steer davies gleave

Birmingham Clean Air Zone Final Business Case - Future Year Traffic Modelling

David Harris

Draft Final Report
November 2018

Our ref: 23013602

steer davies gleave

Birmingham Clean Air Zone Final Business Case - Future Year Traffic Modelling

Draft Final Report
November 2018

David Harris

Our ref: 23013602

Prepared by:

Steer Davies Gleave
28-32 Upper Ground
London SE1 9PD

+44 20 7910 5000
www.steerdaviesgleave.com

Prepared for:

David Harris

Contents

Figures

Figure 1-6: ANPR Site Locations

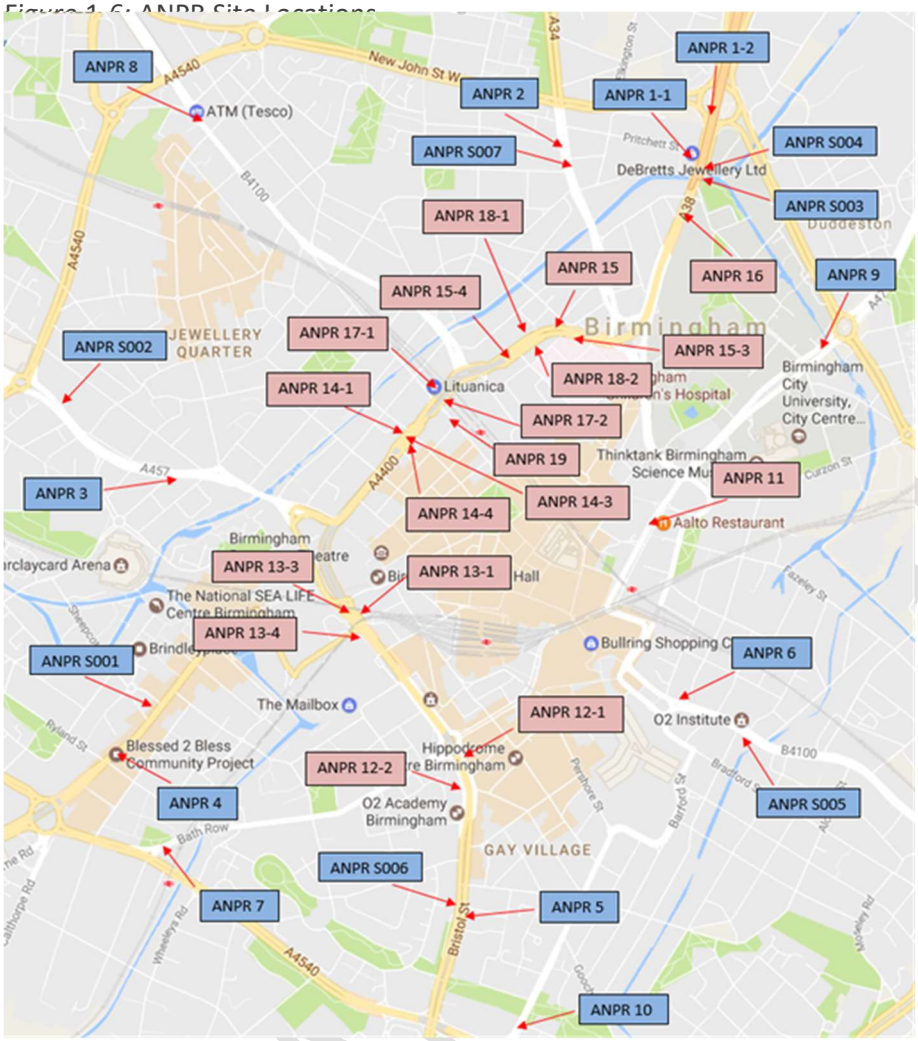


Figure 2-1: Upgrade Rates for City Centre Trips (excluding ramp-up)

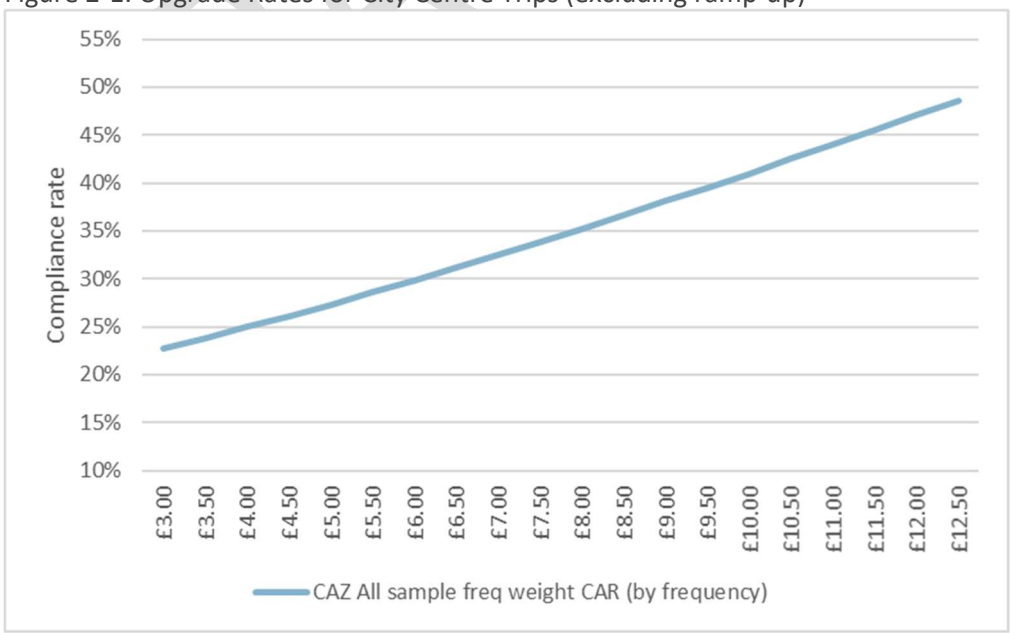
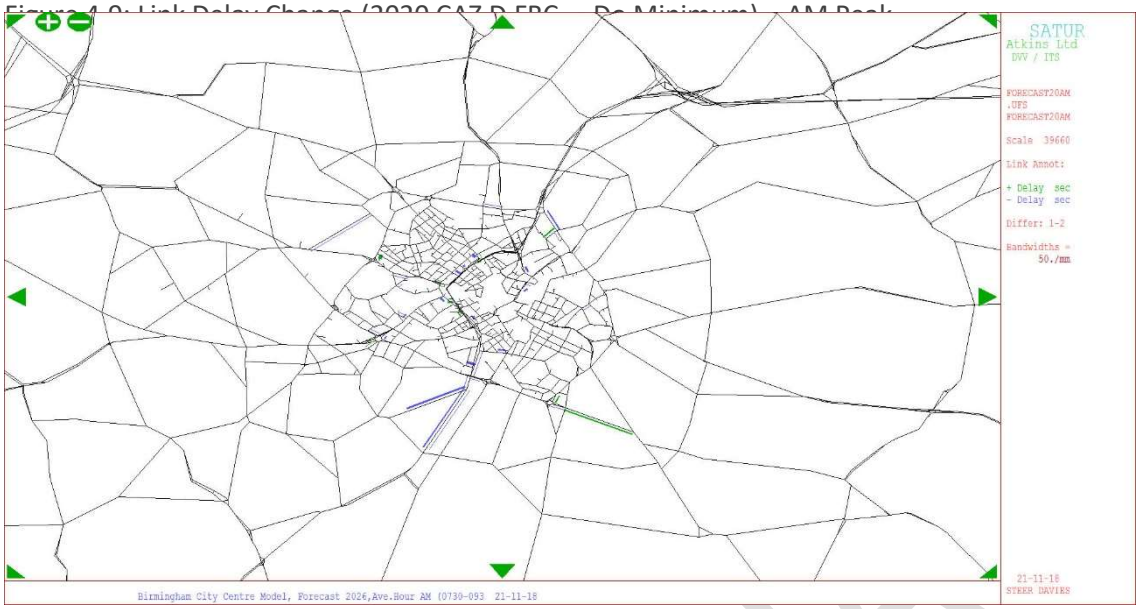


Figure 4.9: Link Delay Change (2020 CAZ D EBC – Do Minimum) – AM Peak



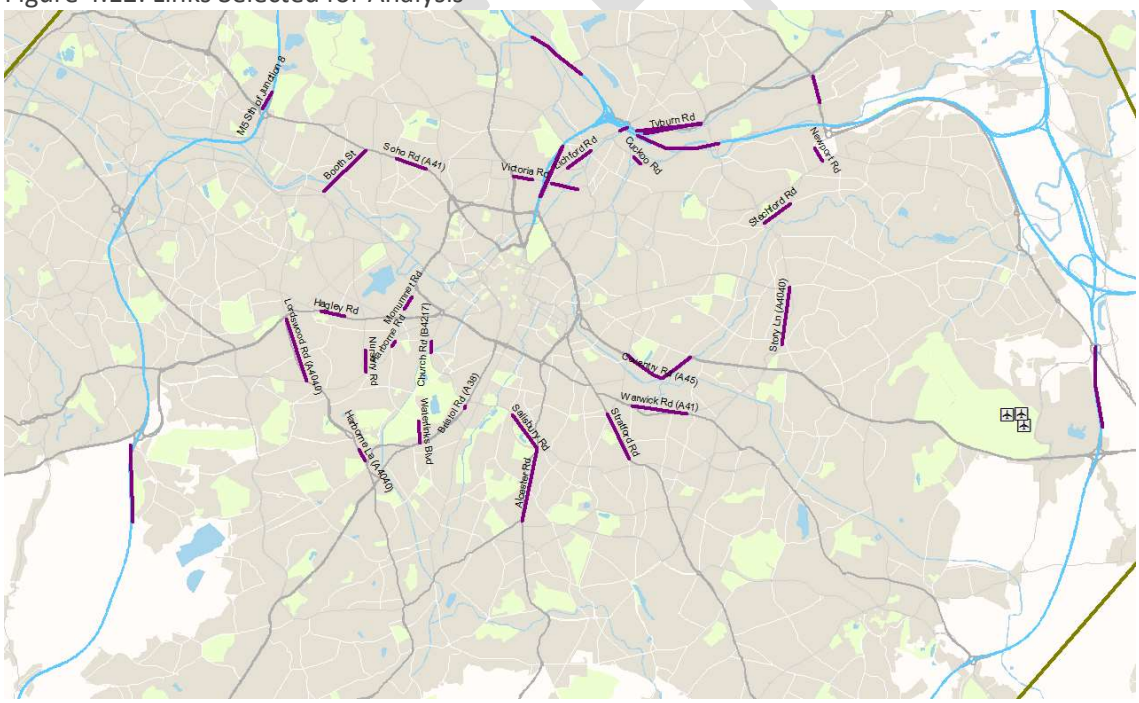
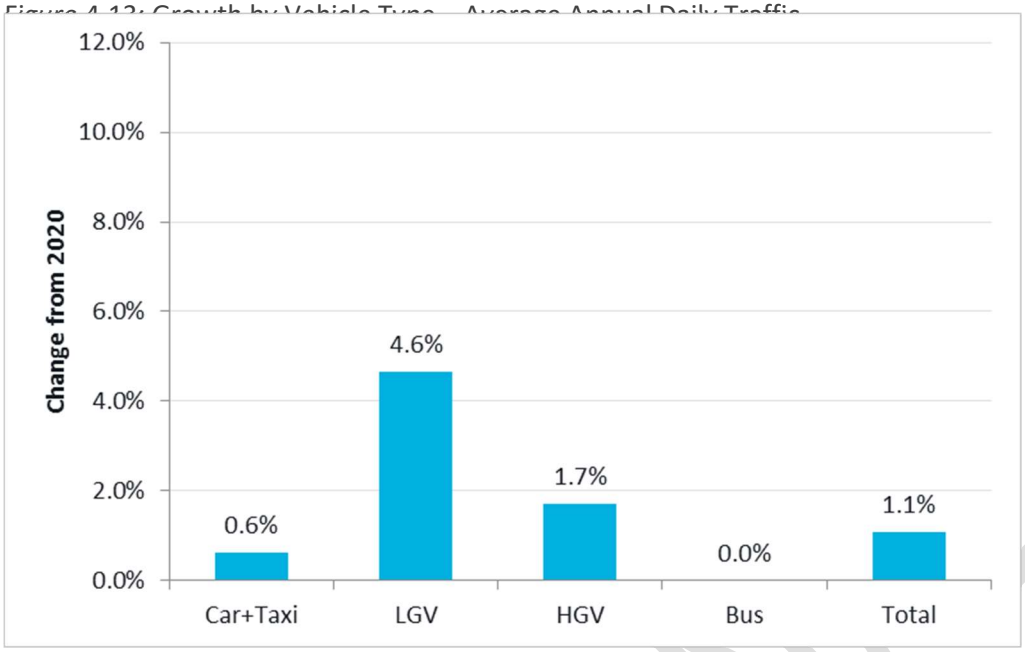


Figure 4.13: Growth by Vehicle Type – Average Annual Daily Traffic



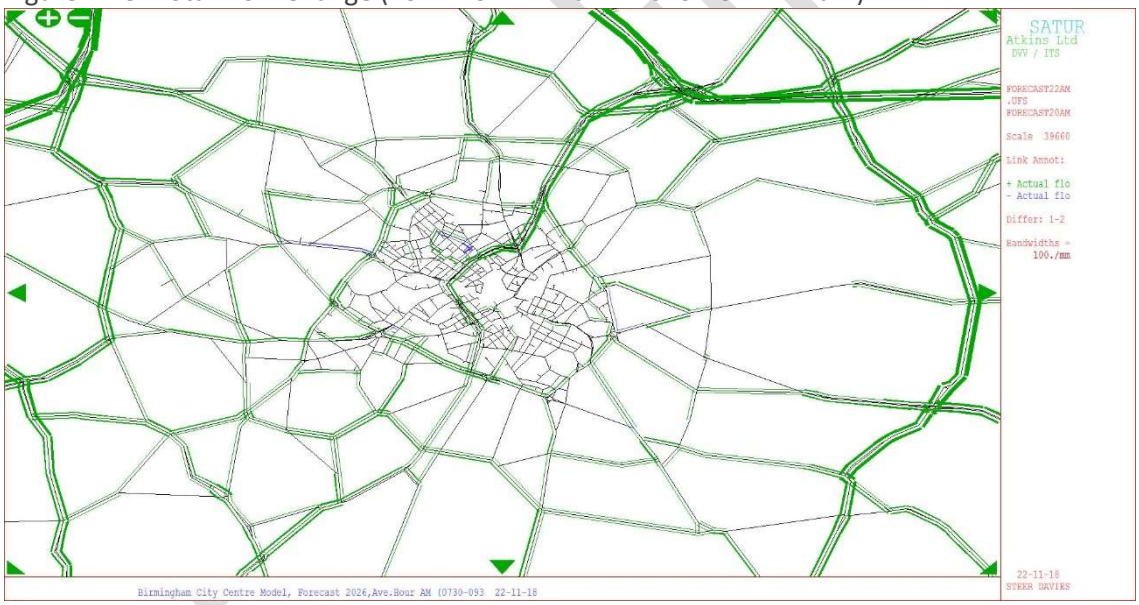


Figure 4.21: Link Delay Change (2020 CAZ D ERC – Do Minimum) – AM Peak

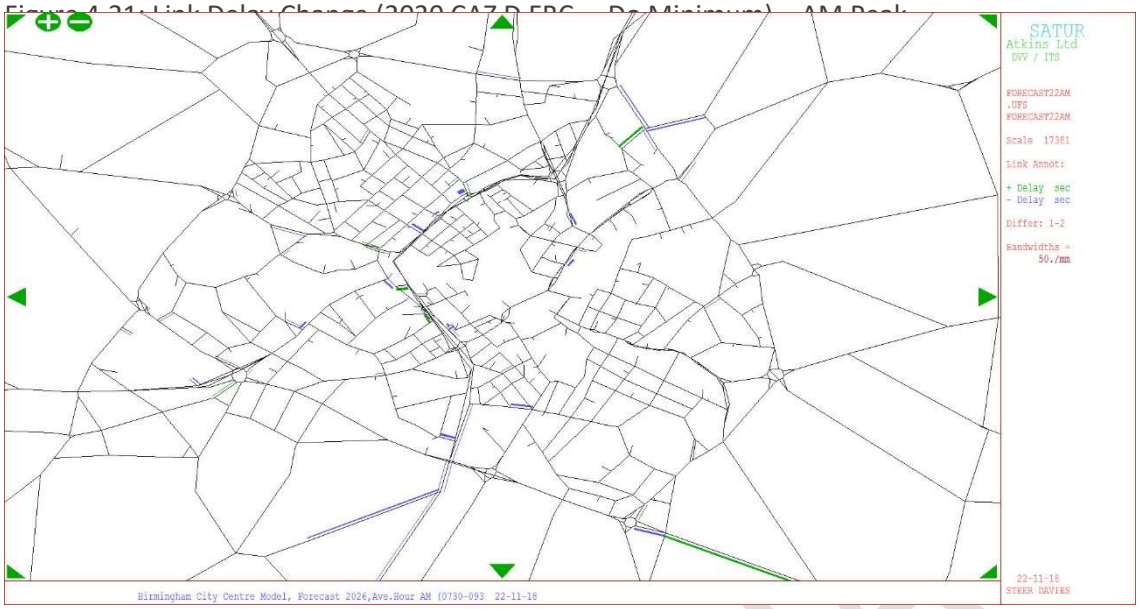


Figure 4.22: Key City Centre Links

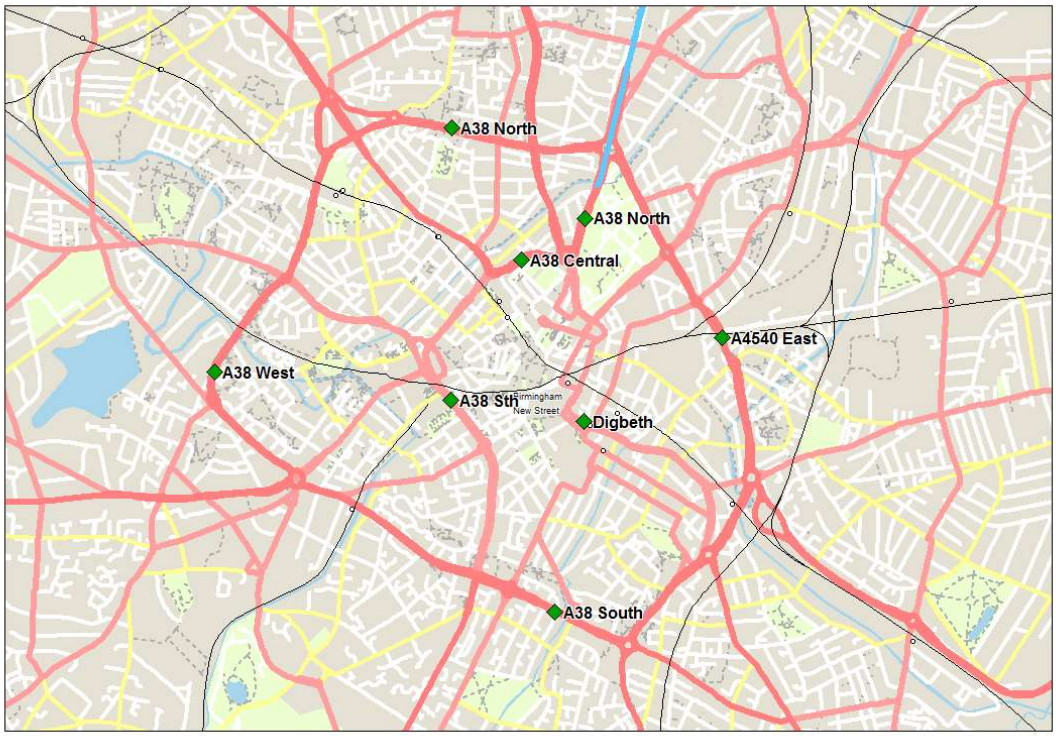
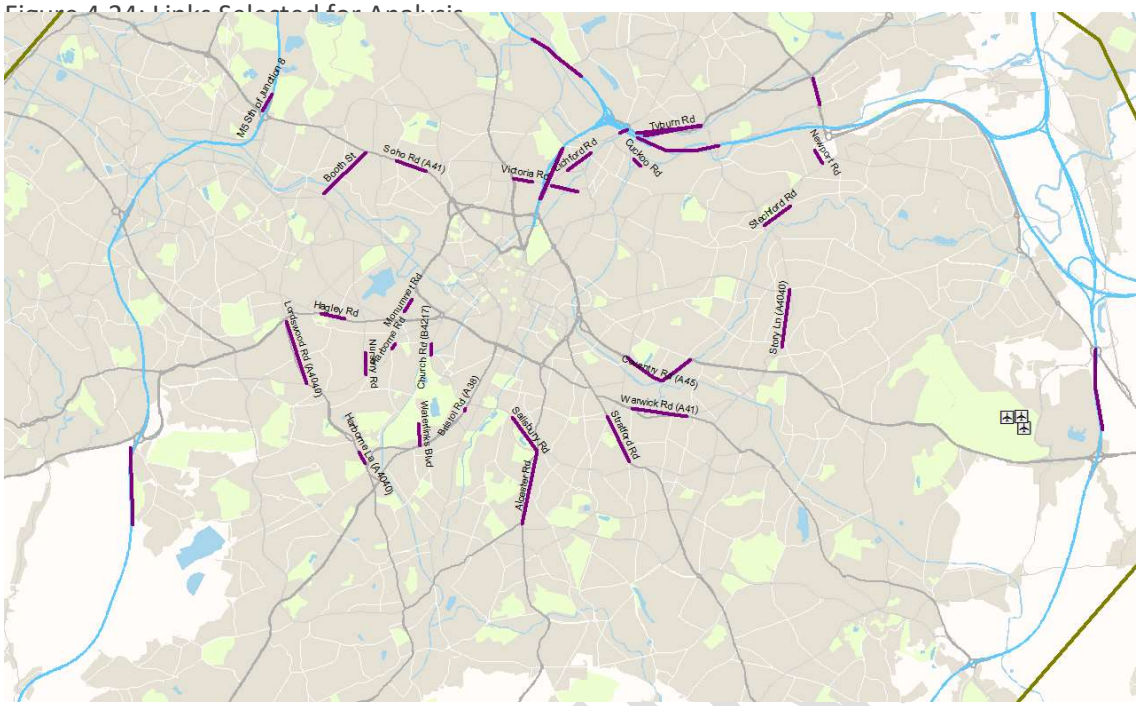


Figure 4.24: Links Selected for Analysis



..... 85

Tables

Appendices

Executive Summary

Overview

This report sets out the transport modelling that has been carried out to support the Final Business Case (FBC) for Birmingham's Clean Air Zone (CAZ).

