town (Luton)	Central Luton	16.5	7.5
Central Luton	Leighton Buzzard	36	20
Arlesey	Biggleswade	45	45
Dunstable	Leighton Buzzard	36	30

Table 8.3: Modelled versus Journey Planner, Journey Travel Times and Routes, Rail

Origin	Destination	Transit Time (Min) Model	Transit Time (Min) Journey Planner
Flitwick	Luton Airport	17	16
Luton Airport	City of London	38.4	39.6
Central Luton	Brighton	124.5	125
Milton Keynes	Linslade	12	11.2
Sandy	Biggleswade	4	4
City of London	Luton Airport	37.7	40.1

Table 8.4: Modelled versus Journey Planner, Journey Headways and Routes, Rail

Origin	Destination	Headway (Min) Model	Headway (Mins) Journey Planner
Flitwick	Luton Airport	10.6	12
Luton Airport	City of London	11.3	12
Central Luton	Brighton	30	30
Milton Keynes	Linslade	12	15
Sandy	Biggleswade	30	30
City of London	Luton Airport	12	12

8.2.3 For rail, the modelled in-vehicle times and frequencies match the journey planners to within a few minutes. For bus movements, the validation is not quite as good, although the journey times are generally close. This is due to the greater complexity of bus movements (especially where interchanges are involved), due to changes in bus services and timetables over time, and differences between the TransXChange data and journey planner estimates of bus journey times.

8.2.4 In two of the cases represented in Table 8.2 there is a significant difference between the headway in the model and the one obtained from online journey planners. These routes are “Tin Town (north-east Luton) to Central Luton” and “Central Luton to Leighton Buzzard”. In both cases, the model has a higher headway than the journey planner. This is due to the journey planner route selection process where the planner considers a bus service which requires a significant amount of walking time (more than 15 minutes). This route option has been excluded from the model.

9 PUBLIC TRANSPORT ASSIGNMENT VALIDATION

9.1 Calibration and Validation Approach

9.1.1 The public transport model assignment (and mode choice process, which is in effect part of the assignment) has been validated by comparing the model results against other available data. Discrepancies have been investigated and where appropriate changes have been made to the assignment parameters or other parts of the process to improve the model. As part of the development of the existing CBLTM public transport model, the following changes were made during model calibration:

- centroid connector coding (adjusted to improve model routeing);
- rail-to-highway connectors coding (reallocated and corrected length);
- reallocation of Bletchley railway station and its catchment area was modified in order to separate from Fenny Stratford railway station;
- some railway stations' catchment areas have been reduced or adjusted to avoid overlapping;
- the gravity model applied to London, Bedford and Milton Keynes zones was adjusted to correct demand from those large zones outside the model area;
- a time period allocation error in the synthetic process corrected;
- Arriva data processing corrected to only consider alightings for certain ticket types (singles and returns);
- balancing process across the 24-hour day applied to the bus demand matrix;
- auxiliary time weight changed; and
- school bus trips have been removed from the model counts at Site 3 in the AM Period and interpeak period, as the observed data from the counts did not include school buses.

9.1.2 As part of the update for the CBLTM-LTN public transport model, further adjustments were made to centroid connectors and rail-to-highway connectors to improve the model routeing and performance against count data.

9.1.3 No manual changes were made to the assignment matrices; although the matrices were altered as part of the calibration of the existing CBLTM through changes to the inputs of the matrix development process.

9.1.4 "Matrix estimation", the technique (used in the highway model) for adjusting a demand matrix to reproduce better observed flow data, was considered, but not used. This is primarily due to relative quality of the demand data (based on ticket data) compared with the observed count data.

9.1.5 While some discrepancies in the bus data could be related to the demand matrix, we considered it inappropriate to adjust a demand matrix developed from three months of ticket sales data to match a count collected manually on a single day, as the former would generally be considered to be more reliable.

9.2 Bus Validation

9.2.1 Limited validation data were available for bus demand, as CBLTM-LTN does not have a comprehensive set of counts covering the whole of the model area.

9.2.2 The initial performance of the model (from the existing CBLTM) against the count data, prior to any adjustment to either the demand or the networks to improve the fit (including corrections to mistakes in the demand process identified during validation), is shown in Table 9.1.