Clean Air Zones

As one of the local authorities identified in the UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations[1], the Government has directed Birmingham City Council (BCC) to develop a plan to deliver compliance with legal limits for nitrogen dioxide in the shortest possible time, as locations in the City exceed legal levels of NO2. The legal limits for all the road links with public access meet the following air quality (AQ) limits are as follows:

Figure1: Statutory limit values for NO2[2]

Averaging period	NO_2 limit value[10]
One hour	200 µg/m^3 not to be exceeded more than 18 times a calendar year
Calendar year	40 µg/m^3

To support the delivery of legal clean air levels, in May 2017 the Government published the Clean Air Zone Framework[3] which sets out the general principles for the operation of Clean Air Zones in England. For authorities that adopt Clean Air Zones (CAZ), they have the option to implement a charging CAZ, where the more polluting vehicle types must pay a charge to enter the zone. There framework sets out four levels of CAZ:

- Class A - Buses, coaches, taxis and private hire vehicles (PHVs)
- Class B - Buses, coaches, taxis, PHVs and heavy goods vehicles (HGVs)
- Class C - Buses, coaches, taxis, PHVs, HGVs and light goods vehicles (LGVs)
- Class D - Buses, coaches, taxis, PHVs, HGVs LGVs and cars

The Framework also sets out the minimum classes and emission standards required for entry into a charging zone without paying a charge. Compliance standards for different vehicle types are shown in Table 1.

Table 1: Compliant Vehicles[4]

Vehicle	Petrol	Diesel
Car	Euro Class 4 and above	Euro Class 6 and above
Taxi	Euro Class 4 and above	Euro Class 6 and above
Light Goods Vehicle	Euro Class 4 and above	Euro Class 6 and above

[1] UK Plan for tackling roadside nitrogen dioxide concentrations, DEFRA/ DfT, 2017

[2] Air Quality Standards Regulations 2010

[3] Clan Air Zone Framework, DEFRA/ DfT, 2017

[4] Clan Air Zone Framework, DEFRA/ DfT, 2017

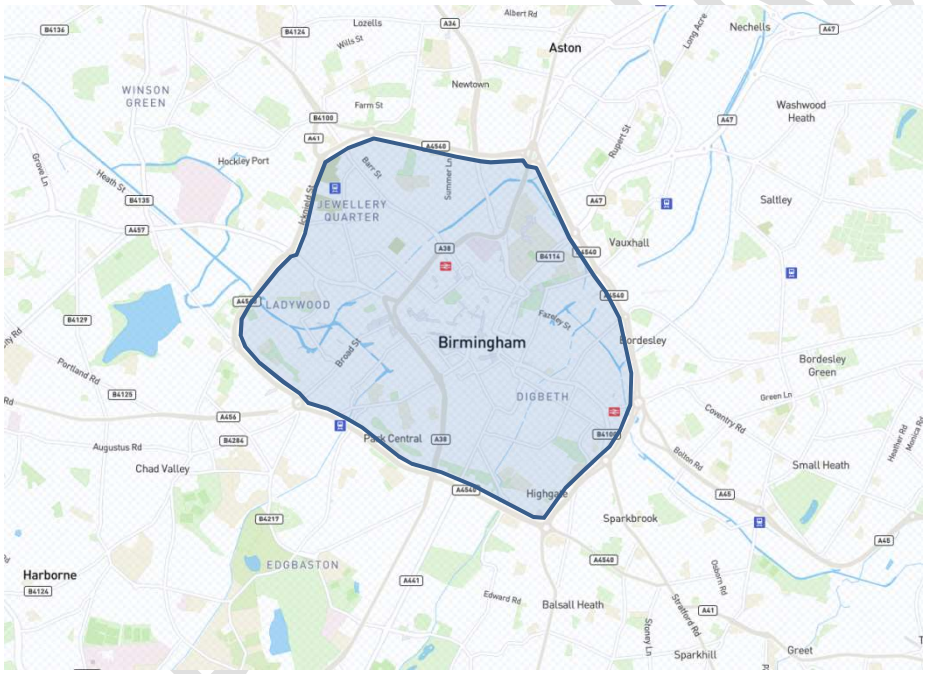
Heavy Goods Vehicle		Euro Class 6 and above
Bus/ Coach		Euro Class 6 and above

During the development of the outline business case delivered in the summer of 2018, the requirement for a CAZ D was identified to be able reach AQ compliance in the shortest possible time. The following charge levels are proposed (see Appendix D benchmarking report for further analysis):

Table 2: CAZ FBC Charge Levels

Vehicle Type	Charge Level
Car	£8.00
Taxi	£8.00
LGV	£8.00
HGV	£50.00
Bus/ Coach	£50.00

Figure 2: CAZ Charing Cordon



Additional Measures

Measures to improve air quality on top of the charging of non-compliant vehicles are included in the business case.

Table 1.1: FBC Additional Measures

Type	Test ID	Summary
Fleet (low emission)	Fleet 1	Increase LPG refuelling for Hackney Carriages and the installation of rapid EV infrastructure for taxi and private hire vehicles. Retrofitting of black taxis to LPG Assumptions tested: 85 taxis upgraded to Electric vehicle 441 PHVs upgraded to Electric Vehicle 65 taxis retrofitted to LPG
	Fleet 2	50 Zero emission buses (new Hydrogen buses)
Parking	Parking 1	Remove all free parking from BCC controlled areas. Replaced with paid parking spaces. Assume cost of parking in line with BCC off-street parking.
Network Changes	Network 1	Ban traffic entering (SB) or leaving (NB) Suffolk Street Queensway (A38) from Paradise Circus (except for local access).
	Network 2	Close Lister Street and Great Lister Street at the junction with Dartmouth Middleway. This reduces delays on the A4540.

Mitigations and Exemptions

In implementing the scheme in as equitable way as possible and to reduce the impact on vulnerable groups a package of mitigations and exemptions have been developed for the FBC. These were developed by Jacobs and Element Energy on behalf of Birmingham City Council with the assumptions built into the transport modelling.

Exemptions exclude certain groups of users with a non-compliant vehicle from paying a charge to enter the CAZ. This is either applied for all trips such as residents of the CAZ or for certain journey purposes (such as medical appointments). The exemptions included in the FBC are shown in the table below, with further details in chapter 3 on how this is incorporated into the modelling.

Table 1.2: Exemptions

Ref	Vehicle type	Group	Description	Years Implemented
E1	HGV	CAZ HGVs	HGVs and coaches registered within the CAZ will receive an exemption	2020
E2	HGV	HGV - existing finance	HGVs registered in the Birmingham City area travelling to the CAZ with and existing finance agreement beyond 2020	2020
E3	Van/LGV	SME Vans/LGVs	Vans and LGVs registered to SMEs within the CAZ	2020
E4	Van/LGV	Vans/LGVs - existing finance	Vans/LGVs registered within the Birmingham City area travelling to the CAZ with and existing finance agreement beyond 2020.	2020

E5	Car	residents in the CAZ	All private car and van owners who are residents of the CAZ, as defined by DfT registration information	2020
E6	Car	income deprived	Income deprived residents of the Birmingham metropolitan area traveling into the CAZ for work	2020
E7	Car	key workers	Key workers and volunteers travelling to work in the CAZ	2020
E8	Car	children's hospital visits	Visitors to select hospitals, GP offices and care homes	2020
E9a	Van/LGV	community and school	Vehicles classified as Section 19 operators	2020-2022
E9b	Car	disabled vehicles	Vehicles with disabled or disabled passenger tax class	2020-2022

Source: "revised exemption and mitigations 181022.xlsx", Jacobs, 2018

Mitigations involve a support package for some non-compliant groups that are not exempt from the charge including financial support to upgrade their vehicle or use public transport.

Table 1.3: Mitigations

Ref	Vehicle type	Group	Description	Years Implemented
M1 (a)	Car	Low income	Mobility credit offered to low income non-compliant car owners living or working within the CAZ.	2020-2022
M2	Car	Taxi	Birmingham Licenced Taxi drivers with non-compliant Hackney Carriages receive financial support to upgrade	2020-2022
M3	Car	Taxi	Birmingham City Council to purchase 50 ULEV taxis to lease out to most vulnerable drivers.	2020-2022
M4	Van/LGV	Van/LGV	ULEV van drivers can register to receive credit on Birmingham's public charging network	2020
M5	HGV	HGV	HGV and Coach fleet operators within the West Midlands will be able to apply for a cash payment towards retrofit technology	2020-2022
M6	ALL	All	Educational and marketing campaign to provide information on the CAZ and reach out to groups eligible for support through mitigation measures	2020
M7m	Car	CAZ workers	Support prioritises key workers and then based on income, those eligible will be exempt for one year and then have access to the mitigation package.	2022
M8m	Car	Non-CAZ residents	Can apply for support package similar to workers package, will include an exemption for one year followed by scrappage scheme in 2021.	2022
M7e	Car	work in CAZ car owners	Workers in the CAZ that receive the mitigation.	2020
M8e	Car	non-CAZ car residents	Exemptions for 3,250 non-CAZ residents that receive the mitigation.	2020

Source: "revised exemption and mitigations 181022.xlsx", Jacobs, 2018

Transport Model

To support the development of the CAZ a traffic model has been developed to provide traffic flows and speed data into the Air Quality (AQ) model, as well as supporting other assessments of the CAZ, such as the economic assessment. The model has been developed to forecast 2020 and 2022 conditions without a CAZ, and to test the impact of various CAZ measures on traffic. The model outputs are used to assess the extent to which CAZ policies can solve Birmingham's clean air problem. Outputs from the model are used:

- To forecast compliant/ non-compliant link flows so that the AQ model can demonstrate levels of compliance
- Inputs into the impact assessment (IA) to show the cost benefit analysis (CBA) of the scheme and the distributional impacts.

This modelling methodology applied is based on that outlined in 'Birmingham Clean Air Zone - Model Development'5 report issued to JAQU in September 2016, with further refinements as new guidance has emerged.

Modelling Tools

The main tools used in forecasting traffic flows in 2020 are as follows:

Table 3: Data/ Modelling Tools

Source	Description
BCC SATURN Model	SATURN assignment model: • 2016 base year and 2020 with and without CAZ scenarios • AM, IP and PM peak weekday periods • Car (taxis included in 2020 scenarios), LGV, HGV and Bus User Classes, split into compliant and non-compliant. • Covers CAZ zone in detail, with network covering the "motorway box". Much of the network outside the CAZ is fixed speed (approx. 2km from ring road) • Feeds traffic link flow data into the air quality models
PRISM Demand Model	Regional demand model covering the West Midlands, maintained by Mott MacDonald on behalf of Transport for the West Midlands, BCC and other stakeholders. Inputs from PRISM are: • Base year prior matrices • Traffic Growth from PRISM, having been updated with TEMPRO V7.0 demographic data (with post model adjustments to account for v7.2 changes). TEMPRO is a DfT software that provides data from their National Trip End Model (NTEM). • To calculate non-route choice responsiveness to charging
ANPR Surveys	A large programme of ANPR surveys carried out in the CAZ area. This has been used to: • Validate base year through trip proportions • Calculate Euro Class fleet mix

[5] Birmingham Clean Air Zone Final Business Case - Future Year Traffic Modelling, Steer Davies Gleave, October 2016

Source	Description
TfL Ultra Low Emission Zone (ULEZ) Behavioural Research	TfL carried out a stated preference survey on car drivers in the extended ULEZ area covering an area not in the current congestion charging zone. Used to forecast vehicle upgrade rates from CAZ charging.
WebTAG	Modelling follows WebTAG guidance and uses various data sources
JAQU Guidance	JAQU guidance and data sources used as appropriate

Base Year Model

The forecasting is built off the 2016 base year BCC SATURN model, which has recently been calibrated to 2016 data. The 2016 model results have been reported to JAQU in the 'Birmingham City Centre Clean Air Zone - Transport Model review' issued in August 2017. The model was passed as fit for purpose by JAQU for the forecasting stage, with some questions/ caveats which have been responded to.

2020 and 2022 Do Minimum

Model forecasts have been prepared for an opening year 2020 and additional future year 2022.

Network

Changes to the highway network have been and are due to be implemented between 2016 ,2020 and 2022. These changes, which are focused on the City Centre CAZ area were agreed with BCC highways and transportation team and coded into the highway model. Discussions with Highways England indicated that there would not be any significant changes to the strategic road network that would affect the CAZ, so no adjustments were made to the regional motorway network.

Growth

For growth between 2016 and 2020 the PRISM model's traffic growth forecasts are used. PRISM was updated with TEMPRO V7.0 demographic forecasts, and development locations and network assumptions. A minor adjustment was made post PRISM runs to account for changes between TEMPRO V7.0 and V7.2.

The sites of specific major developments within Birmingham were agreed with BCC development planners. A process has been implemented to ensure the demand from these developments is loaded onto the transport network in the correct locations, while also ensuring that there is no double counting of developments already included in PRISM. The table below shows the overall growth rates that resulted from this process. Taxi are included within the car vehicle class in PRISM and are then split based on observed proportions from the ANPR survey in the BCC model.

Table 4: Traffic Model Growth 2016 - 2020

Sector	AM Peak			Inter Peak			PM Peak		
	Car/ Taxi	LGV	HGV	Car/ Taxi	LGV	HGV	Car/ Taxi	LGV	HGV
City Centre	7.9%	10.8%	3.5%	8.0%	10.8%	3.6%	7.4%	10.8%	3.6%
Rest of Birmingham	3.7%	10.7%	3.2%	3.7%	10.7%	3.1%	3.7%	10.7%	3.1%

Birmingham (Total)	**4.2%**	**10.7%**	**3.2%**	**4.2%**	**10.7%**	**3.2%**	**4.1%**	**10.7%**	**3.2%**
Rest of West Midlands	4.4%	10.6%	2.9%	5.3%	10.7%	2.9%	4.6%	10.8%	3.0%
Total	**4.3%**	**10.7%**	**3.0%**	**4.7%**	**10.7%**	**3.0%**	**4.4%**	**10.7%**	**3.0%**

Traffic growth between 2020 and 2022 is taken derived directly from TEMPRO forecasts for car and NTEM for LGV and HGVs. For car growth into the City Centre the car mode share is constrained to 2020 levels with the overall growth rates across modes used (this is based on latest trends in transport mode shares in the City Centre).

Table 1.4: Traffic Model Growth 2020 - 2022

Sector	AM Peak			Inter Peak			PM Peak		
	Car/ Taxi	LGV	HGV	Car/ Taxi	LGV	HGV	Car/ Taxi	LGV	HGV
City Centre	0.4%	4.7%	0.8%	0.4%	4.7%	0.8%	0.4%	4.7%	0.8%
Rest of Birmingham	2.1%	4.7%	0.8%	2.1%	4.7%	0.8%	2.1%	4.7%	0.8%
Birmingham (Total)	**1.9%**	**4.7%**	**0.8%**	**1.9%**	**4.7%**	**0.8%**	**1.9%**	**4.7%**	**0.8%**
Rest of West Midlands	1.9%	4.7%	1.2%	1.9%	4.7%	1.2%	1.9%	4.7%	1.2%
Total	**1.9%**	**4.7%**	**1.1%**	**1.9%**	**4.7%**	**1.1%**	**1.9%**	**4.7%**	**1.1%**

Compliance

JAQU guidance on forecasting future year compliance rates was followed. This involved using the existing age profile of vehicles derived from the ANPR survey and deriving new compliance rates assuming the overall age profile remains constant. An additional adjustment was made increasing the diesel car fleet in line with JAQU guidance.

Table 5: 2016 Base Year and 2020 and 2022 Do Minimum Compliance Rates

Vehicle	Compliance Status	2016	2020	2022
Car/ PHV	Compliant	55%	77%	84%
Car/ PHV	Non-Compliant	45%	23%	16%
LGV	Compliant	23%	59%	70%
LGV	Non-Compliant	77%	41%	30%
HGV	Compliant	34%	61%	78%
HGV	Non-Compliant	66%	39%	22%
Bus	Compliant	38%	60%	63%
Bus	Non-Compliant	62%	40%	37%
Taxi	Compliant	17%	29%	46%
Taxi	Non-Compliant	83%	71%	54%

CAZ Charging

A methodology was developed in consultation with JAQU to model the various expected responses to charging as shown in Table 6.

Table 6: CAZ Responses

Hierarchy	Response	Method
1	Upgrade to compliant/ switch to already owned compliant vehicle (for households with more than one car)	Choice Modelling based on TfL Stated Preference Research for Cars and LGV. Taxis and buses assumed to upgrade through licencing agreements HGVs users value for money over 5 years period on whether to upgrade
2 (Car only)	Cancel – do not make a journey	Elasticity to charge derived from PRISM run to apply to Do Minimum trips to/ from the City Centre.
	Change Mode to non-highway PT/ Walk/ Cycle option	
	Avoid (Change destination from City Centre to non-City Centre trips)	
	Pay (with a city centre origin/ destination)	
3	Avoid (through trips change route to non-City Centre route).	BCC CAZ assignment model to forecast diversion due to charge for through trips.
	Pay (through trips use City Centre)	

CAZ FBC Results

Table 7 below shows the forecast reduction in non-compliant vehicles in the clean air zone in 2020 as a result of the CAZ FBC scenario (with additional measures, mitigations and exemptions), and Table 8 the forecast daily flows entering the CAZ zone.

Table 7: 2020 CAZ FBC Non- Compliant Vehicle Change in the CAZ (Percentage)

Car	LGV	HGV	Total
-72%	-34%	-64%	-70%

Table 8: 2020 CAZ D FBC Annual Average Daily Flows – Entering the Clean Air Zone

Do Minimum	Car	Taxi/ PHV	LGV	HGV	Bus	Total
Compliant	127,200	2,700	13,200	4,700	3,300	151,100
Non-compliant	37,600	6,500	9,300	2,500	2,200	58,100
Total	164,700	9,200	22,500	7,100	5,500	209,000
OBC	**Car**	**Taxi/ PHV**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	134,200	9,400	14,500	5,800	5,500	169,400
Non-compliant	10,600	-	6,100	900	-	17,600
Total	144,800	9,400	20,600	6,700	5,500	187,000

Table 9 below shows the forecast reduction in non-compliant vehicles in the clean air zone in 2022 as a result of the CAZ FBC scenario (with additional measures, mitigations and exemptions), and Table 10 the forecast daily flows entering the CAZ zone.

Table 9: Overall Response Reduction CAZ D

Car	LGV	HGV	Total
-90%	-51%	-88%	-85%

Table 10: 2022 CAZ D Annual Average Daily Flows – Entering the Clean Air Zone

Do Minimum	Car	Taxi	LGV	HGV	Bus	Total
Compliant	125,900	2,700	13,100	4,600	3,300	149,500
Non-compliant	37,100	6,500	9,100	2,500	2,200	57,400
Total	163,000	9,200	22,200	7,000	5,500	206,900
OBC	**Car**	**Taxi**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	142,700	9,500	17,200	6,700	5,500	181,500
Non-compliant	2,900	-	3,600	100	-	6,600
Total	145,600	9,500	20,800	6,800	5,500	188,100

Report Structure

This report describes the modelling in more detail and is structured as follows:

- Chapter 1: Do Minimum Without CAZ Scenario Model Development – Describes the process in creating the 2020 and 2022 without CAZ scenario
- Chapter 2: Do Something With CAZ Charging Scenario Model Development - Describes the process to forecast the impact of charging non-compliant traffic
- Chapter 3: Do Something With CAZ Additional Measures, Exemptions and Mitigations Scenarios Model Development -Describes the methodology to test additional measures.
- Chapter 4: Results – Presents analysis of the model results and the impacts on the highway network
- Chapter 5: Summary – A summary of findings, caveats and potential next steps

1 Do Minimum Without CAZ Scenario Model Development

Overview

1.1 This chapter describes the process of updating the model from 2016 to 2020 to produce a baseline without CAZ scenario (Do Minimum)

Network

1.2 The highway network was updated with proposed changes to the highway network between 2016 and 2020.

City Centre

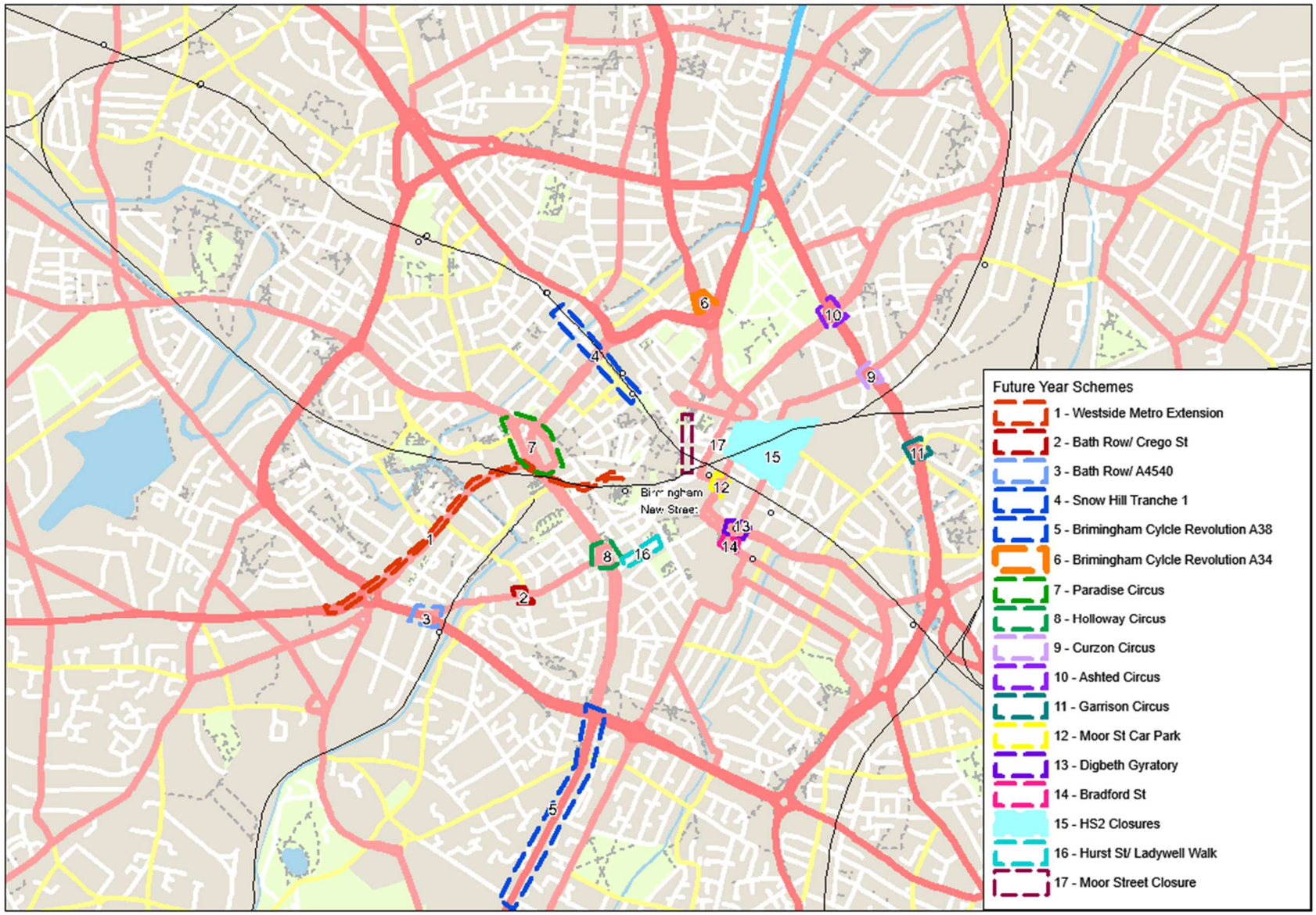
1.3 The majority of changes to the highway network are focused on the City Centre within the CAZ zone or on the A4540 inner ring road. A list of schemes to be included was agreed with BCC streets team and are described in Table 1.1 and shown on the map in Figure 1-1 below. Given the short timescales all schemes are c or near certain. The only difference between the 2020 and 2022 scenarios is the opening of the Westside Metro extension, however the construction of the scheme will start in 2019 and we have assumed the highway network changes will be in place by 2020.

Table 1.1: City Centre Network Schemes

Scheme ID	Scheme Name	Description
1	Midland Metro (Centenary Sq. / Edgbaston)	Extension of the metro line from Grand Central to Centenary Square and Edgbaston (Hagley Road) via Broad Street with associated re-routeing of private vehicles. Grand Central to Centenary Square will be complete by 2020. Centenary Square to the Five Ways junction will be under construction, with the assumption, taken that the highway impacts will affectively be the same as when the Metro is in operation. This includes the Navigation Street Scheme.
2	Bath Row / Cregoe St	Signalisation of junction to complement Midland Metro works
3	Bath Row / Ring Road	Signalised right turn from Bath Row onto A4540 Ring Road.

Scheme ID	Scheme Name	Description
4	Snow Hill Tranche 1	Closure of right turn from Livery Street to Colmore Row with changes to lane allocations, re-routeing of bus routes and reconfiguring junctions. Livery Street partially made 2-way and bus gate added on Lionel Street.
5	Birmingham Cycle Revolution A38 Improvements	Changes to several junctions including addition of right turn from Bristol Road to Wellington Road and southbound lane reallocation at Lee Bank Middleway Junction. Conversion of Wrentham Street to a 1-way arrangement and Gooch Street to a 2-way arrangement.
6	Birmingham Cycle Revolution A34 Improvements	Narrowing of Newtown Row northbound exit from Lancaster Circus junction. Majority of other scheme works are offline.
7	Paradise Circus	Temporary construction traffic management arrangement re-coded to represent final arrangement, opening access up to Spring Hill and including new access points for underground car park. Broad Street re-opened to buses.
8	Holloway Circus	Installation of a left slip road on the Holloway Head approach.
9	Curzon Circle	Part of HS2 mitigation. Roundabout removed and replaced with signalised junction. Signal staging timings based on designs provided by HS2.
10	Ashted Circus	Roundabout removed and replaced with signalised junction.
11	Garrison Circus	Part of HS2 mitigation. Roundabout removed and replaced with signalised junction. Signal staging timings based on designs provided by HS2.
12	Moor St Car Park Left Turn Only	Left turn only out of Moor St car park.
13	Digbeth Gyratory SE Loop	Bus only turn implemented banning eastbound general traffic from turning right towards Barford Street.
14	Bradford St	Right turn into Barford Street removed.
15	HS2 Closures	Road closures associated with HS2 Curzon Street Station. Includes partial removal of Park Street, Fazeley Street, Banbury Street. Under construction, but closures relating to
16	Hurst Street/Ladywell Walk – Pedestrianised (Follow on from the closure of Hurst Street)	This includes the reversal of Thorpe Street direction.
17	Moor Street Queensway Closure	Moor Street Queensway closed to general traffic to create Public Transport/ Walk/ Cycle corridor

Figure 1-1: Network Schemes



External Fixed Speed Network

1.4 The fixed speed network has been updated using assumptions of changes in average speeds on the network, using the same approach as in the BCC 2026 model updated, where "changes have been applied based on the proportional change in average speed taken from NRTF core scenario 1 for the West Midlands"[6]. The table below shows the assumed reduction in speeds of 5% which was applied to the 2016 model speeds. It should be noted that the speeds shown are those from the NRFT data used to calculate the adjustment factor rather than the actual modelled speeds in the study area.

Table 1.2: Change in Average Speeds derived from the NRTF data

Year	Average Speed in NRTF
2016	31.9 kph
2020	30.3 kph
% Change 2016-20	-5%

Highways England

1.5 We have discussed with HE whether there any changes or planned roadworks to the strategic network are likely to have an impact on traffic flows in Birmingham. Our understanding, based on the table of assumptions describing the Smart Motorways Programme (SMP) including 'start of works' and 'open for traffic' dates for the SMP programme is that these works will not affect Birmingham in 2020, as they either occur post 2020 or is geographically out of scope for this study.[7]

1.6 Road schemes that are proposed to be in construction in the period from the end of 2020 are:

- M40-M42 Interchange
- M5/M42 Birmingham Box 4

1.7 While these roads are on the Birmingham Motorway Box, they are some miles outside of Birmingham and to the south where there are less air quality issues. The roadworks are therefore not likely to have any impacts on air quality within Birmingham, but we will work with HE to ensure that any issues with these roadworks are considered when implementing the scheme.

Assignment Parameters

1.8 WebTAG guidance on adjusting values of time and vehicle operating costs were applied to the 2016 values. The updates follow guidance in Unit 3.5.6/ Unit A 1.3 and the associated databook from the July 2017 release v1.8[8]. The 2016 and adjusted 2020 values as input into the BCC model are shown in Table 1.3 and Table 1.4.

Table 1.3: 2016 Values of Time in Pence per Minute

User Class	AM	IP	PM
Car Business/ Taxi	30.20	30.90	30.63

[6] Birmingham City Centre Model Traffic Forecasting Report Birmingham City Council 5 May 2017

[7] "PROGRAMME SCHEDULE OVERVIEW", attached in email from HE 09/08/2017

[8] WebTAG Databook, A1.3.2, A1.3.11 and A1.3.11, July 2017

Car Other	17.30	15.70	17.29
LGV	21.30	21.30	21.34
HGV	43.30	43.30	43.34

Table 1.4: 2016 and 2020 Vehicle Operating Costs in Pence per Kilometre

User Class	AM	IP	PM
Car Business/ Taxi	15.20	15.20	15.20
Car Other	6.83	6.83	6.83
LGV	14.19	14.19	14.19
HGV	49.32	49.32	49.32

Table 1.5: 2016 and 2020 Values of Time in Pence per Minute

User Class	AM		IP		PM	
	2020	2022	2020	2022	2020	2022
Car Business/ Taxi	31.57	32.50	32.30	33.25	32.02	32.96
Car Other	18.09	18.62	16.41	16.90	18.07	18.61
LGV	22.27	22.92	22.27	22.92	22.31	22.96
HGV	45.27	46.60	45.27	46.60	45.31	46.64

Table 1.6: 2016 and 2020 Vehicle Operating Costs in Pence per Kilometre

User Class	AM		IP		PM	
	2020	2022	2020	2022	2020	2022
Car Business/ Taxi	14.94	14.87	14.94	14.87	14.94	14.87
Car Other	6.63	6.59	6.63	6.59	6.63	6.59
LGV	14.44	14.63	14.44	14.63	14.44	14.63
HGV	51.54	53.68	51.54	53.68	51.54	53.68

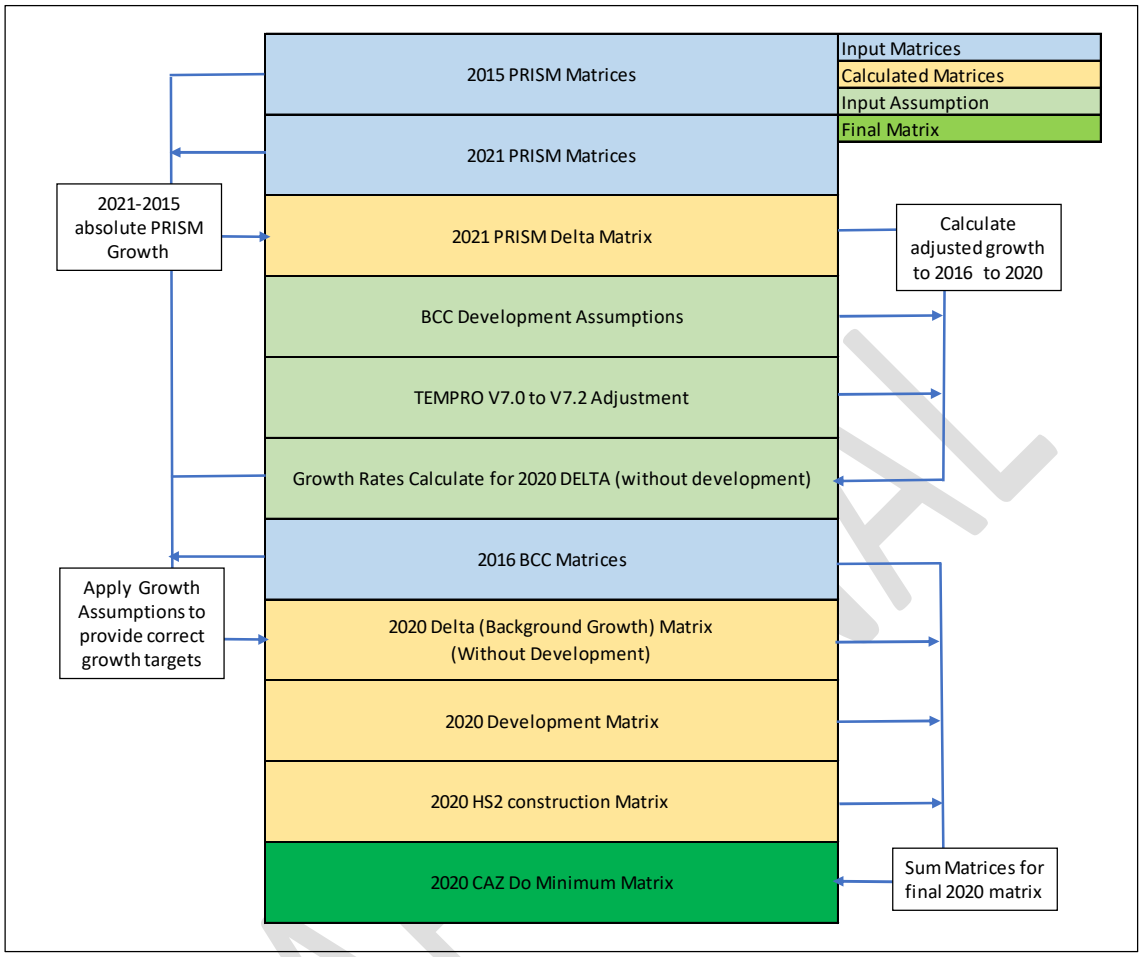
Traffic Growth

2020 Methodology

1.9 Figure 1-2 below gives an overview of the methodology applied to produce the 2020 CAZ Do Minimum matrices. This involves the following steps which are described in more detail below:

- Creating a delta matrix by subtracting the 2015 PRISM matrices from the future 2021 PRISM matrices.
- Calculating the compound annual growth rates (CAGR) at a sector level and adjusting the overall growth to represent 2016 to 2020 levels.
- Ensuring that specific major development's traffic demand, are located in the correct places
- Include traffic related to HS2

Figure 1-2: Traffic Growth Methodology



PRISM Delta Matrix

1.10 Overall traffic growth is derived from the regional PRISM[9] model. The PRISM model is a full demand model forecasting the growth in journeys across all modes and has been used on major scheme bids in the West Midlands and by Transport for the West Midlands in their regional planning. PRISM has the following advantages:

- WebTAG compliant demand model, including forecasts of mode share
- Recently updated using planning data from TEMPRO version 7.0
- Areas of new developments are more spatially accurate than TEMPRO
- Provides consistency with the CAZ forecasting, which uses behavioural responses to user charging in PRISM.

1.11 The Delta Matrix is created by subtracting the 2015 matrix from the 2021. This creates the absolute growth to 2021 as forecast by the PRISM model. However further processing is required to ensure that the growth forecasts represent a 2016 to 2020 period and that the development trips are included in the correct locations.

[9] http://217.206.77.231/prism/pages/About.aspx

Background Growth

1.12 As described above the overall growth has been implemented using a pivot point/ delta approach, by applying the growth implied by the PRISM forecast 2021 (*Sf*) and base 2015 (*Sb*) year matrices to the CAZ model 2016 base year matrices (*B*) to estimate the 2020 forecast year matrices (*F*). This includes a linear adjustments (*a*) to reflect that the base and future year of the CAZ model is different from the PRISM forecast year, and to reflect that PRISM was updated using TEMPRO V7.0 rather than V7.2. The exact calculations followed the formula shown below.

$$F = B \times \frac{S_f}{S_b} \times a$$

1.13 To ensure that development trips are located in the correct locations, a separate process was undertaken to derive demand related to specific development sites (described below in this chapter). Where developments had been included in PRISM trips were removed and the overall growth scaled so that it equals the correct level once the development trips are added back in.

1.14 As mentioned above the starting PRISM year is 2015 compared to the BCC base of 2016. Therefore, analysis of TEMPRO was carried out to check growth between 2015 and 2016 before applying the adjustment. Growth rates in TEMPRO v7.2 indicated that car traffic remained flat between 2015 and 2016 in Birmingham.

1.15 To address the flat traffic growth, a new growth rate was calculated assuming that the demand matrices would remain at the same level between 2015 and 2016. Therefore, the annual growth rates were calculated over a 5-year rather than a 6-year period, but assuming the overall growth would get to the same level by 2021, although starting from 2016.

1.16 LGV and HGV growth is assumed to be less volatile and therefore the growth rates were applied directly with no similar adjustment made to these vehicle classes.

TEMPRO V7.0 to V7.2 Adjustment

1.17 An additional adjustment factor was applied to the demand based on the difference in the planning data between the two versions of TEMPRO, to ensure the overall model growth is reflecting the latest government forecasts. We extracted the data from TEMPRO, as shown in Table 2 below, which shows the difference in growth rates between the two versions. To adjust the demand, we took a simplified approach and factored down the demand by 0.2% across the model.

Table 1.7: Difference in Growth Rate 2015 to 2021 for Population and Workers (TEMPRO V7.0 to V7.2)

Sector	Population	Workers
City Centre	-0.2%	-0.7%
Birmingham West (3)	-0.2%	-0.7%
Birmingham North (4)	-0.2%	-0.7%
Birmingham South West (5)	-0.2%	-0.8%
Birmingham East/South East (6)	-0.2%	-0.7%
Total	-0.2%	-0.7%

Developments

1.18 To verify the locations of growth implied by PRISM matrices on the CAZ model future growth, the distribution of incremental trip ends during the modelled periods was compared against trip generation data from city centre developments.

1.19 While producing the 2026 BCC model, Atkins went through an exercise of reviewing transport assessments (TA) to derive the incremental demand for the various developments in Birmingham. These were reviewed by ourselves and BCC development planners who confirmed which developments should be included in the model by 2020 (given the short timescales to 2020, only those developments considered to be 'near certain' are included).

1.20 Adjustments were made during the process to ensure that the development trips were incorporated correctly:

- Where new developments replace existing sites, trips related to the old developments were removed from the new target totals.
- Comparisons were made against the PRISM matrix growth in the development locations with trips removed from the Delta matrix so that these locations were not overloaded by double counting the sites trip generation.

1.21 The total trips derived for each employment and residential site are shown in two tables on the following page respectively, and their locations in Figure 1-3 (sites 20 and 21 are related to HS2 construction and are discussed later in the chapter). In creating the development matrix, the distribution for the development sites were taken from the 2026 BCC model, which are based on the distribution of similar neighbouring land uses.

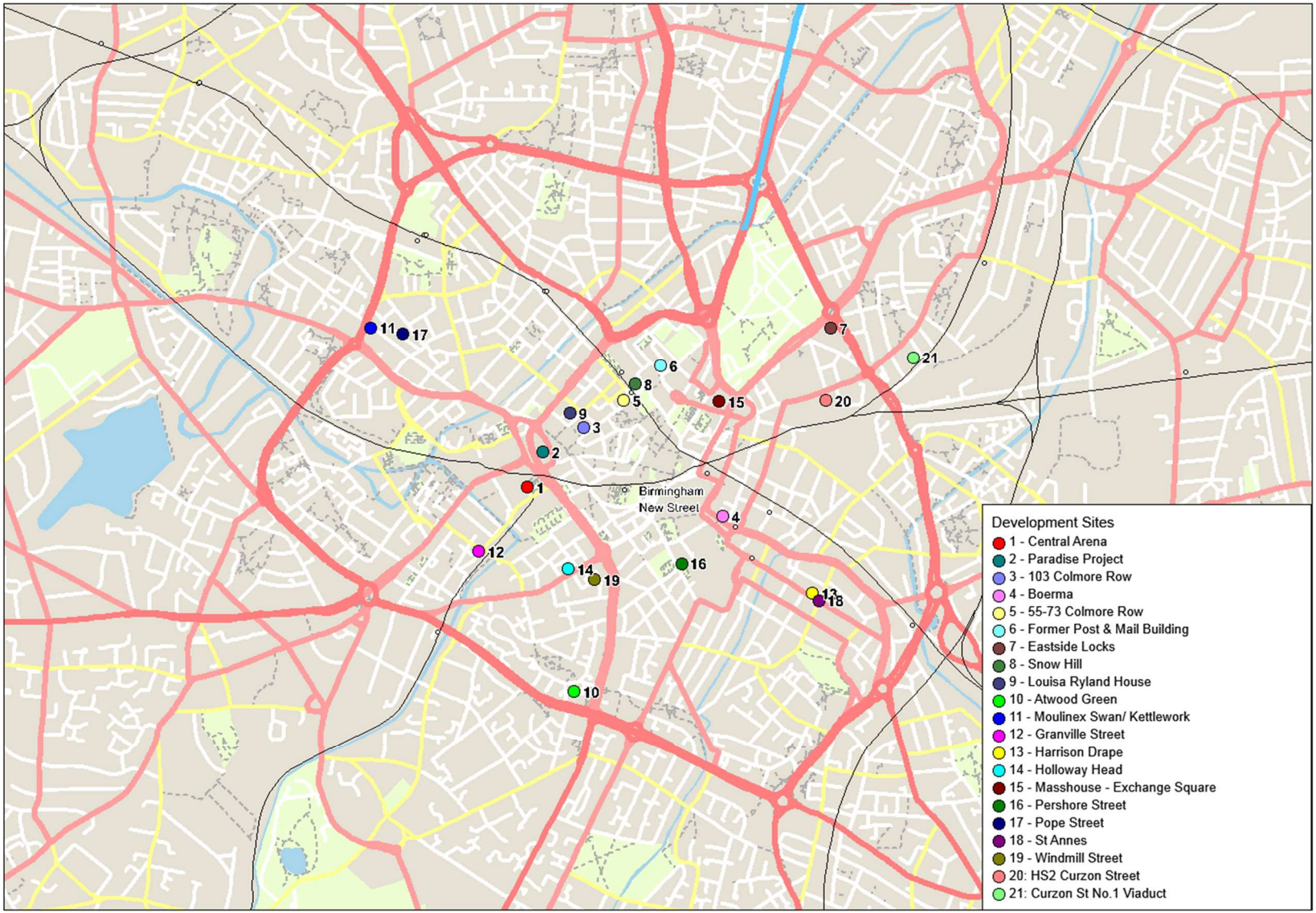
Table 1.8: Developments' Employment Vehicle Trips

Development Site	Map ID	AM Peak		Inter Peak		PM Peak	
		In	Out	In	Out	In	Out
ARENA CENTRAL PLOT D	1	83	5	4	3	6	66
ARENA CENTRAL PLOT A	1	86	5	4	3	6	68
ARENA CENTRAL PLOT C	1	128	8	6	5	9	102
PARADISE PROJECT	2	468	42	61	25	93	419
103 COLMORE ROW	3	161	31	46	38	38	136
55-73 COLMORE ROW	5	35	22	30	26	26	39
'BOERMA' - PHASE 2	4	9	2	4	3	3	7
FORMER POST & MAIL BUILDING	6	161	32	22	19	33	134
EASTSIDE LOCKS PHASE1	7	12	6	8	7	7	13
EASTSIDE LOCKS PHASE 1(BUILDING 5)	7	14	1	0	0	1	12
SNOW HILL SITE 3	8	85	13	8	7	13	76
LOUISA RYLAND HOUSE	9	46	7	1	4	2	45

Table 1.9: Developments' Residential Vehicle Trips

Development Site	Map ID	AM Peak		Inter Peak		PM Peak	
		In	Out	In	Out	In	Out
ARENA CENTRAL PLOT G.	1	18	40	18	24	27	21
ATTWOOD GREEN ZONE 11	10	13	34	26	20	39	22
FORMER MOULINEX SWAN / KETTLEWORKS	11	33	62	44	37	68	41
GRANVILLE STREET	12	5	15	8	9	13	7
HARRISON DRAPE	13	17	21	14	12	22	20
HOLLOWAY HEAD PHASE 1	14	3	12	8	7	12	4
MASSHOUSE: "EXCHANGE SQUARE"	15	12	37	31	22	47	28
PERSHORE STREET	16	18	22	7	13	11	14
SGUV-1: POPE STREET	17	25	47	34	28	51	31
ST.ANNES	18	10	30	25	18	39	16
WINDMILL STREET	19	8	39	26	23	40	14

Figure 1-3: Development Sites



HS2 Construction Traffic

1.22 The TA for HS2 published by DfT and HS2 ltd[10] has forecasts of construction traffic across all the development compounds across the HS2 route. The two main sites relevant to Birmingham city centre (see Figure 1-3 above for site location) are at Curzon Street and another just outside the ring road.