Table 9.1: Bus Link Flow Validation, Hourly Passengers, Prior Assignment

		AM			IP			PM		
Site	**Dir**	**Obs.**	**Model**	**Diff**	**Obs.**	**Model**	**Diff**	**Obs.**	**Model**	**Diff**
1: Ampthill Road	SB	11	24	122%	20	5	-73%	15	5	-69%
2: Stanbridge Road	EB	29	48	62%	38	42	13%	62	43	-31%
3: Biscot Road	SB	155	220	42%	124	200	62%	63	65	4%
4: Barton Road	SB	92	52	-44%	52	52	0%	27	12	-55%
1: Ampthill Road	NB	26	23	-9%	14	4	-72%	6	4	-28%
2: Stanbridge Road	WB	50	63	27%	34	54	58%	27	48	76%
3: Biscot Road	NB	48	128	164%	123	193	57%	207	180	-13%
4: Barton Road	NB	44	121	173%	54	26	-53%	52	37	-29%
Total		**455**	**678**	**49%**	**458**	**576**	**26%**	**458**	**394**	**-14%**

9.2.3 This shows a poor match in general. In most of the three periods and four count sites, the error is significant, being up to 173% above and 73% below the observed data. However, the overall level of demand is of the right order, and there is a correlation between the observed and modelled flows.

9.2.4 It was noted that the modelled flow at Site 1 is entirely synthetic, while Site 3 is fully observed by ETM data. The other two sites had a mixture of observed and synthetic demand data, but mostly observed in both cases.

9.2.5 Following adjustments to the network, observed data processes, synthetic matrix process, and the updates to produce the CBLTM-LTN model (zone disaggregation and refined Luton Airport demand), the final validation is shown in Table 9.2.

Table 9.2: Bus Link Flow Validation, Hourly Passengers, Final Model

		AM			IP			PM		
Site	**Dir**	**Obs.**	**Model**	**Diff**	**Obs.**	**Model**	**Diff**	**Obs.**	**Model**	**Diff**
1: Ampthill Road	SB	11	10	-7%	20	20	3%	15	20	39%
2: Stanbridge Road	EB	29	30	2%	38	38	0%	62	59	-5%
3: Biscot Road	SB	155	197	27%	124	177	43%	63	64	2%
4: Barton Road	SB	92	85	-8%	52	59	13%	27	38	43%
1: Ampthill Road	NB	26	19	-25%	14	19	34%	6	14	126%
2: Stanbridge Road	WB	50	56	12%	34	47	37%	27	36	30%
3: Biscot Road	NB	48	75	56%	123	197	61%	207	213	3%
4: Barton Road	NB	44	44	-2%	54	51	-5%	52	91	76%
Total		**455**	**516**	**13%**	**458**	**608**	**33%**	**458**	**534**	**17%**

9.2.6 For individual links (as detailed in Section 2.8) the WebTAG guidance (Unit M3.2, §7.1.6) is that assigned flows should be within ±25% of observed data where the observed flow is at least 150 passengers per hour.

9.2.7 Across the four locations, two directions and three time periods where observed data are available, only two observed flows are about 150 passengers per hour. These are Biscot Road Southbound in the AM Peak (where modelled flows are 27% above the observed count), and Biscot Road Northbound in the PM Peak (where modelled flows are 3% above the observed data).

9.2.8 In general, the bus link validation flow results shown in Table 9.2 are substantially improved from the prior assignment (see Table 9.1) in the AM Period, with similar levels of performance in the other two time periods.

9.2.9 Site 1 in particular has been substantially improved by changes to the synthetic matrix process and now validates quite well. The other three sites have also generally improved from the prior matrix assignment due to changes in the processing of Arriva data.

9.2.10 Within the base year model, Site 3 has a relatively poor validation compared with the other sites after the network and matrix adjustments. This appears to relate to route choice between three parallel bus corridors, with the Site 3 corridor having relatively too much bus passenger flows relative to the other two.

9.2.11 Consideration was given to applying matrix estimation to these sites to create a better match in the model between modelled and observed flows, but the idea was rejected.

9.2.12 There will be error on the observed counts. Pure day-to-day variation in the flows could account for a 20% discrepancy or more, which explains residual errors at the some locations. Site 3, mainly in the northbound direction, has a discrepancy larger than would be expected from sampling error on the count, but here we are confident that the problem relates to assignment routeing, not the matrix, so applying matrix estimation would be the incorrect approach.

9.2.13 It should be noted that all changes applied to the matrix, network and assignment to achieve the above validation were global; applied to the whole model. There is reason to expect, therefore, that the model may perform broadly similarly in other areas where we have no validation data.

9.2.14 The validation at Site 3 could be corrected by adding additional boarding penalties, in-vehicle time weights or other perception-related costs to the services on the corridor (or subtracting same from the parallel corridors). Should the model be required to assess some intervention in this corridor, such adjustments would be sensible. For general purpose use, however, it is decided to present the validation without such localised adjustments to ensure that the validation is representative of the model as a whole.