1.23 While other sites are listed they tend to be operational for a shorter time, and may not cover the 2020 modelled year. To avoid the HS2 forecasts being too conservative we have assumed that the two sites will be operating at their busiest period during 2020.

1.24 The TA publishes traffic at the daily level as shown in Table 1.10, with Table 1.11 showing the factors used convert to the modelled periods assuming predominant arrivals departures of car/LHV trips are in the morning and evening peak respectively, with HGV arrivals and departures timed to avoid the peak traffic periods where possible. Industry standard assumptions were taken on how this demand would be distributed across the day. Table 1.9 to Table 1.11 show the traffic levels generated using these assumptions.

Table 1.10: Daily Vehicles Busiest Period

Location	Map ID	Car	HGV
Curzon Street No. 1 viaduct (Duddeston Mill Rd)	21	60	25
Curzon Street No. 3 viaduct (Curzon St)	20	150	40

Table 1.11: Daily to Model Period Factors

Time period	Car/ LGV		HGV		Hours
	IB	OB	IB	OB	Hours
AM	0.70	0.10	0.30	0.05	2
IP	0.20	0.20	0.65	0.65	6
PM	0.10	0.70	0.05	0.30	3.5

Table 1.12: AM Peak HS2 Additional PCUs

Location	Car/ LGV		HGV	
	Inbound	Outbound	Inbound	Outbound
Curzon Street No. 1 viaduct (Duddeston Mill Rd)	21	3	4	1
Curzon Street No. 3 viaduct (Curzon St)	53	8	6	1
Total	**74**	**11**	**10**	**2**

[10] London-West Midlands ENVIRONMENTAL STATEMENT, Volume 5 | Technical Appendices

Transport Assessment (TR-001-000) Part 8: West Midlands assessment Traffic and Transport, HS2 Ltd, November 2013

Table 1.13: Inter Peak HS2 Additional PCUs

Location	Car		HGV	
	Inbound	Outbound	Inbound	Outbound
Curzon Street No. 1 viaduct (Duddeston Mill Rd)	2	2	3	3
Curzon Street No. 3 viaduct (Curzon St)	5	5	4	4
Total	**7**	**7**	**7**	**7**

Table 1.14: PM Peak HS2 Additional PCUs

Location	Car		HGV	
	Inbound	Outbound	Inbound	Outbound
Curzon Street No. 1 viaduct (Duddeston Mill Rd)	2	12	0	2
Curzon Street No. 3 viaduct (Curzon St)	4	30	1	3
Total	**6**	**42**	**1**	**6**

Final Growth Rates

1.25 The process described above resulted in 3 demand matrices in each time period:

1. Delta Matrix scaled to correct 2016-20 growth at the sector level with development trips removed
2. Development Trip matrix
3. HS2 matrix

1.26 These matrices are summed together to create the final do minimum matrices, which results in the following growth rates for the different time periods.

Table 1.15: AM Peak Growth Rates

Sector	CAR			LGV			HGV		
	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	7.0%	8.4%	7.9%	10.7%	10.9%	10.8%	3.3%	3.7%	3.5%
Rest of Birmingham	4.2%	3.1%	3.7%	10.7%	10.8%	10.7%	3.1%	3.2%	3.2%
Birmingham (Total)	***4.5%***	***3.9%***	***4.2%***	***10.7%***	***10.8%***	***10.7%***	***3.2%***	***3.2%***	***3.2%***
Rest of West Midlands	4.1%	4.7%	4.4%	10.7%	10.6%	10.6%	2.9%	2.9%	2.9%
Total	**4.3%**	**4.3%**	**4.3%**	**10.7%**	**10.7%**	**10.7%**	**3.0%**	**3.0%**	**3.0%**

Table 1.16: Inter Peak Growth Rates

Sector	CAR			LGV			HGV		
	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	8.1%	7.9%	8.0%	10.7%	10.8%	10.8%	3.6%	3.6%	3.6%
Rest of Birmingham	3.7%	3.7%	3.7%	10.7%	10.7%	10.7%	3.1%	3.1%	3.1%
Birmingham (Total)	***4.2%***	***4.2%***	***4.2%***	***10.7%***	***10.7%***	***10.7%***	***3.2%***	***3.2%***	***3.2%***
Rest of West Midlands	5.4%	5.3%	5.3%	10.7%	10.7%	10.7%	2.9%	2.9%	2.9%
Total	**4.7%**	**4.7%**	**4.7%**	**10.7%**	**10.7%**	**10.7%**	**3.0%**	**3.0%**	**3.0%**

Table 1.17: PM Peak Growth Rates

Sector	CAR			LGV			HGV		
	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	8.2%	6.3%	7.4%	10.7%	10.8%	10.7%	3.8%	3.4%	3.6%
Rest of Birmingham	3.3%	4.2%	3.7%	10.7%	10.7%	10.7%	3.1%	3.1%	3.1%
Birmingham (Total)	**3.9%**	**4.4%**	**4.1%**	**10.7%**	**10.7%**	**10.7%**	**3.2%**	**3.1%**	**3.2%**
Rest of West Midlands	4.8%	4.4%	4.6%	10.8%	10.8%	10.8%	2.9%	3.0%	3.0%
Total	**4.4%**	**4.4%**	**4.4%**	**10.7%**	**10.7%**	**10.7%**	**3.0%**	**3.0%**	**3.0%**

Comparison With NTEM

1.27 As a benchmarking exercise, the outcome of this process has been compared against the DfT's National Trip End Model's (NTEM) forecasts. For LGV and HGVs results are very similar (see Figure 1-4 below) with growth rates within 0.5% of the NTEM forecasts, but there are some differences with the car forecasts.

1.28 Table 1.15 to Table 1.20 shows a comparison of all car trips between NTEM (v7.2) and BCC. These totals have then been aggregated to 3-sector level showing the CAZ zone, rest of Birmingham and rest of the modelled area for 2016-20.

Table 1.18: AM Peak Growth Rates 2016 to 2020 Car – Comparison of BCC and NTEM

City Centre	BCC	NTEM	Difference
City Centre	7.9%	4.6%	3.3%
Rest of Birmingham	3.7%	5.1%	-1.4%
Birmingham (Total)	***4.2%***	***5.0%***	***-0.8%***
Rest of West Midlands	4.4%	4.8%	-0.4%
Total	**4.3%**	**4.8%**	**-0.6%**

Table 1.19: Inter Peak Growth Rates 2016 to 2020 Car – Comparison of BCC and NTEM

City Centre	BCC	NTEM	Difference
City Centre	8.0%	5.1%	2.9%
Rest of Birmingham	3.7%	5.5%	-1.8%
Birmingham (Total)	***4.2%***	***5.5%***	***-1.3%***
Rest of West Midlands	5.3%	3.8%	1.5%
Total	4.7%	4.8%	-0.1%

Table 1.20: PM Peak Growth Rates 2016 to 2020 Car – Comparison of BCC and NTEM

City Centre	BCC	NTEM	Difference
City Centre	7.4%	4.5%	2.8%
Rest of Birmingham	3.7%	4.9%	-1.2%
Birmingham (Total)	***4.1%***	***4.9%***	***-0.7%***
Rest of West Midlands	4.6%	4.8%	-0.2%
Total	**4.4%**	**4.8%**	**-0.5%**

1.29 The main differences between the forecasts are at the spatial level with PRISM forecasting larger levels of traffic growth within the City Centre compared to the rest of the city. This is plausible given that the main development sites within the City over the next few years are scheduled for the City Centre. In addition, the City Centre has had major works around Paradise Circus in recent years which has caused disruption to traffic flows, with this work scheduled to finish by 2020 there is the potential for better traffic management at this key part of the city centre allowing for some traffic growth.

1.30 To summarise the overall Birmingham growth rates are similar between TEMPRO and those applied in the BCC model particularly in the AM and PM peaks with total growth within 1%. In addition, the higher growth in the City Centre is in line with the locations of growth in Birmingham in terms of population and job development sites. We therefore adopted the growth rates derived from the processes set out above for the 2020 modelling of the CAZ.

Figure 1-4: Matrix Totals, Growth and Comparison with NTEM Forecasts

2016 _Base Year

AM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Sector	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	7,559	14,792	22,351	1,234	1,586	2,820	1,287	1,584	2,871
Rest of Birmingham	84,066	83,422	167,488	13,067	13,668	26,735	9,084	9,508	18,592
BirminghamTotal	91,625	98,214	189,840	14,302	15,253	29,555	10,371	11,092	21,463
Rest of Model	110,035	103,446	213,481	21,261	20,309	41,570	20,949	20,227	41,176
Total	201,660	201,660	403,321	35,562	35,562	71,125	31,320	31,320	62,639

Inter Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
9,943	10,293	20,237	1,279	1,294	2,573	1,029	1,077	2,106	
84,083	81,663	165,746	11,697	11,272	22,969	9,034	9,331	18,365	
94,026	91,956	185,983	12,976	12,566	25,542	10,063	10,408	20,471	
89,022	91,093	180,115	16,519	16,929	33,448	25,775	25,430	51,205	
183,049	183,049	366,098	29,495	29,495	58,990	35,838	35,838	71,676	

PM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
14,880	10,748	25,628	934	686	1,621	485	418	903	
104,089	101,467	205,556	11,154	10,714	21,868	4,164	4,688	8,853	
118,969	112,215	231,184	12,088	11,400	23,489	4,649	5,107	9,756	
118,255	125,010	243,266	15,605	16,293	31,897	13,810	13,352	27,163	
237,225	237,225	474,450	27,693	27,693	55,386	18,459	18,459	36,918	

2020 Do Miniumum

AM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Sector	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	8,087	16,031	24,118	1,366	1,758	3,125	1,330	1,643	2,973
Rest of Birmingham	87,626	85,978	173,603	14,464	15,143	29,607	9,370	9,808	19,178
BirminghamTotal	95,713	102,009	197,721	15,830	16,901	32,731	10,699	11,451	22,151
Rest of Model	114,572	108,276	222,848	23,530	22,459	45,990	21,565	20,814	42,379
Total	210,285	210,285	420,569	39,360	39,361	78,721	32,265	32,265	64,530

Inter Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
10,746	11,104	21,850	1,416	1,434	2,850	1,066	1,116	2,181	
87,185	84,703	171,887	12,948	12,478	25,426	9,318	9,624	18,942	
97,931	95,806	193,737	14,363	13,913	28,276	10,383	10,740	21,123	
93,806	95,931	189,737	18,283	18,734	37,017	26,534	26,178	52,712	
191,737	191,737	383,474	32,647	32,647	65,293	36,917	36,918	73,835	

PM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
16,097	11,421	27,517	1,034	760	1,794	503	432	935	
107,559	105,692	213,251	12,347	11,856	24,203	4,295	4,834	9,129	
123,656	117,113	240,769	13,380	12,617	25,997	4,798	5,267	10,065	
123,927	130,470	254,396	17,289	18,053	35,342	14,217	13,748	27,965	
247,582	247,583	495,165	30,670	30,670	61,340	19,015	19,015	38,030	

2020 - 2016 Growth (CAZ Model)

AM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Sector	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	7.0%	8.4%	7.9%	10.7%	10.9%	10.8%	3.3%	3.7%	3.5%
Rest of Birmingham	4.2%	3.1%	3.7%	10.7%	10.8%	10.7%	3.1%	3.2%	3.2%
BirminghamTotal	4.5%	3.9%	4.2%	10.7%	10.8%	10.7%	3.2%	3.2%	3.2%
Rest of Model	4.1%	4.7%	4.4%	10.7%	10.6%	10.6%	2.9%	2.9%	2.9%
Total	4.3%	4.3%	4.3%	10.7%	10.7%	10.7%	3.0%	3.0%	3.0%

Inter Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
8.1%	7.9%	8.0%	10.7%	10.8%	10.8%	3.6%	3.6%	3.6%	
3.7%	3.7%	3.7%	10.7%	10.7%	10.7%	3.1%	3.1%	3.1%	
4.2%	4.2%	4.2%	10.7%	10.7%	10.7%	3.2%	3.2%	3.2%	
5.4%	5.3%	5.3%	10.7%	10.7%	10.7%	2.9%	2.9%	2.9%	
4.7%	4.7%	4.7%	10.7%	10.7%	10.7%	3.0%	3.0%	3.0%	

PM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
8.2%	6.3%	7.4%	10.7%	10.8%	10.7%	3.8%	3.4%	3.6%	
3.3%	4.2%	3.7%	10.7%	10.7%	10.7%	3.1%	3.1%	3.1%	
3.9%	4.4%	4.1%	10.7%	10.7%	10.7%	3.2%	3.1%	3.2%	
4.8%	4.4%	4.6%	10.8%	10.8%	10.8%	2.9%	3.0%	3.0%	
4.4%	4.4%	4.4%	10.7%	10.7%	10.7%	3.0%	3.0%	3.0%	

2020 - 2016 Growth (TEMPRO)

AM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Sector	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	6.0%	4.1%	4.6%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%
Rest of Birmingham	5.7%	4.3%	5.1%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%
BirminghamTotal	5.8%	4.3%	5.0%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%
Rest of Model	4.7%	4.8%	4.8%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%
Total	5.1%	4.6%	4.8%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%

Inter Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
4.9%	5.3%	5.1%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	
5.5%	5.6%	5.5%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	
5.4%	5.5%	5.5%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	
4.5%	3.3%	3.8%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	
5.1%	4.6%	4.8%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	

PM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
4.1%	5.4%	4.5%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	
4.5%	5.4%	4.9%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	
4.4%	5.4%	4.9%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	
5.5%	4.2%	4.8%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	
5.1%	4.6%	4.8%	10.2%	10.2%	10.2%	3.1%	3.1%	3.1%	

2020 - 2016 Growth (TEMPRO)

AM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Sector	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	1.0%	4.3%	3.3%	0.5%	0.7%	0.6%	0.3%	0.6%	0.5%
Rest of Birmingham	-1.5%	-1.3%	-1.4%	0.4%	0.6%	0.5%	0.1%	0.1%	0.1%
BirminghamTotal	-1.3%	-0.4%	-0.8%	0.4%	0.6%	0.5%	0.1%	0.1%	0.1%
Rest of Model	-0.6%	-0.1%	-0.4%	0.4%	0.3%	0.4%	-0.1%	-0.2%	-0.2%
Total	-0.8%	-0.3%	-0.6%	0.4%	0.4%	0.4%	-0.1%	-0.1%	-0.1%

Inter Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
3.2%	2.6%	2.9%	0.4%	0.6%	0.5%	0.5%	0.5%	0.5%	
-1.8%	-1.8%	-1.8%	0.4%	0.5%	0.5%	0.1%	0.1%	0.1%	
-1.3%	-1.3%	-1.3%	0.4%	0.5%	0.5%	0.1%	0.1%	0.1%	
0.9%	2.1%	1.5%	0.4%	0.4%	0.4%	-0.1%	-0.1%	-0.1%	
-0.3%	0.1%	-0.1%	0.4%	0.4%	0.4%	-0.1%	-0.1%	-0.1%	

PM Peak

	1	1		2	2		3	3	
	Car			LGV			HGV		
Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total	
4.1%	0.8%	2.8%	0.4%	0.5%	0.5%	0.7%	0.3%	0.5%	
-1.1%	-1.2%	-1.2%	0.5%	0.4%	0.4%	0.0%	0.0%	0.0%	
-0.5%	-1.0%	-0.7%	0.4%	0.4%	0.4%	0.1%	0.0%	0.1%	
-0.8%	0.2%	-0.2%	0.6%	0.6%	0.6%	-0.1%	-0.1%	-0.1%	
-0.7%	-0.3%	-0.5%	0.5%	0.5%	0.5%	-0.1%	-0.1%	-0.1%	

2022 Scenario Growth

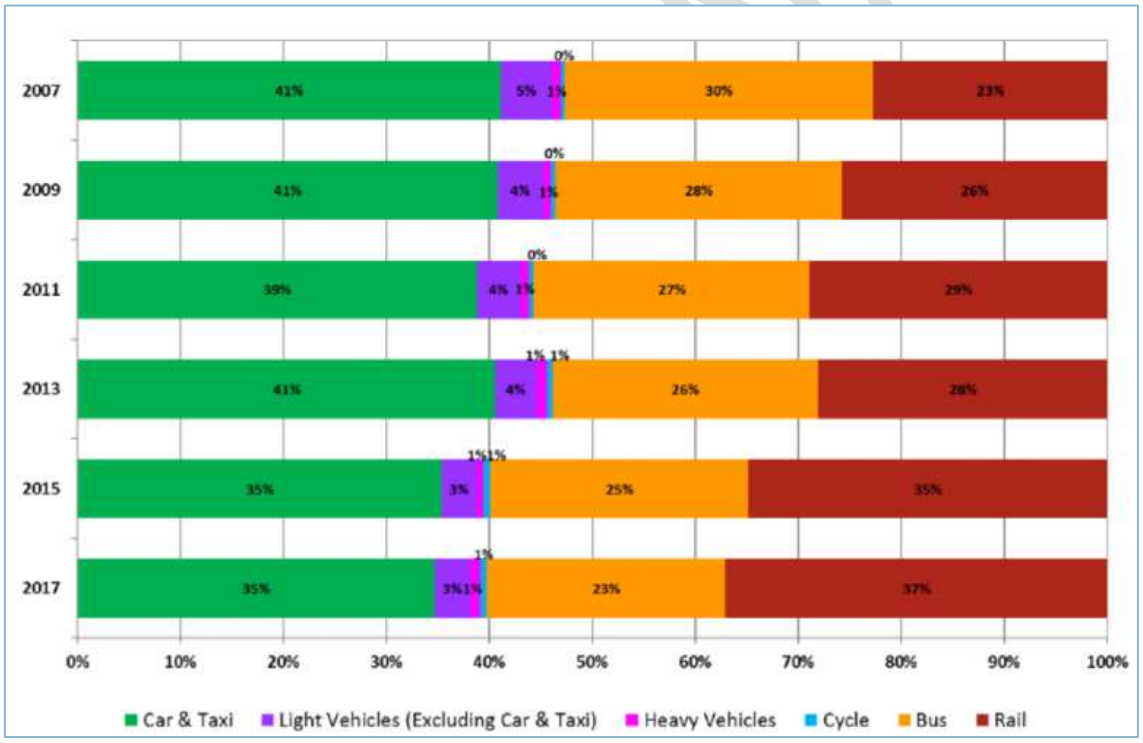
1.31 In addition to the core 2020 scenario, a further future year representing 2022 has been created to assess air quality beyond the CAZ opening year. Traffic growth for the period between 2020 and 2022 is derived from TEMPRO (Version 7.2).

1.32 Before applying the growth, further analysis was carried out on recent trends in car traffic in the City Centre. The Birmingham City Centre cordon survey is carried out every two years and includes an assessment of changes in mode shares into the City Centre. Car mode shares fell significantly between 2013 and 2015, and remained stable from 2015 and 2017.

1.33 There will be reductions in highway capacity in the City Centre with the Moor St Queensway Closure and Metro Extension (on-street running). There will also as improvements in the public transport network between 2020 and 2022:

- New stations on the Camp Hill Line
- New Bus Rapid Transit (SPRINT) routes
- Westside Midland Metro Extension

Figure 1.5: AM Peak Mode Shares from the Birmingham Cordon Survey



Source: Birmingham City Council, Cordon Counts, presentation to 'Sustainability and Transport Overview and Scrutiny Committee', 8 November 2018

1.34 Given these recent trends and the increased attractiveness in non-highway modes due to changes to the transport network it is unlikely that the car mode share will increase in the coming years. However, TEMRPO forecasts an increase in car trips into the City Centre. Therefore, to produce more realistic forecasts the overall growth rates to/from the city centre are constrained to the total growth across all modes with the car mode share remaining constant between 2020 and 2022.

Table 1.21: Change in 2020-2022 Growth Rates

Car Growth	Growth
TEMPRO Forecasts	2.0%
TEMPRO (Assuming Flat Mode Share 2020-2022)	0.4%
Reduction in 2022 Traffic to/from City Centre	-1.5%

Table 1.22: AM Peak Growth Rates 2020 to 2022

Sector	CAR			LGV			HGV		
	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	0.4%	0.4%	0.4%	4.7%	4.7%	4.7%	0.8%	0.8%	0.8%
Rest of Birmingham	2.1%	2.1%	2.1%	4.7%	4.7%	4.7%	0.8%	0.8%	0.8%
Birmingham (Total)	2.0%	1.9%	1.9%	4.7%	4.7%	4.7%	0.8%	0.8%	0.8%
Rest of West Midlands	1.9%	1.9%	1.9%	4.7%	4.7%	4.7%	1.2%	1.2%	1.2%
Total	2.0%	1.9%	1.9%	4.7%	4.7%	4.7%	1.1%	1.1%	1.1%

Table 1.23: Inter Peak Growth Rates 2020 to 2022

Sector	CAR			LGV			HGV		
	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	0.4%	0.4%	0.4%	4.7%	4.7%	4.7%	0.8%	0.8%	0.8%
Rest of Birmingham	2.1%	2.1%	2.1%	4.7%	4.7%	4.7%	0.8%	0.8%	0.8%
Birmingham (Total)	1.9%	1.9%	1.9%	4.7%	4.7%	4.7%	0.8%	0.8%	0.8%
Rest of West Midlands	1.9%	1.9%	1.9%	4.7%	4.7%	4.7%	1.2%	1.2%	1.2%
Total	1.9%	1.9%	1.9%	4.7%	4.7%	4.7%	1.1%	1.1%	1.1%

Table 1.24: PM Peak Growth Rates 2020 to 2022

Sector	CAR			LGV			HGV		
	Origin	Destination	Total	Origin	Destination	Total	Origin	Destination	Total
City Centre	0.4%	0.4%	0.4%	4.7%	4.7%	4.7%	0.8%	0.8%	0.8%
Rest of Birmingham	2.1%	2.1%	2.1%	4.7%	4.7%	4.7%	0.8%	0.8%	0.8%
Birmingham (Total)	1.9%	2.0%	1.9%	4.7%	4.7%	4.7%	0.8%	0.8%	0.8%
Rest of West Midlands	1.9%	1.9%	1.9%	4.7%	4.7%	4.7%	1.2%	1.2%	1.2%
Total	1.9%	1.9%	1.9%	4.7%	4.7%	4.7%	1.1%	1.1%	1.1%

Fleet Mix

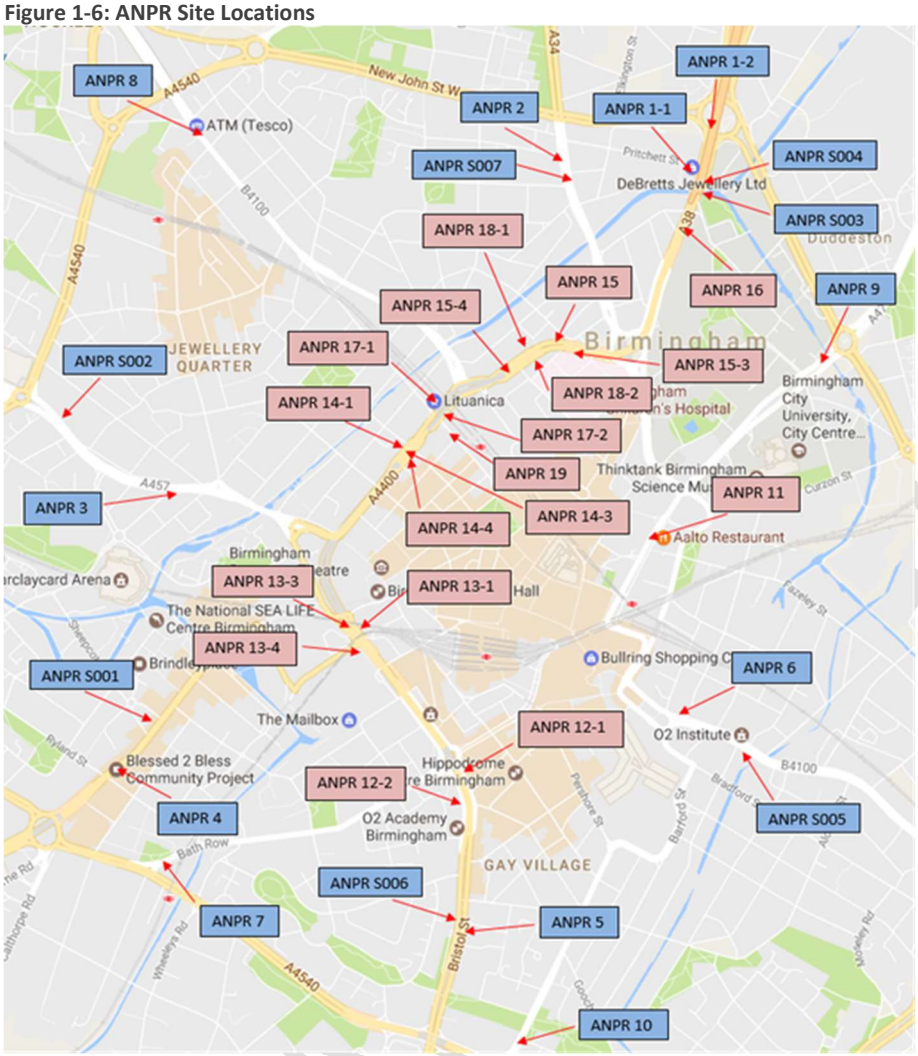
1.35 An additional step in creating the do minimum is in deriving compliant and non-compliant vehicle splits. This is important for the AQ modelling and is also a key input into the CAZ forecasting

1.36 The base year fleet mix data was derived from ANPR surveys in and around the city centre undertaken by specialist data collection company, Intelligent Data Collection (ID)[11], for a 7-day period commencing Tuesday 8th November 2016. ID installed cameras at 29 unique locations and these were supplemented by a further 7 existing sites which are managed by Amey on behalf of BCC. The following diagram shows the location of each site, with pink sites representing the city centre and blue sites representing a cordon of entry/exit points to the city centre.

1.37 The collection of vehicle registration plate data was then matched to the DVLA database providing various information about the vehicle. This includes providing a breakdown of different Euro Class emission standards by vehicle class.

[11] **City Centre Data Collection Report (QU043), Reference: ID02908, 11/04/2017, Issue 2.0**

Figure 1-6: ANPR Site Locations



1.38 JAQU guidance on how to forecast future year traffic was followed. This is then used to derive a compliant and non-compliant traffic fleet for future year CAZ testing. The following assumptions were applied:

- National forecasts on change in petrol verses diesel proportions of cars were applied to the local fleet proportions observed in the ANPR surveys. Conventional hybrid vehicles are included in petrol and diesel car numbers when deriving these proportions.
- For other vehicle classes the petrol verses diesel splits remain as observed in the ANPRs.
- The age distribution of vehicles remains the same but increasing in line with each additional year. This causes a natural increase in compliance vehicles i.e. a five-year-old car in 2020 will be of a higher Euro standard than a five-year-old car in 2016.
- There is no change in electric vehicle fleet – plug in hybrids, battery electric or hydrogen vehicles (but this can be included if data becomes available)

Table 1.25: Compliance Rates

Vehicle	Compliance Status	2016	2020	2022
Car	Compliant	55%	77%	84%
Car	Non-Compliant	45%	23%	16%
LGV	Compliant	23%	59%	70%
LGV	Non-Compliant	77%	41%	30%
HGV	Compliant	34%	65%	78%
HGV	Non-Compliant	66%	35%	22%
Bus	Compliant	38%	60%	63%
Bus	Non-Compliant	62%	40%	37%
Taxi	Compliant	17%	29%	46%
Taxi	Non-Compliant	83%	71%	54%

2 Do Something With CAZ Charging Scenario Model Development

Summary

2.1 This chapter sets out the approach used to model the impact of charging non-compliant vehicles to enter the Birmingham Clean Air Zone (CAZ). The impacts reported are only applied to those vehicles forecasted to be non-compliant in 2020. Additional measures that effect all users will have been tested using different approaches and is described in Chapter 3. Table 2.1 shows the compliance rate assumed in 2020 for the without CAZ scenario.

Table 2.1: 2020 Without CAZ Scenario Forecast Compliance Rate

Percentage	Compliance Status	2020	2022
Car	Compliant	77%	84%
Car	Non-Compliant	23%	16%
LGV	Compliant	59%	70%
LGV	Non-Compliant	41%	30%
HGV	Compliant	65%	78%
HGV	Non-Compliant	35%	22%
Bus	Compliant	60%	63%
Bus	Non-Compliant	40%	37%
Taxi	Compliant	29%	46%
Taxi	Non-Compliant	71%	54%

Cars

2.2 There are various responses to the introduction of charging for trips made by non-compliant vehicles entering the CAZ. This has been modelled hierarchically in the order shown in Table 2.2.

Table 2.2: Demand Response Hierarchy

Hierarchy	Response	Method
1	Upgrade to compliant/ switch to already owned compliant vehicle (for households with more than one car)	Choice Modelling based on TfL Stated Preference Research
2	Cancel – do not make a journey	Elasticity to charge derived from PRISM run to apply to Do Minimum trips to/ from the City Centre.
	Change Mode to non-highway PT/ Walk/ Cycle option	

Hierarchy	Response	Method
	Avoid (Change destination from City Centre to non-City Centre trips)	
	Pay (with a city centre origin/ destination)	
3	Avoid (through trips change route to non-City Centre route.	BCC CAZ assignment model to apply to through trips.
	Pay (through trips use City Centre)	

2.3 The model has been developed at the journey rather than individual user level, so is comparable to the vehicle kilometre table shown in the JAQU technical reports (rather than the vehicle tables).

Compliance

2.4 Users that choose to upgrade to a compliant vehicle have been represented in the model by using Transport for London's behavioural research for the extended Ultra Low Emission Zone – see Appendix B for the stated preference report. Stated preference is a survey exercise used to extract the value for different attributes of alternatives based the respondents' choice behaviour. In this case the exercise was aimed at understanding how much people were willing to pay to upgrade their vehicle in response to different charge levels.

2.5 This research is relevant to Birmingham as it covers an area of London that is currently free to drive in (rather than the congestion charging area), and therefore captures individuals that do not currently pay a charge.

2.6 To ensure that the forecasts reflect local conditions the TfL research was reweighted with local data in the following ways:

- Frequency from the ANPR City Centre survey by grouping into Low, Medium and High frequency as follows:
  - High 4-7 days a week
  - Medium 2-3 days a week
  - Low 1 day a week
- Income grouping size from the PRISM model into Low, medium and High as defined in PRISM (Low <-£35k, Medium £35k-£50k, High >£50k)
- Journey Purposes from the PRISM model

Cost to Upgrade

2.7 The cost of upgrading to a compliant vehicle is an important consideration in the choice to upgrade. JAQU published their research on the cost of a new vehicle, deprecation rates, and the choice users will make when choosing to upgrade. The value of a "typical" brand-new compliant car by 2020 is £18,000[12].

2.8 Several responses are considered when upgrading a vehicle:

- Scrap: A proportion, 25%, of those people taking the upgrade response will scrap their old vehicle. This assumes that the cost to upgrade is equal to the purchase cost, neglecting any resale value. It is assumed that the replacement vehicle is brand new.
- Buy new: A proportion, 25%, of those people choosing to upgrade will buy a brand-new vehicle, selling their former car.

[12] National data inputs for Local Economic Models.xlsx, JAQU, 2018

- Switch: A proportion, (75% of 75%), of those people who elect to upgrade will sell their old vehicle and buy the cheapest unaffected one. The purchase cost has been calculated in a similar fashion to the analysis above, plus £200 in transaction costs. It is assumed that all replacement vehicles are the eldest compliant Petrol Euro 4.
- Keep fuel: A proportion, (25% of 75%), of those people who decide to upgrade will sell their old vehicle and buy the cheapest unaffected one of the same fuel type. £200 in transaction costs plus depreciation are included in the estimation of the upgrade cost. This follows the same methodology used by Steer.

2.9 For those with a non-compliant vehicle who would sell their existing vehicle before upgrading, the following depreciation rates published by JAQU were used. This was combined with the ANPR data which provided the age of cars entering the CAZ to generate an average monetary value of non-compliant vehicles.

Table 2.3: Depreciation Assumptions

Year	Depreciation Rate per Year
1	0.37
2	0.18
3+	0.16

2.10 The resulting costs to upgrade, weighted by age of current fleet as per ANPR data, are as follows:

Response	Average cost to upgrade
Scrap (Buy new)	£18,000
Sell Existing Vehicle and Buy new	£14,051
Sell Existing Vehicle and Buy Cheapest 2nd hand	£401
Sell Existing Vehicle and Buy Cheapest 2nd hand within same fuel group	£3,187

Source: Steer analysis using JAQU methodology and assumptions

2.11 Applying the shares assumed by JAQU results in an average cost to upgrade of £4,582.

Upgrade Rates

2.12 The figures on the following page show the resulting compliance rates to apply to non-compliant trips to/from the CAZ in the Do Minimum model at different charge levels.

2.13 An additional adjustment is made to the compliance rates in the early years of opening to reflect the likely short-term lag in people choosing to upgrade their vehicles. Factors that could delay upgrade rates are:

- Initial resistance to spend sizeable amount on something that had previously been free
- Car market struggling to provide sudden increase in compliant vehicles
- During the 'natural' turnover of vehicles individuals are more likely to choose a compliant vehicle, but this process will occur over time.

2.14 This is adjustment is applied as a ramp up process that which dampens down the upgrade rates in the early years. Ramp up is standard practice in forecasting demand in the early years of a transport scheme. With the following proportion of forecast vehicle upgrades occurring in the opening years:

- 2020 – 85%
- 2021 – 95%
- 2022 – 100%

Figure 2-1: Upgrade Rates for City Centre Trips (excluding ramp-up)

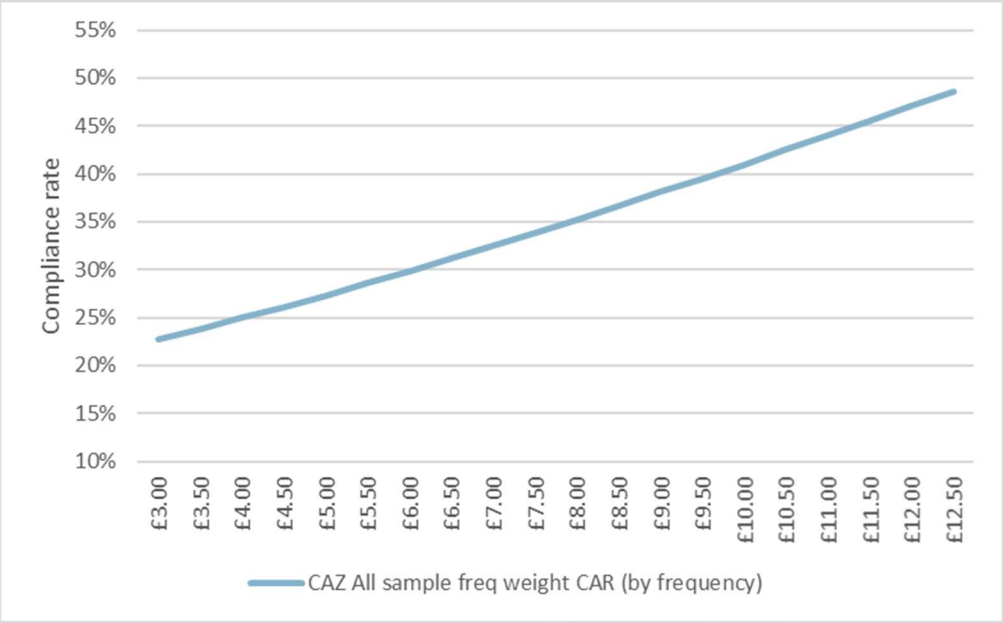
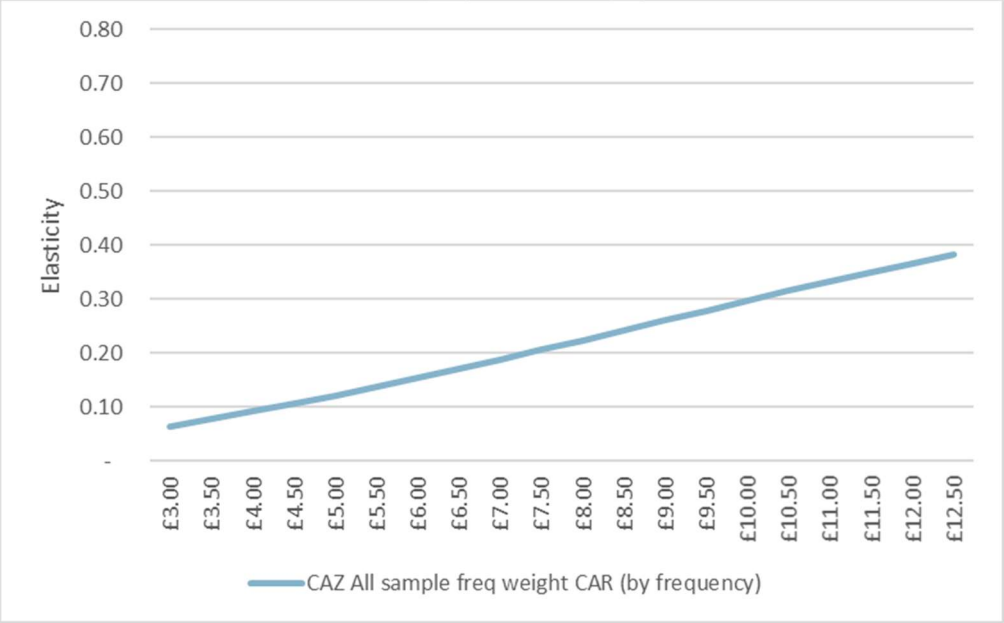


Figure 2.2: Upgrade Elasticity to Charge



Other City Centre Response

2.15 For the remaining proportion of non-compliant vehicles with an origin/ destination in the City Centre we have used the PRISM[13] model with the responses adjusted based on emerging research from other studies (including from the second wave of CAZ cities). This is a modification of the methodology set out in the OBC forecasts[14], following the benchmarking review carried out as part of the FBC forecasting (this report is contained in Appendix D).

PRISM Response

2.16 The PRISM[15] model was used to estimate what proportion of users with an origin or destination in the city centre would respond by:

- Paying the charge;
- Shift to a new mode;
- Cancel their trip; or
- Avoid the zone by travelling somewhere else (this option is not applicable to those trips with a home origin in the city centre).

2.17 The model was run with the charges set to the ULEZ value of £12.50. The charges were coded on the centroid connectors of City Centre zones to isolate the impacts on the City Centre and to not impact through trips. The PRISM model is not set up to be able to separate compliant and non-compliant vehicles so could not be used directly to forecast the full responsiveness to the charge.

2.18 The PRISM demand model outputs provide a large set of demand responses across different:

- Income segments
- Journey purposes
- Origin/ destination pairs with
  - Different highway;
  - public transport; and
  - walk/ cycle times

2.19 An average elasticity to charge was calculated by analysing the changes in demand between Do Minimum and CAZ scenarios against the change in generalised costs of each potential City Centre journey. The generalised costs were calculated as a sum of journey time costs, vehicle operating costs, charges and parking charges to ensure that costs other than the CAZ charge were considered in the choice.

2.20 Within PRISM different responsiveness to charges due to journey purposes' is represented through values of time, taking into attributes issues such as trip frequency (for commuters this will be high), whether the costs can be passed on (business trips) or shared (vehicle occupancy). The adjustment to the matrices are carried out on the two journey purpose levels within the BCC model, using an average responsiveness weighted across the different journey purposes. The two BCC purposes are shown below, aggregating across a large number of purposes in PRISM:

[13] http://www.prism-wm.com/

[14] Transport Model Forecasting Report for OBC, Steer, 2018

[15] http://www.prism-wm.com/

- In Work; and
- Other

2.21 The city centre demand was also analysed in 3 different geographical segments depending on where the trip was generated. Trip generation refers to the home end of a trip unless it is part of a trip chain in which case it is modelled in origin/ destination format.

2.22 The BCC assignment model is in origin/ destination format, where journeys cannot be directly linked to the home end of the trip, so an average response across the day was calculated. The different responsiveness by geographical area is weighted by the relative size of that segment with the following assumptions applied:

Table 2.4: Geographical responses

Geography	Response
Trips Generated in the City Centre to a destination outside the City Centre (CC to Non CC)	These trips can be cancelled, pay the charge or change mode. No change in destination assumed.
Trips Generated in the City Centre which complete their journey within the City Centre (CC to CC)	For home based trips, no change assumed as there would no way to charge them. For non-home based trips, mode shift or cancelled trip assumed.
Trips Generated outside of the City Centre to inside the City Centre (Non CC to CC)	Pay the charge, mode choice, cancel trip, and change destination is modelled.

2.23 The following responses to different charge rates are shown in Figures below, which includes the upgrade to compliant vehicle response discussed earlier. It should be noted that these results apply only to those vehicles forecast to be non-compliant vehicles in 2020 without any CAZ interventions and does not included through trips route choice. The overall model response in terms of the proportion of the fleet that will pay the charge or change mode, for example, will be smaller than presented in the figures below.