9.3 Rail Validation

9.3.1 For rail demand across Central Bedfordshire and Luton, the ORR station usage data are available to confirm that modelled rail passengers (after application of the bus-rail mode choice and the assignment process) reproduce the number of tickets sold at each station.

9.3.2 The comparison of the modelled station entries against the ORR data are summarised in Table 9.3. Note that this comparison compares the assignment results against the ORR data, whereas the comparison presented in Table 6.3 compares the processed LENNON data (i.e. the trip matrices) with the ORR data before assignment.

Table 9.3: Rail Station Boarding Validation

Station	ORR Daily Entry	Model Entry	Difference
Luton Airport Parkway	4,285	3,900	-9%
Luton	5,519	5,239	-5%
Leighton Buzzard	2,687	2,610	-3%
Leagrave	2,947	3,141	7%
Flitwick	2,257	1,917	-15%
Biggleswade	1,467	1,435	-2%
Arlesey	976	842	-14%
Sandy	780	781	0%
Harlington	506	522	3%
Ridgmont	55	201	264%
Lidlington	45	39	-14%
Millbrook (Bedfordshire)	25	42	63%
Aspley Guise	16	15	-2%
Milton Keynes Central	10,343	10,451	1%
Bedford Midland	5,776	5,427	-6%
St. Albans City	11,626	12,410	7%
Harpenden	5,158	5,580	8%
Bletchley	1,538	1,159	-25%

9.3.3 The correlation is very strong between the model and ORR data, and the validation is good for the key stations inside and outside the model area. There are a few stations with significant discrepancies (namely Ridgmont and Millbrook), but these are all small stations with a very low number of trips per day.

10 CONCLUSIONS

10.1 Introduction

10.1.1 The preceding sections of this report detail the development of the CBLTM-LTN public transport, the definition and derivation of the observed data used to build and validate the model, and the results of the base year model performance against the standards set out within WebTAG.

10.1.2 This section summarises these processes and results, and assesses the model performance in light of the known and expected application of the model.

10.2 Review of Development

10.2.1 The CBLTM-LTN public transport model builds on the existing 2016 base year public transport model contained within the CBLTM. Within this update to the model, additional zone detail has been added throughout the model suite, providing additional zone detail within Luton Borough and areas of Hertfordshire to the east and south of Luton Airport. The bus/coach and rail demand to / from Luton Airport has also been refined as part of this model update.

10.2.2 The network and service representation of buses within Central Bedfordshire and Luton has been largely based on data from the Traveline National Data Set. Substantial validation and checking of the processed service data has been undertaken, including an independent review of the service coding in the vicinity of Luton Airport as part of the development of the CBLTM-LTN public transport model.

10.2.3 The 2016 base year bus/coach and rail demand matrices have been primarily based on ticket data, either from LENNON data or ETM data from the bus operators. Travel demand to / from Luton Airport has been based on independent sources of data, such as the CAA Passenger survey data, and has replaced demand derived from ticket data for movements to / from the airport.

10.3 Review of Development

10.3.1 The modelled rail demand performs well against ORR station usage data at all the key stations within the modelled area. Where there are significant percentage differences between the modelled and ORR data (such as at Ridgemont and Millbrook), these occur at smaller stations within the model where observed and modelled passenger numbers are low.

10.3.2 In terms of bus flows, there is a limited number of available observed bus flow data, with only two locations where the observed flows are above the 150 threshold set out within WebTAG. At these two locations, the PM Peak northbound modelled flow at Biscot Road is within 3% of the observed data, with the AM Peak southbound modelled flow at the same location being marginally outside the WebTAG criteria (±25%) at 27% above the observed data.

10.3.3 Additional checks on the processed matrix data derived from ticket sales using independent data sources such as the National Travel Survey have been undertaken. This includes checks on the purpose split, trip-length profiles and trip rates.

10.4 Model Uses and Suitability

10.4.1 The CBLTM-LTN public transport model is a strategic model designed to forecast effects upon broad travel patterns and the viability of corridors for investment. It is not a detailed operational model, and cannot produce results down to the level of individual bus stops, for example.

10.4.2 For the purposes of assessing the proposed expansion at Luton Airport, the CBLTM-LTN public transport model will be used to forecast the impacts of changes in public transport fares over time, expected infrastructure changes (such as the introduction of the DART service between Luton Airport Parkway and Luton Airport), and changes in land-uses within the modelled area.

10.4.3 It is noted that the Luton Airport demand forecasts, including forecasts of mode share for passengers, are to be forecast outside the CBLTM-LTN suite. It is therefore not in the specification or scope of this public transport model to inform these assumptions and forecasts. However, the public transport model will provide forecasts for the routeing of public transport passenger and staff trips to and from Luton Airport, including the proportion of airport-related trips along given corridors for bus and rail travel.