Figure 2-3: NCC to CC Non work

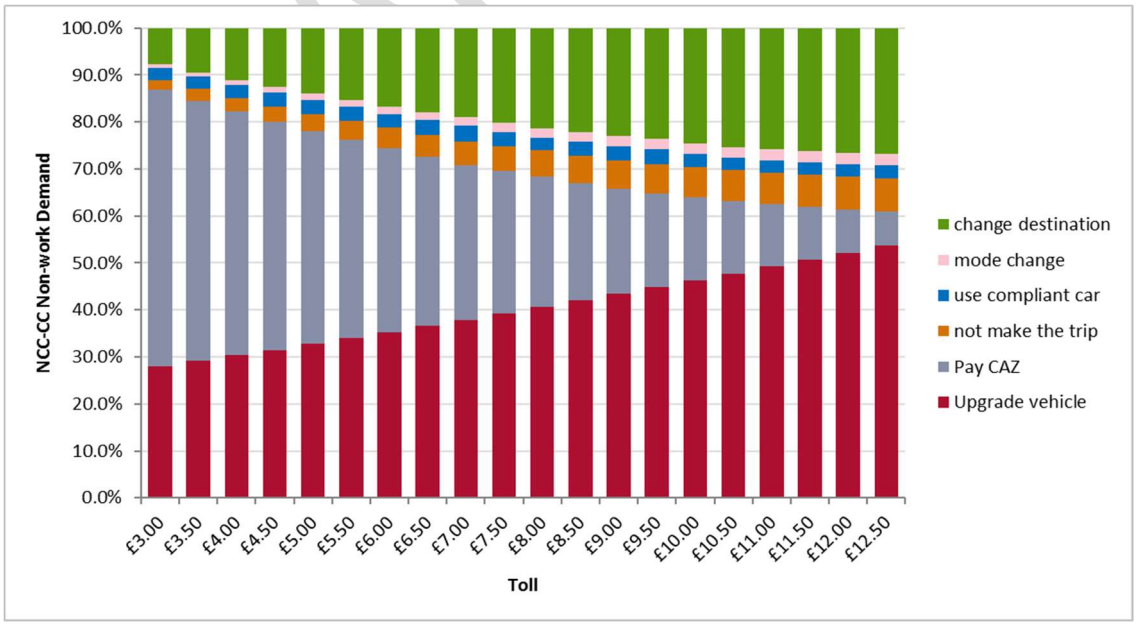


Figure 2-4: NCC to CC In Work

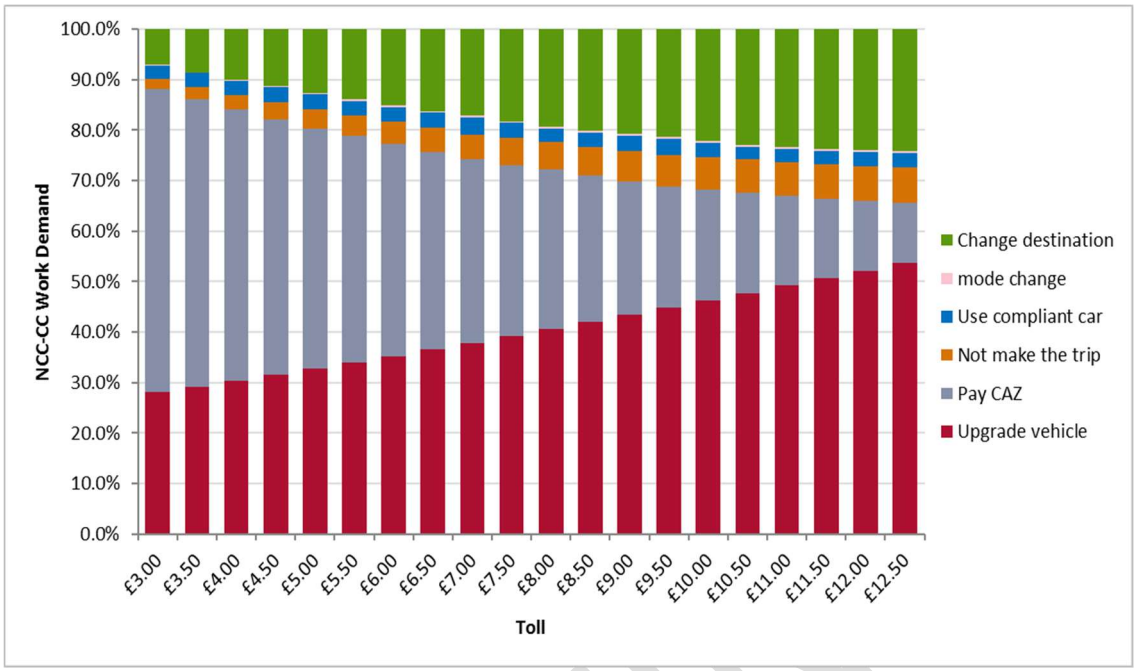


Figure 2-5: CC to CC Non Home based

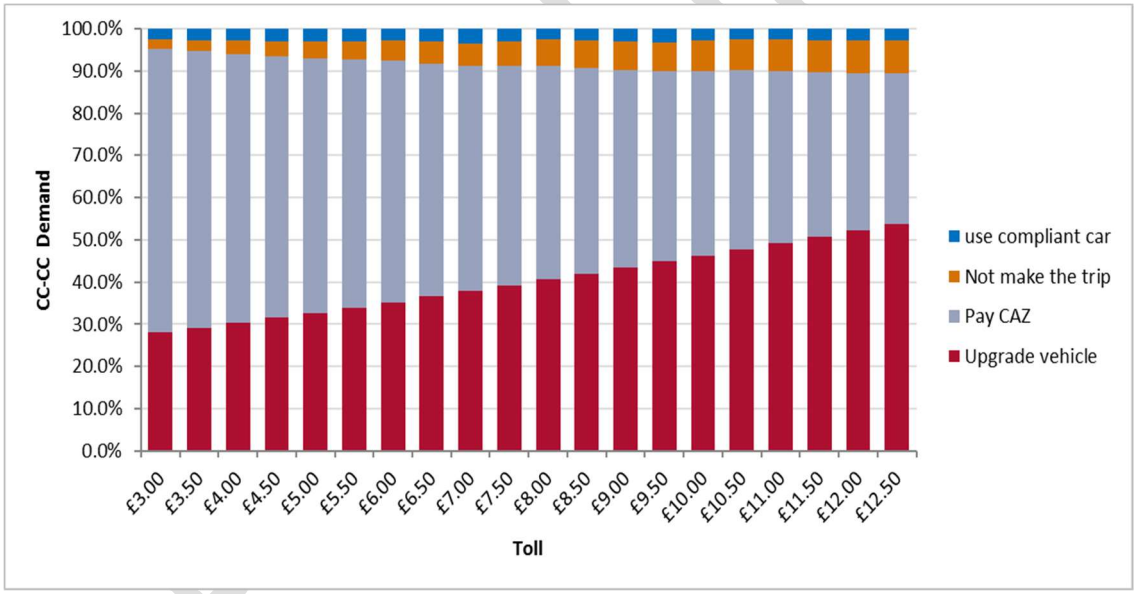


Figure 2-6: CC to NCC Non work

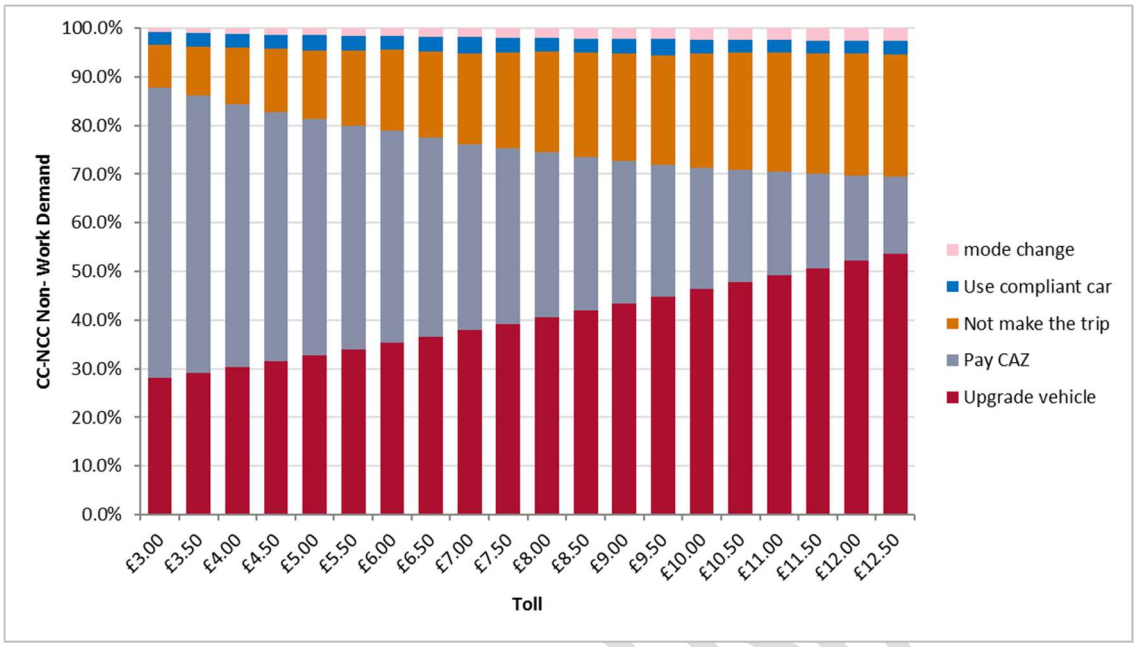
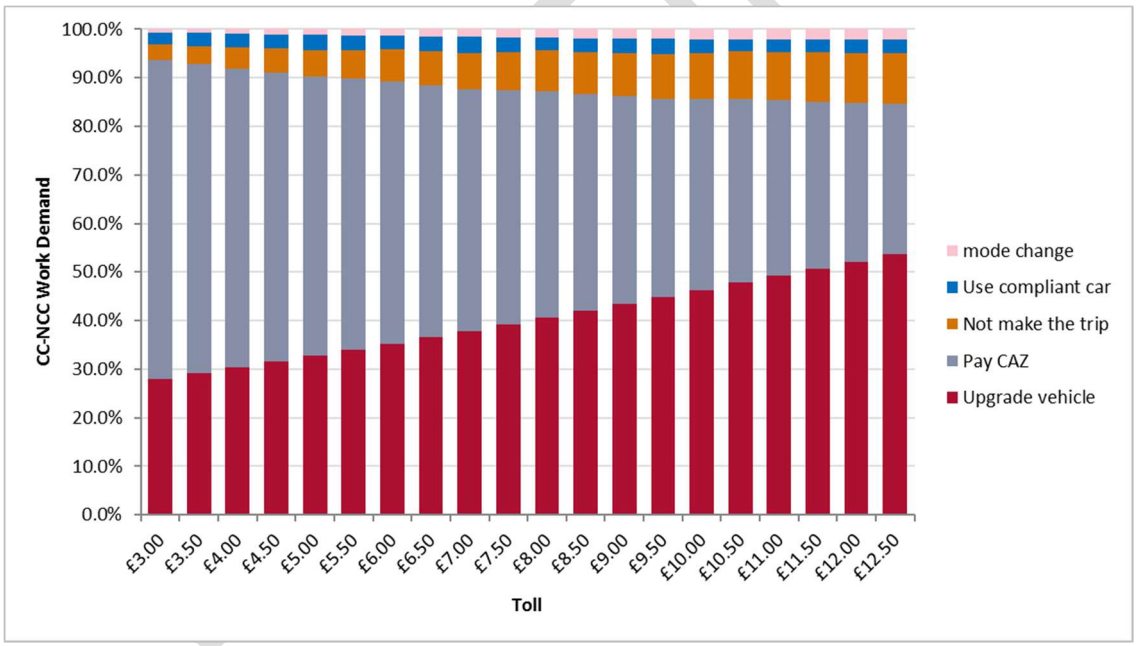


Figure 2-7: CC to NCC in work



Adjustment to PRISM Responses

2.24 The benchmarking exercise carried out as part of the FBC (see appendix D) indicated that the elasticity to the toll at the £12.50 charge is reasonable. However, when comparing to research from other cities the change in people willing to pay the charge between the £12.50 and £7.00 charge is steeper using the approach in the OBC.

2.25 The previous approach used in the OBC had been benchmarked against TfL's ULEZ research, however, however we believe that cities outside of London are more comparable to Birmingham conditions. Given this and the fact that the PRISM model had been run at £12.50 (with the lower levels derived from analysing the changes across different OD pairs

generalised costs) an approach was adopted that adjusted the £12 willingness to pay based on analysis in the benchmarking study.

2.26 To do this elasticity was derived of those willing to pay to the charge to apply to charges between £12.50 and £7.00. The elasticity based on the numbers in the table below, is -1.09. In other words, every £1 increase from £7 up to £12.50 results in a 1.09% decrease in users willing to pay the charge.

Table 2.5: SP Results

Fare level	% respondents who would pay the charge
£7.00	8%
£12.50	2%

Source: Steer Benchmarking report (appendix D)

2.27 In addition to the willingness to pay adjustment, changes to the mode shift response have been undertaken. PRISM forecasts low levels of mode shift in response to the charge. This is a reasonable long-term response and is calibrated against observed behaviour in the West Midlands. However, in the short term, users will have less choice to change destination and are more likely to cancel their trip or change mode.

2.28 This response has been adjusted using the Bristol 'short term' SP survey to redistribute the 'Mode Shift', 'Cancel Trip' and 'Change distribution', but keeping the total response across all the three responses at the same level as currently forecast. The tables below show the responses at the FBC £8.00 charge and high £12.50 charge in 2020 (including upgrade ramp-up) and 2022, against the assumptions used in the OBC (this excludes route choice).

Table 2.6: FBC £8.00 Charge

Response	OBC Response	FBC Response	
		2020	2022
Pay Charge	31%	18%	17%
Change Destination	19%	6%	7%
Cancel Trip	8%	19%	15%
Replace Vehicle	41%	35%	41%
Mode Shift	2%	23%	21%
Total	100%	100%	100%

Table 2.7: FBC £12.50 Charge

Response	OBC Response	FBC Response	
		2020	2022
Pay Charge	10%	12%	10%
Change Destination	23%	5%	6%
Cancel Trip	10%	17%	12%
Replace Vehicle	54%	46%	54%
Mode Shift	2%	20%	18%
Total	100%	100%	100%

2.29 To apply these responses to the City Centre assignment model the following adjustments are made:

Table 2.8: Application of Responses to Assignment Model

Response	Modelled
Upgrade Vehicle	The compliant user class is uplifted and the non-compliant reduced
Mode Shift	The non-compliant car trips to/ from the City Centre are reduced
Cancel Journey	The non-compliant car trips to/ from the City Centre are reduced
Change Destination	The non-compliant trips to/ from the city centre are redistributed to outside so that neither trip end is in the City Centre, using the existing demand distribution from the appropriate origin/destination zone outside the city centre

Through Trips

2.30 Non-compliant through trips are modelled using route choice in the assignment model. Charges are coded onto links forming a cordon into the City Centre. As the charge is only used for route choice it is only applied in the inbound direction to avoid double charging. Values of time are used (described above in chapter 2), converting charges into a generalised journey time, with the model forecasting whether users are prepared to pay for the time savings of making a through trip.

Taxi/ PHV

2.31 We assume that all Birmingham registered taxis and PHVs will upgrade to compliant vehicles, based on policy being developed by Birmingham City Council.

LGV

2.32 Light goods vehicles are assumed to respond by:

- upgrading their vehicle;
- pay the charge and continuing to drive into the CAZ; or
- route choice for through trips by bypassing the CAZ

2.33 We have used TfL's ULEZ behavioural model to forecast the response to upgrading the vehicle. We have assumed that LGV users' behaviour will more closely reflect car users than heavy goods users, as:

- the charges and upgrade costs are similar.
- The costs used are based on JAQU costings published in their technical report to the National Air Quality Plan[16]

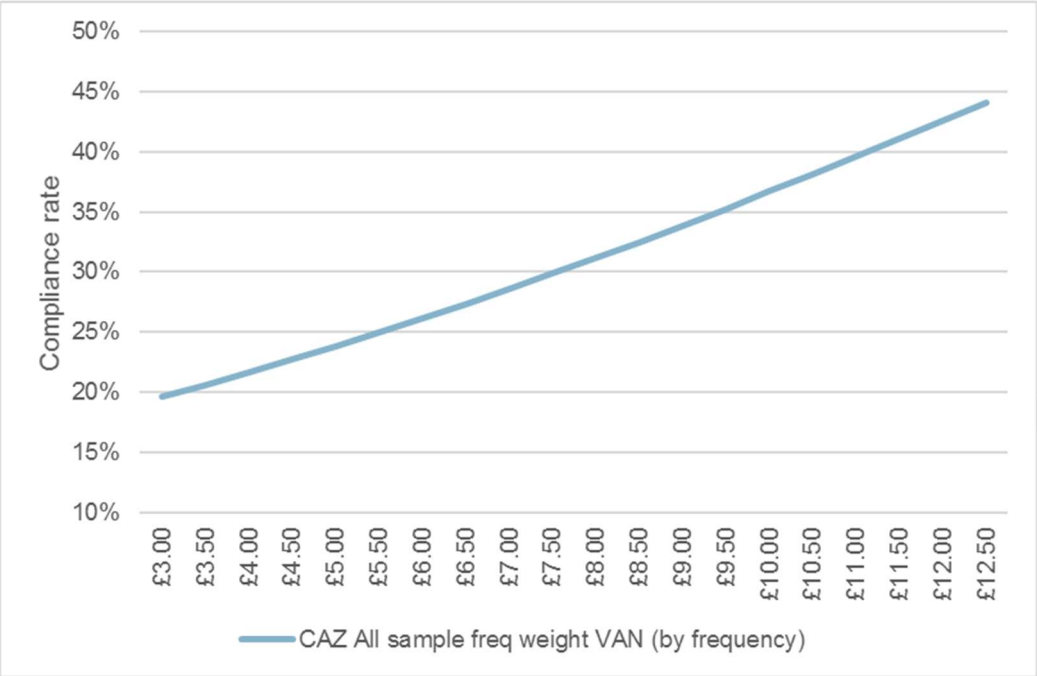
Table 2.9: Cost to Upgrade LGV

Element	Cost
Average sell value	£3,500
Average buy value	£10,000
Net Cost	**£6,500**

[16] UK Plan for tackling roadside nitrogen dioxide concentrations - Technical report, DEFRA/ DfT July 2017

2.34 The modelled response for the proportion of compliant LGVs against increasing charges is illustrated below:

Figure 2-8: LGV Compliance Rate



2.35 As with cars a ramp up period is assumed as below:

- 2020 – 85%
- 2021 – 95%
- 2022 – 100%

HGV

2.36 The approach to modelling HGVs has been to consider the cost to upgrade over a 5-year period against the cost of paying a charge throughout this period. The costs involved both in upgrading, the charge paid, and the value of the business being carried out is considerably higher than for the lighter vehicle classes. Users are therefore likely to take a longer-term outlook on whether to upgrade their vehicle.

2.37 Compliance rates were calculated by applying the following assumptions:

- Depreciation and Vehicle cost rates from JAQU
- Users will upgrade to cheapest available option
- Frequency taken from the ANPR survey data, with assumptions of how the vehicle counted once in the week are distributed across the year.
- Costs were calculated for rigid and artic separately with proportions in the ANPR surveys used to derive the fleet proportions to apply these assumptions to.

Table 2.10: HGV Costs

Type	Cost to Buy
Rigid	£68,000
Arctic	£81,000

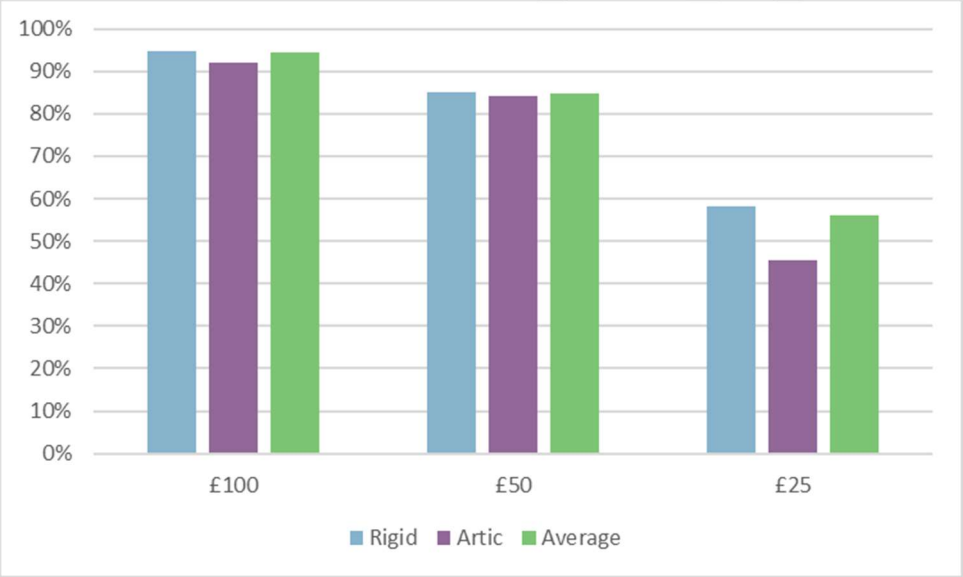
Table 2.11: Depreciation Assumptions

Year	Depreciation Rate per Year
1	0.37
2	0.18
3+	0.18

Table 2.12: Cost to Upgrade HGV

HGV Type	Euro Class	Resale Cost	Cost of Compliant Vehicle	Cost to Upgrade
Rigid	Euro 1	£835	£19,984	£19,149
	Euro 2	£1,847	£19,984	£18,137
	Euro 3	£3,350	£19,984	£16,634
	Euro 4	£9,035	£19,984	£10,949
Arctic	Euro 1	£995	£23,804	£22,810
	Euro 2	£2,200	£23,804	£21,604
	Euro 3	£3,990	£23,804	£19,814
	Euro 4	£10,762	£23,804	£13,042

Figure 2.9: Compliance Rate at 3 levels of charge



2.38 As with cars and LGVs a ramp-up period for upgrades is assumed as follows:

- 2020 – 70%
- 2021 – 85%
- 2022 – 100%

Bus

2.39 The effect of CAZ charges on buses is not explicitly modelled as its assumed that all buses in the CAZ will be compliant, with an out of model adjustment made when applying the results in the AQ model.

Birmingham City Council Fleet

2.40 We have assumed that the full Birmingham fleet will be made compliant. However, using number plate data provided by Birmingham City Council and matching against the ANPR surveys showed that the proportion of the fleet within the traffic model was too small to include specifically within the modelling. Measures for staff owned vehicles would be an additional measure, and would be considered at a later stage in the study.

Results

2.41 Full model runs have been completed for CAZ C and CAZ D for three pricing levels for both CAZ types. Full analysis of the model results is contained in Chapter 4, with the following section describing the overall responsiveness. The analysis focuses on car, LGV and HGV, as the assumption for bus and taxi is that they will all upgrade.

2.42 The charges that have been tested as part of the FBC are summarised in Table 2.1 below. CAZ C and lower charges were tested as part of the OBC.

Table 2.13: Scenarios Tested

CAZ	CAZ D	
	Medium	High
Car	£8.00	£12.50
Taxi	£8.00	£12.50
LGV	£8.00	£12.50
HGV	£50.00	£100.00
Bus/ Coach	£50.00	£100.00

2.43 Table 2.14 shows the overall response rates including route choice for non-compliant vehicles entering the CAZ. This represents the change in non-compliant vehicle numbers within the CAZ compared to the Do Minimum scenario, and is the combined effects of the various responses including the diversion of through trips.

2.44 Responses for CAZ D are found in Table 2.14 and Table 2.15. At the high charge level, the forecasts are for high levels of compliance within the CAZ, with only 12% of cars paying the charge.

Table 2.14: 2020 Overall Response Reduction CAZ D

	Car	LGV	HGV*
FBC (£8.00)	-86%	-48%	-70%
High (£12.50)	-88%	-54%	-75%

Table 2.15: 2020 CAZ D Response of Non-Compliant Vehicles to the Charge

Response	£8.00			£12.50		
	Car	LGV	HGV	Car	LGV	HGV
Pay Charge	14%	52%	30%	10%	46%	25%
Avoid Zone (Change Route)	21%	26%	27%	21%	26%	27%
Avoid Zone (Change Destination)	4%	0%	0%	4%	0%	0%
Cancel Trip	13%	0%	0%	13%	0%	0%
Replace Vehicle	31%	22%	44%	36%	28%	48%

Mode Shift	16%	0%	0%	16%	0%	0%
Total	100%	100%	100%	100%	100%	100%

Table 2.16: 2022 Overall Response Reduction CAZ D

	Car	LGV	HGV
FBC (£8.00)	-88%	-52%	-89%
High (£12.50)	-88%	-54%	-75%

Table 2.17: 2022 CAZ D Response of Non-Compliant Vehicles to the Charge

Response	£8.00			£12.50		
	Car	LGV	HGV	Car	LGV	HGV
Pay Charge	12%	48%	11%	9%	46%	25%
Avoid Zone (Change Route)	16%	27%	27%	16%	26%	27%
Avoid Zone (Change Destination)	6%	0%	0%	5%	0%	0%
Cancel Trip	14%	0%	0%	10%	0%	0%
Replace Vehicle	32%	25%	62%	45%	28%	48%
Mode Shift	19%	0%	0%	15%	0%	0%
Total	100%	100%	100%	100%	100%	100%

2.45 Table 2.18 compares the response rates with those from TfL's ULEZ study and those published by JAQU in the National Air Quality Plan (for full details see

2.46 Figure 2.9 and Figure 2.10 on the following pages). The National Air Quality Plan does not state the charge levels assumed, but as the research is based on TfL's studies we have assumed it is based on the ULEZ charge.

2.47 The overall response rate of those who will still pay the charge is in line with the National Air Quality and TfL assumptions. This provides evidence that the change in compliance rates within the CAZ zone are plausible, and therefore the flows used in the AQ models are reasonable.

2.48 The main differences occur in the mode shift assumptions where low rates of mode shift are forecast compared to the other studies with two observations:

- London has higher public transport use and more options compared to Birmingham, so people are more likely to change mode in London
- CAZ is to be implemented in the short term, so it will be challenging for people to avoid the zone by changing their destination to areas outside the City Centre, particularly for those who currently work there, so the reality may be higher rates of mode shift in the short term.

2.49 For "replacement of vehicles", the BCC study in in line with TfL forecasts but significantly higher than forecast by JAQU. Given the short timescales while the response is reasonable, it may be difficult to achieve these upgrade rates by 2020, without government support.

Table 2.18: Car Compliance Response Comparisons at the High Charge Level

Response	BCC (High Charge)	TfL (ULEZ Charge)	JAQU*
Pay Charge	8%	9%	7%
Change Route	22%	4%	11%

Change Destination	18%	6%	
Cancel Trip	9%	9%	7%
Replace Vehicle	41%	48%	64%
Mode Shift	2%	24%	11%
Total	100%	100%	100%

* JAQU only publishes avoid zone, not separately for change destination/ change route.

2.50 LGV and HGV responses are shown in Table 2.19 and compared to the National Plan assumptions. For LGVs a higher proportion is assumed to pay the charge than assumed in the national plan. However, for HGVs higher upgrade rates are assumed than by JAQU, although these are more in line with JAQUs assumptions in comparison to LGVs.

Table 2.19: LGV and HGV Compliance Response Comparisons

Response	LGV		HGV	
	BCC	JAQU	BCC	JAQU
Pay Charge	41%	20%	4%	9%
Avoid Zone	12%	8%	1%	4%
Cancel Trip	-	6%	-	4%
Replace Vehicle	47%	64%	95%	83%
Mode Shift	-	4%	-	-

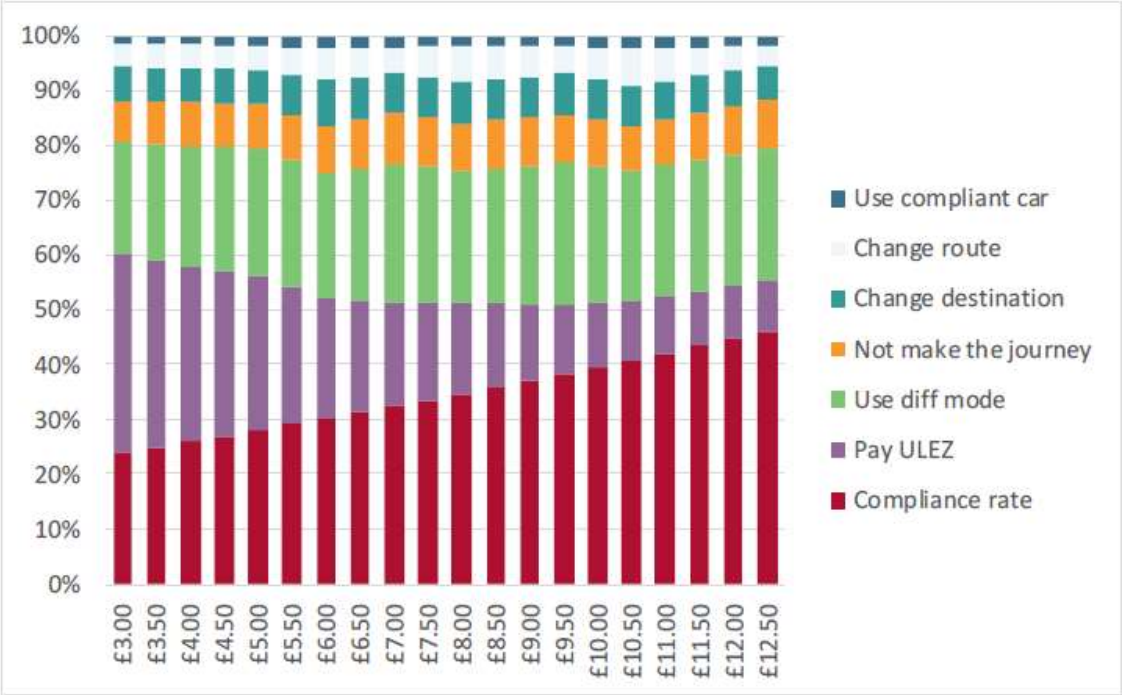
Figure 2.10: National Air Quality Plan Technical Report Assumed Responses[17]

Table 3.3: Proportions of non-compliant vehicle kilometres (VKM) and non-compliant vehicles (V) by response to the presence of a charging CAZ

Response	Cars		LGVs		HGVs		Buses		Coaches	
	VKM	V	VKM	V	VKM	V	VKM	V	VKM	V
Upgrade	64%	22%	64%	25%	83%	44%	94%	62%	72%	41%
Cancel	7%	16%	6%	12%	4%	13%	6%	38%	13%	26%
Change mode	11%	23%	2%	4%	0%	0%	0%	0%	0%	0%
Avoid	11%	23%	8%	17%	4%	13%	0%	0%	0%	0%
Pay	7%	16%	20%	42%	9%	29%	0%	0%	16%	32%

[17] UK Plan for tackling roadside nitrogen dioxide concentrations, Technical report, Section E, JAQU, July 2017

Figure 2.11: Ultra Low Emission Zone Expansion Stated Preference Survey Model Results[18]



[18] Ultra Low Emission Zone Expansion Stated Preference Survey Report, Steer Davies Gleave, 2017

3 Do Something With CAZ Additional Measures, Mitigation and Exemptions

Summary

Overview

3.1 The CAZ FBC includes measures on top of the CAZ charging, as follows:

- Additional Measures – measures aimed at improving air quality
- Exemptions – certain users given exemptions from paying the charge
- Mitigations – Financial and other support for certain users who are affected by the CAZ

3.2 The Chapter is structured as follows:

- Addition Measures – an overview of the additional measures
- Exemptions and Mitigations - summary
- Methodology – A summary of the approach taken in modelling the measures
- FBC Responses – A summary of the changes in traffic as a result of the preferred FBC option.

Additional Measures and Early Measures

3.3 Table 3.2 below described the options tested and a summary of their impacts, and whether they were selected for inclusion in the preferred scheme for OBC.

3.4 In addition to the schemes tested, the closure of Moor Street Queensway between Masshouse and Park Street to general traffic (open to Public Transport, Hackneys and cycles) has been adopted as Birmingham City policy to be implemented by 2020, separate from the Clean Air project. This has benefits, in significant reductions in emissions at Digbeth gyratory, which is one of the links forecast to exceed legal limits in 2020. It will also improve bus reliability and times in this corridor supporting model shift. However, this pushes additional traffic onto the A38 and A4050 links which are forecast to exceed the legal limits.

Table 3.1: Additional Measures

Type	Test ID	Summary
Fleet (low emission)	Fleet 1	Increase LPG refuelling for Hackney Carriages and the installation of rapid EV infrastructure for taxi and private hire vehicles. Retrofitting of black taxis to LPG Assumptions tested: 85 taxis upgraded to Electric vehicle 441 PHVs upgraded to Electric Vehicle 65 taxis retrofitted to LPG
	Fleet 2	22 Zero emission buses (new Hydrogen buses)
Parking	Parking 1	Remove all free parking from BCC controlled areas. Replaced with paid parking spaces. Assume cost of parking in line with BCC off-street parking.
Network Changes	Network 1	Ban traffic entering (SB) or leaving (NB) Suffolk Street Queensway (A38) from Paradise Circus (except for local access).
	Network 2	Close Lister Street and Great Lister Street at the junction with Dartmouth Middleway. This reduces delays on the A4540.

Exemptions and Mitigations

3.5 In implementing the scheme in as equitable way as possible and to reduce the impact on vulnerable groups a package of mitigations and exemptions have been developed for the FBC. These were developed by Jacobs and Element Energy on behalf of Birmingham City Council with the assumptions built into the transport modelling.

Table 3.2: FBC Exemptions

Year	Ref	Vehicle type	Group	Description
2020	E1	HGV	CAZ HGVs	HGVs and coaches registered within the CAZ will receive an exemption.
2020	E2	HGV	HGV - existing finance	HGVs registered in the Birmingham City area travelling to the CAZ with and existing finance agreement beyond 2020.
2020	E3	Van/LGV	SME Vans/LGVs	Vans and LGVs registered to SMEs within the CAZ.
2020	E4	Van/LGV	Vans/LGVs - existing finance	Vans/LGVs registered within the Birmingham City area travelling to the CAZ with and existing finance agreement beyond 2020.
2020	E5	Car	residents in the CAZ	All private car and van owners who are residents of the CAZ, as defined by DfT registration information.
2020	E6	Car	income deprived	Income deprived residents of the Birmingham metropolitan area traveling into the CAZ for work.
2020	E7	Car	key workers	Key workers and volunteers travelling to work in the CAZ.
2020	E8	Car	children's hospital visits	Visitors to select hospitals, GP offices and care homes.
2020-2022	E9a	Van/LGV	community and school	Vehicles classified as Section 19 operators.

2020-2022	E9b	Car	disabled vehicles	Vehicles with disabled or disabled passenger tax class.

Source: "revised exemption and mitigations 181022.xlsx", Jacobs, 2018

Table 3.3: FBC Mitigations

Year	Ref	Vehicle type	Group	Description
2020-2022	M1 (a)	Car	Low income	Mobility credit offered to low income non-compliant car owners living or working within the CAZ.
2020	M2	Car	Taxi	Birmingham Licenced Taxi drivers with non-compliant Hackney Carriages given financial support.
2020-2022	M3	Car	Taxi	Birmingham City Council to purchase 50 ULEV taxis to lease out to most vulnerable drivers.
2020	M4	Van/LGV	Van/LGV	ULEV van drivers can register to receive credit on Birmingham's public charging network.
2022	M5	HGV	HGV	HGV and Coach fleet operators within the West Midlands will be able to apply for a cash payment towards retrofit technology
2020	M6	ALL	All	Educational and marketing campaign to provide information on the CAZ and reach out to groups eligible for support through mitigation measures
2022	M7m	Car	CAZ workers	Support prioritises key workers and then is based on income, those eligible will be exempt for one year and then have access to mitigation package in 2021
2022	M8m	Car	Non-CAZ residents	Can apply for support package similar to workers package, will include an exemption for one year followed by scrappage scheme in 2021
2020	M8e	Car	non-CAZ car residents	Exemptions for 3,250 non-CAZ residents that receive the mitigation

Source: "revised exemption and mitigations 181022.xlsx", Jacobs, 2018

Approach to Testing Additional Measures and Early Measures

3.6 The section below provides additional detail on the additional measures tested and the approach taken.

Fleet Upgrades

Taxi and PHV

3.7 Birmingham Council have undertaken taxi/ PHV studies, investigating the numbers of vehicles expected to upgrade to cleaner vehicles due to the cities' clean air policies. We have directly adopted these forecasts of the number of vehicles that will upgrade to Electric or LPG retrofitting.

3.8 These assumptions do not affect the numbers of taxi/ PHV vehicles in the CAZ scenarios, but assumes they will be less polluting vehicles. Therefore, the adjustments were made to the link level Air Quality inputs rather than adjusting the model demand and running the full modelling process. The adjustments were made to the traffic model outputs:

- For electric vehicles, they are removed from the AQ inputs as they are assumed to have 0 emissions.
- For taxis retrofitting to LPG, they were removed from diesel and added into petrol, assuming to be the equivalent to a petrol Euro Class 4.

3.9 To adjust the flows input to the AQ model, we analysed the numbers of individual vehicles entering the CAZ zone during the week that the ANPR surveys were undertaken. The numbers of vehicles upgrading, was used to calculate a factor to apply to the AQ inputs as shown in Table 3.3 below.

Table 3.4: Upgrade Assumptions

Vehicle Upgrade	Numbers of Diesel Taxis Entering CAZ	Numbers of Vehicles Upgraded	Taxi VKM Reduction
Taxi to Electric	1985	85	4.3%
Taxi to LPG		65	3.3%
Vehicle Upgrade		**Numbers of Vehicles**	**PHV VKM Reduction**
PHV to Electric	1289	441	34%

Bus Upgrades

3.10 22 hydrogen buses are included as part of clean air policy to support the development of the CAZ. These new buses have been assigned to routes that that run along the A38 between Paradise Circus and Holloway Circus (which is the area with the highest concentration levels). This is implemented in the modelling post traffic assignment by removing bus flows from links along the selected routes in the modelling data provided to the Air Quality team. This is done post model run so that the traffic impacts are considered within the modelling, but the emission impacts are removed for the AQ modelling.

3.11 The following routes were assumed to be Hydrogen Buses, with the assumption that each Hydrogen bus can make a two-way journey within the city centre during the modelled hour, i.e. one inbound and one outbound journey.

Table 3.5: Bus Routes Assumed to be Hydrogen

Route	Peak Hourly Frequency
82	6
87	7
22	4
23	4

Network Tests

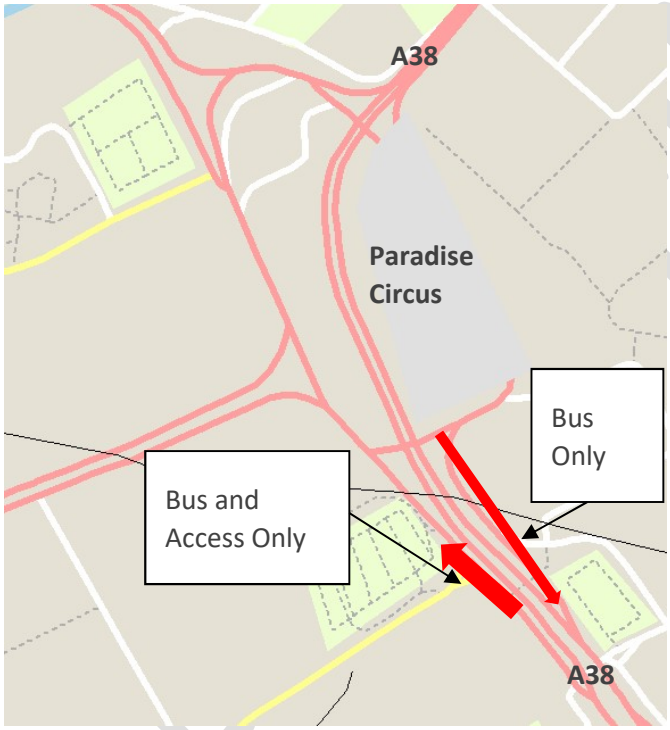
3.12 Changes to the network were tested through coding changes into the SATURN highway model and the new route choices and change in link delay past into the AQ model. The section below describes the changes tested.

Paradise to A38

3.13 Traffic entering (SB) or leaving (NB) Suffolk Street Queensway (A38) from Paradise Circus (except for local access), is banned as in figure 3.1 below. This causes a reduction in traffic on the section of A38 just to the south of Paradise Circus which is a link which exceeds the legal AQ limits. It will also remove weaving movements on the A38 reducing acceleration/ deceleration on this key section of road.

3.14 Implementing these changes also reduces traffic through Paradise Circus, which is an important area of regeneration within the City Centre with a major masterplan currently in construction.

Figure 3.1: Paradise Access Changes



Lister Street Closure

3.15 Access from Lister Street and Great Lister Street to and from the A4050 Dartmouth Middleway is removed. This allows more green-time to be provided for the A4540 at the traffic light junction, reducing delay on this link mitigating against the increase in flows caused by the CAZ charging and reducing emissions.

Ban on all CAZ through trips

3.16 Bans on CAZ through trips for all vehicle types was coded by adding a high toll onto links into the City Centre. This will only affect through trips within the assignment, as trips destined to the City Centre are "forced" to reach their destination within the network model. This test was run banning all vehicles and separately for LGV and HGVs.

3.17 These tests resulted in significant reductions in traffic within the ring road, with resulting AQ improvements. However, this caused significant increases in traffic on the Eastern section of the A4540, which exceeds the AQ levels, and adds rat-running movements on local roads parallel to the Ring Road.

CAZ on the A4050 Ring Road (Eastern Section)

3.18 A charge was applied to the eastern section of the ring road between Bordesley Circus and Dartmouth Circus. This was run for a CAZ C and CAZ D option. The option was rejected as it did not reach compliance, and also increased rat-running traffic on local roads.

Parking

3.19 According to the Birmingham City Centre Parking[19] study undertaken by JACOBS on behalf of Birmingham City Council in 2016 over 12% of parking spaces within Birmingham City Centre are free on-street parking. Once average utilisation, is considered this increases to 16% as shown in table 3.4 below.

[19] Birmingham City Centre Parking Study, JACOBS, 2016

Table 3.6: Parking Supply Birmingham City Centre

Parking Type	Spaces	Free % of Total
Public On-Street (Free Parking Spaces)	6,300	12%
Total Parking Spaces	51'800	
Public On-Street (Average Peak Utilised Spaces)	6,100	16%
Total Parking (Average Peak Utilised Spaces)	38,500	

3.20 As a means of reducing traffic entering the City Centre Birmingham Council have proposed removing all free parking within the zone. A test has therefor been developed to assess the impacts on overall traffic levels of parking charges. The following assumptions have been applied:

- The charge will be capped at the average charge of a Birmingham City Council controlled car park (£4.94). There is spare capacity in the Cities' car parks with users switching to these car parks if the price exceeds this charge.
- For non-compliant vehicles currently using free parking the charge experienced will be £8.50 plus £4.94
- This is applied to cars only, with freight and taxi assumed to pass on charges or have alternatives to on-street parking.
- PRSIM elasticity to charge used in the CAZ charge testing applied to all users to calculate the responsiveness to removing the parking charge.
- The changes are only applied to the proportion of the demand that has free parking and disaggregated to the areas of the City with free parking.
- Controlled parking will be introduced on the edge of the City Centre if needed to prevent users parking for free (but this has not been explicitly modelled).

Table 3.7: Removal of Free Parking Responsiveness

Response	Non-Compliant	Compliant
Pay Charge	20%	72%
Avoid Zone (Change Destination)	10%	3%
Cancel Trip	32%	11%
Mode Shift	39%	14%
Total	100%	100%

3.21 Applying the assumptions above results in a 5.5% reduction in car traffic with an origin and destination in the City Centre.

3.22 More detail on the assumptions applied can be found in Appendix D.

Approach to Testing Exemptions and Mitigations

3.23 In the work undertaken by Jacobs and Elemental Energy identifying mitigations and exemptions, they estimated the numbers of vehicles that would be affected by each measure and then converted into AADT figures, as shown below.

3.24 The compliant and non-compliant demand matrices for the without additional measures were adjusted as follows:

- Mitigations – increase in compliant trips with a reduction in non-compliant trips
- Exemptions – increase in non-compliant trips and reduction in a proportion of upgraded trips.

3.25 To convert these AADT figures into the highway model the following adjustments needed to be made:

- Convert the AADT figures into weekday peak period numbers to match the assignment model periods. These factors are based on the count data used to convert the modelling outputs into AADT figures for the AQ model
- Ensure that the behavioural responses mirror the charging responses so that the change increases in mitigations or exemptions reflects that in the CAZ charge only scenario they would have:
  - Paid the charge
  - Upgraded
  - Change Mode/ Destination or Cancelled

Table 3.8: AADT Exemptions (Increase in Non-Compliant Vehicles)

Vehicle	2020	2022
Car	5,992	423
Van/LGV	1,274	77
HGV	331	0
Total	**7,597**	**500**

Table 3.9: AADT Mitigations (Increase in Compliant Vehicles)

Vehicle	2020	2022
Car	877	4,435
Van/LGV	0	0
HGV	0	0
Total	**877**	**4,435**

3.26 For the electric taxi mitigation, analysis of taxi frequency data was undertaken to assess how much taxi vehicle KM emissions would be removed from the network. This adjustment factor was applied to the model output taxi link flows (as in the approach used for the additional measures) before providing the data to the AQ model.

Table 3.10: Taxi Electric Vehicle Upgrade Assumptions

Vehicle Upgrade	Numbers of Diesel Taxis Entering CAZ	Numbers of Vehicles Upgraded	Taxi VKM Reduction
Taxi to Electric	1985	50	2.5%

FBC Behavioural Responses

3.27 The FBC scenarios have been run with a CAZ D scenario in 2020 and 2022 with the following additional measures.

- Increase LPG refuelling for Hackney Carriages and the installation of rapid EV infrastructure for taxi and private hire vehicles and Retrofitting of black taxis to LPG
  - 85 taxis upgraded to Electric vehicle
  - 441 PHVs upgraded to Electric Vehicle
  - 65 taxis retrofitted to LPG
- Zero emission buses (new Hydrogen buses)
- Remove all free parking from BCC controlled areas. Replaced with paid parking spaces. Assume cost of parking in line with BCC off-street parking.
- Ban traffic entering (SB) or leaving (NB) Suffolk Street Queensway (A38) from Paradise Circus (except for local access).
- Close Lister Street and Great Lister Street at the junction with Dartmouth Middleway. This allows, more green time for the A4540.

3.28 A set of mitigations and exemptions have been assumed on top of the additional measures, as described above.

3.29 In developing the FBC the following scenarios have been run in the transport model with corresponding Air Quality Runs for 2020 and 2022:

- Do Minimum (no CAZ scenario)
- CAZ D FBC (with additional measures, mitigations and exemptions)
- CAZ D with FBC charges (with additional measures and exemptions)
- CAZ D with FBC charges (with additional measures only)
- CAZ D FBC with high charge (with additional measures, mitigations and exemptions)

3.30 The section below briefly summarises the impacts of the results of the different scenarios:

- Change in flows crossing the cordon – combined impact of route choice and behavioural impacts on flow entering the CAZ cordon.
- Car behavioural impacts, as a result of CAZ charging and parking charges
- Other vehicle's behaviour as a result of CAZ charging.

2020 CAZ D FBC Scheme

3.31 This version of the model has:

- CAZ Charge
  - £8 - car, LGV, taxi
  - £50 – HGV, Bus, Coach
- Additional Measures (Including removal of free on-street parking)
- Exemptions
- Mitigations

Figure 3.2: Cordon Crossings CAZ D High (FBC)

	DM					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	127,200	2,700	13,200	4,700	3,300	151,000
Non-compliant	37,600	6500	9,300	2500	2200	58,000
Total	164,700	9,200	22,500	7,100	5,500	209,000
	CAZ Scenario					
Compliance	**Car**	**Taxi**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	134,200	9,400	14,500	5,800	5,500	169,400
Non-compliant	10,600	0	6,100	900	0	17,700
Total	144,800	9,400	20,600	6,700	5,500	187,000
	Difference CAZ - DM					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	7,000	6,800	1,200	1,200	2,200	18,400
Non-compliant	27,000	6,500	3,200	1,600	2,200	40,400
Total	20,000	300	1,900	400	0	-22,000
	% Difference CAZ - DM					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	6%	251%	9%	26%	67%	12%
Non-compliant	-72%	-100%	-34%	-64%	-100%	-70%
Total	-12%	3%	-9%	-6%	0%	-11%

Table 3.11: Compliant Car Response to Removal of Free Parking

Response	Compliant Car Response (With Free Parking)	Response as Proportion of Total Car Fleet
Pay Parking Charge	72%	8.5%
Avoid Zone (Change Destination)	3%	0.4%
Cancel Trip	11%	1.3%
Replace Vehicle	0%	0.0%
Mode Shift	14%	1.6%
Total	**100%**	**11.9%**

Table 3.12: Non-Compliant Car Response

Response	Response of Non-Compliant Vehicles	Response as Proportion of Total Car Fleet
Pay CAZ Charge	12%	0.4%
Pay CAZ Charge and Parking	0%	0.1%
Avoid Zone (Change Route)	21%	4.8%
Avoid Zone (Change Destination)	5%	1.1%
Cancel Trip	16%	3.7%
Replace Vehicle (No Parking Change)	23%	5.2%
Replace Vehicle and Pay Parking	3%	0.6%
Mode Shift	20%	4.5%
Total	100%	22.8%

Table 3.13: Non-Car Behavioural Responsiveness

Response	LGV	HGV	Taxi	Bus
Pay CAZ Charge	66%	36%	0%	0%
Avoid Zone (Change Route)	26%	27%	0%	0%
Cancel Trip	0%	0%	0%	0%
Replace Vehicle	7%	37%	100%	100%
Total	100%	100%	100%	100%

2020 CAZ D FBC Scheme Without Mitigations

3.32 This version of the model has:

- CAZ Charge
  - £8 - car, LGV, taxi
  - £50 – HGV, Bus, Coach
- Additional Measures (Including removal of free on-street parking)
- Exemptions

Figure 3.3: Cordon Crossings CAZ D High (OBC)

	CAZ D FBC					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	127,200	2,700	13,200	4,700	3,300	151,000
Non-compliant	37,600	6,500	9,300	2,500	2,200	58,000
Total	164,700	9,200	22,500	7,100	5,500	209,000
	CAZ D FBC Scheme Without Mitigations					
Compliance	**Car**	**Taxi**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	134,200	9,400	14,500	5,800	5,500	169,400
Non-compliant	10,600	0	6,100	900	0	17,700
Total	144,800	9,400	20,600	6,700	5,500	187,000
	Difference (CAZ without Mitigations – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total

Compliant	7,000	6,700	1,300	1,100	2,200	18,400
Non-compliant	-27,000	-6,500	-3,200	-1,600	-2,200	-40,300
Total	-19,900	200	-1,900	-400	0	-22,000

	% Difference (CAZ without Mitigations – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	6%	248%	10%	23%	67%	12%
Non-compliant	-72%	-100%	-34%	-64%	-100%	-69%
Total	-12%	2%	-8%	-6%	0%	-11%

Table 3.14: Compliant Car Response to Removal of Free Parking

Response	Compliant Car Response (With Free Parking)	Response as Proportion of Total Car Fleet
Pay Parking Charge	72%	8.5%
Avoid Zone (Change Destination)	3%	0.4%
Cancel Trip	11%	1.3%
Replace Vehicle	0%	0.0%
Mode Shift	14%	1.6%
Total	**100%**	**11.9%**

Table 3.15: Non-Compliant Car Response

Response	Response of Non-Compliant Vehicles	Response as Proportion of Total Car Fleet
Pay CAZ Charge	12%	0.4%
Pay CAZ Charge and Parking	0%	0.1%
Avoid Zone (Change Route)	21%	4.8%
Avoid Zone (Change Destination)	5%	1.1%
Cancel Trip	16%	3.7%
Replace Vehicle (No Parking Change)	23%	5.2%
Replace Vehicle and Pay Parking	3%	0.6%
Mode Shift	20%	4.5%
Total	100%	22.8%

Table 3.16: Non-Car Behavioural Responsiveness

Response	LGV	HGV	Taxi	Bus
Pay CAZ Charge	66%	36%	0%	0%
Avoid Zone (Change Route)	26%	27%	0%	0%
Cancel Trip	0%	0%	0%	0%
Replace Vehicle	7%	37%	100%	100%
Total	100%	100%	100%	100%

2020 CAZ D FBC Scheme Without Mitigations or Exemptions

3.33 This version of the model has:

- CAZ Charge
  - £8 - car, LGV, taxi
  - £50 – HGV, Bus, Coach
- Additional Measures (Including removal of free on-street parking)

Figure 3.4: Cordon Crossings CAZ D High (OBC)

	CAZ D FBC					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	134,200	9,400	14,500	5,800	5,500	169,400
Non-compliant	10,600	0	6,100	900	0	17,700
Total	144,800	9,400	20,600	6,700	5,500	187,000
	CAZ D (without mitigations or exemptions)					
Compliance	**Car**	**Taxi**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	135,800	9,500	15,900	6,100	5,500	172,700
Non-compliant	5,300	0	4,900	700	0	10,800
Total	141,100	9,500	20,700	6,800	5,500	183,500
	Difference (CAZ **without mitigations or exemptions** – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	1,700	0	1,400	200	0	3,300
Non-compliant	-5,400	0	-1,300	-200	0	-6,800
Total	-3,700	0	100	100	0	3,500
	% Difference (CAZ **without mitigations or exemptions** – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	1%	0%	10%	4%	0%	2%
Non-compliant	-50%	0%	-21%	-18%	0%	-39%
Total	-3%	0%	1%	1%	0%	-2%

Table 3.17: Compliant Car Response to Removal of Free Parking

Response	Compliant Car Response (With Free Parking)	Response as Proportion of Total Car Fleet
Pay Parking Charge	72%	8.5%
Avoid Zone (Change Destination)	3%	0.4%
Cancel Trip	11%	1.3%
Replace Vehicle	0%	0.0%
Mode Shift	14%	1.6%
Total	**100%**	**11.9%**

Table 3.18: Non-Compliant Car Response

Response	Response of Non-Compliant Vehicles	Response as Proportion of Total Car Fleet
Pay CAZ Charge	14%	0.5%
Pay CAZ Charge and Parking	0%	0.0%
Avoid Zone (Change Route)	21%	4.8%
Avoid Zone (Change Destination)	4%	0.9%
Cancel Trip	13%	3.0%
Replace Vehicle (No Parking Change)	28%	6.4%
Replace Vehicle and Pay Parking	3%	0.8%
Mode Shift	16%	3.7%
Total	100%	22.8%

Table 3.19: Non-Car Behavioural Responsiveness

Response	LGV	HGV	Taxi	Bus
Pay CAZ Charge	52%	30%	0%	0%
Avoid Zone (Change Route)	26%	27%	0%	0%
Cancel Trip	0%	0%	0%	0%
Replace Vehicle	21%	43%	100%	100%
Total	100%	100%	100%	100%

2020 CAZ D FBC Scheme (with high charge)

3.34 This version of the model has:

- CAZ Charge
  - £12.50 - car, LGV, taxi
  - £100 – HGV, Bus, Coach
- Additional Measures (Including removal of free on-street parking)
- Exemptions
- Mitigations

Figure 3.5: Cordon Crossings CAZ D High (OBC)

	CAZ D FBC					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	134,200	9,400	14,500	5,800	5,500	169,400
Non-compliant	10,600	0	6,100	900	0	17,700
Total	144,800	9,400	20,600	6,700	5,500	187,000
	CAZ D FBC High Charge					
Compliance	**Car**	**Taxi**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	136,600	9,400	15,500	5,900	5,500	172,900
Non-compliant	9,000	0	5,200	800	0	15,000
Total	145,600	9,400	20,700	6,700	5,500	187,900
	Difference (High Charge – FBC)					

Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	2,400	0	1,000	100	0	3,500
Non-compliant	-1,600	0	-1,000	-100	0	-2,700
Total	800	0	100	0	0	-900

	% Difference (High Charge – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	2%	0%	7%	1%	0%	2%
Non-compliant	-15%	0%	-16%	-9%	0%	-15%
Total	1%	0%	0%	0%	0%	0%

Table 3.20: Compliant Car Response to Removal of Free Parking

Response	Compliant Car Response (With Free Parking)	Response as Proportion of Total Car Fleet
Pay Parking Charge	72%	8.5%
Avoid Zone (Change Destination)	3%	0.4%
Cancel Trip	11%	1.3%
Replace Vehicle	0%	0.0%
Mode Shift	14%	1.6%
Total	**100%**	**11.9%**

Table 3.21: Non-Compliant Car Response

Response	Response of Non-Compliant Vehicles	Response as Proportion of Total Car Fleet
Pay CAZ Charge	8%	0.3%
Pay CAZ Charge and Parking	0%	0.0%
Avoid Zone (Change Route)	21%	4.8%
Avoid Zone (Change Destination)	5%	1.0%
Cancel Trip	14%	3.3%
Replace Vehicle (No Parking Change)	31%	7.0%
Replace Vehicle and Pay Parking	4%	0.8%
Mode Shift	18%	4.0%
Total	100%	22.8%

Table 3.22: Non-Car Behavioural Responsiveness

Response	LGV	HGV	Taxi	Bus
Pay CAZ Charge	56%	33%	0%	0%
Avoid Zone (Change Route)	26%	27%	0%	0%
Cancel Trip	0%	0%	0%	0%
Replace Vehicle	18%	40%	100%	100%
Total	100%	100%	100%	100%

2022 CAZ D FBC Scheme

3.35 This version of the model has:

- CAZ Charge
  - £8 - car, LGV, taxi
  - £50 – HGV, Bus, Coach
- Additional Measures (Including removal of free on-street parking)
- Exemptions
- Mitigations

Figure 3.6: Cordon Crossings CAZ D High (FBC)

	DM					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	140,300	3,900	16,400	5,700	3,300	169,600
Non-compliant	25,700	5100	7,100	1600	2200	41,700
Total	166,000	9,000	23,600	7,300	5,500	211,300
	CAZ FBC					
Compliance	**Car**	**Taxi**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	148,900	9,200	18,600	6,800	5,500	189,100
Non-compliant	2,600	0	3,500	200	0	6,300
Total	151,500	9,200	22,200	7,000	5,500	195,400
	Difference (CAZ FBC – DM)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	8,600	5,300	2,200	1,200	2,200	19,400
Non-compliant	23,100	5,100	3,600	1,400	2,200	35,400
Total	14,500	300	1,400	200	0	-15,900
	% Difference (CAZ FBC – DM)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	6%	136%	13%	21%	67%	11%
Non-compliant	-90%	-100%	-51%	-89%	-100%	-85%
Total	-9%	3%	-6%	-3%	0%	-8%

Table 3.23: Compliant Car Response to Removal of Free Parking

Response	Compliant Car Response (With Free Parking)	Response as Proportion of Total Car Fleet
Pay Parking Charge	72%	9.4%
Avoid Zone (Change Destination)	3%	0.5%
Cancel Trip	11%	1.5%
Replace Vehicle	0%	0.0%
Mode Shift	14%	1.8%
Total	**100%**	**13.1%**

Table 3.24: Non-Compliant Car Response

Response	Response of Non-Compliant Vehicles	Response as Proportion of Total Car Fleet
Pay CAZ Charge	8%	0.2%
Pay CAZ Charge and Parking	0%	0.0%
Avoid Zone (Change Route)	16%	2.5%
Avoid Zone (Change Destination)	7%	1.0%
Cancel Trip	15%	2.3%
Replace Vehicle (No Parking Change)	30%	4.7%
Replace Vehicle and Pay Parking	4%	0.6%
Mode Shift	20%	3.1%
Total	100%	15.5%

Table 3.25: Non-Car Behavioural Responsiveness

Response	LGV	HGV	Taxi	Bus
Pay CAZ Charge	49%	11%	0%	0%
Avoid Zone (Change Route)	27%	27%	0%	0%
Cancel Trip	0%	0%	0%	0%
Replace Vehicle	24%	62%	100%	100%
Total	100%	100%	100%	100%

2022 CAZ D FBC Scheme Without Mitigations

3.36 This version of the model has:

- CAZ Charge
  - £8 - car, LGV, taxi
  - £50 – HGV, Bus, Coach
- Additional Measures (Including removal of free on-street parking)
- Exemptions

Figure 3.7: Cordon Crossings CAZ D High (OBC)

	CAZ D FBC					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	134,200	9,400	14,500	5,800	5,500	169,400
Non-compliant	10,600	0	6,100	900	0	17,700
Total	144,800	9,400	20,600	6,700	5,500	187,000
	CAZ D FBC Scheme Without Mitigations					
Compliance	**Car**	**Taxi**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	145,900	9,200	18,600	6,900	5,500	186,100
Non-compliant	3,400	0	3,500	200	0	7,100
Total	151,500	9,200	22,200	7,000	5,500	195,400
	Difference (CAZ without Mitigations – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total

Compliant	-2,900	0	0	0	0	-2,900
Non-compliant	800	0	0	0	0	800
Total	0	0	0	0	0	0

	% Difference (CAZ without Mitigations – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	-2%	0%	0%	0%	0%	-2%
Non-compliant	32%	0%	0%	0%	0%	13%
Total	0%	0%	0%	0%	0%	0%

Table 3.26: Compliant Car Response to Removal of Free Parking

Response	Compliant Car Response (With Free Parking)	Response as Proportion of Total Car Fleet
Pay Parking Charge	72%	9.4%
Avoid Zone (Change Destination)	3%	0.5%
Cancel Trip	11%	1.5%
Replace Vehicle	0%	0.0%
Mode Shift	14%	1.8%
Total	**100%**	**13.1%**

Table 3.27: Non-Compliant Car Response

Response	Response of Non-Compliant Vehicles	Response as Proportion of Total Car Fleet
Pay CAZ Charge	11%	0.3%
Pay CAZ Charge and Parking	0%	0.1%
Avoid Zone (Change Route)	16%	2.5%
Avoid Zone (Change Destination)	6%	1.0%
Cancel Trip	14%	2.2%
Replace Vehicle (No Parking Change)	29%	4.5%
Replace Vehicle and Pay Parking	3%	0.5%
Mode Shift	19%	3.0%
Total	**100%**	**15.5%**

Table 3.28: Non-Car Behavioural Responsiveness

Response	LGV	HGV	Taxi	Bus
Pay CAZ Charge	49%	11%	0%	0%
Avoid Zone (Change Route)	27%	27%	0%	0%
Cancel Trip	0%	0%	0%	0%
Replace Vehicle	24%	62%	100%	100%
Total	100%	100%	100%	100%

2022 CAZ D FBC Scheme Without Mitigations or Exemptions

3.37 This version of the model has:

- CAZ Charge
  - £8 - car, LGV, taxi
  - £50 – HGV, Bus, Coach
- Additional Measures (Including removal of free on-street parking)

Figure 3.8: Cordon Crossings CAZ D High (OBC)

	CAZ D FBC					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	134,200	9,400	14,500	5,800	5,500	169,400
Non-compliant	10,600	0	6,100	900	0	17,700
Total	144,800	9,400	20,600	6,700	5,500	187,000
	CAZ D (without mitigations or exemptions)					
Compliance	**Car**	**Taxi**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	146,100	9,300	18,700	6,900	5,500	186,400
Non-compliant	3,200	0	3,500	200	0	6,800
Total	151,500	9,200	22,200	7,000	5,500	195,400
	Difference (CAZ **without mitigations or exemptions** – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	-2,800	0	100	0	0	-2,700
Non-compliant	600	0	-100	0	0	500
Total	0	0	0	0	0	0
	% Difference (CAZ **without mitigations or exemptions** – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	-2%	0%	0%	0%	0%	-1%
Non-compliant	22%	0%	-2%	0%	0%	8%
Total	0%	0%	0%	0%	0%	0%

Table 3.29: Compliant Car Response to Removal of Free Parking

Response	Compliant Car Response (With Free Parking)	Response as Proportion of Total Car Fleet
Pay Parking Charge	72%	9.4%
Avoid Zone (Change Destination)	3%	0.5%
Cancel Trip	11%	1.5%
Replace Vehicle	0%	0.0%
Mode Shift	14%	1.8%
Total	**100%**	**13.1%**

Table 3.30: Non-Compliant Car Response

Response	Response of Non-Compliant Vehicles	Response as Proportion of Total Car Fleet
Pay CAZ Charge	12%	0.3%
Pay CAZ Charge and Parking	0%	0.1%
Avoid Zone (Change Route)	16%	2.5%
Avoid Zone (Change Destination)	6%	1.0%
Cancel Trip	14%	2.2%
Replace Vehicle (No Parking Change)	29%	4.4%
Replace Vehicle and Pay Parking	3%	0.5%
Mode Shift	19%	2.9%
Total	100%	15.5%

Table 3.31: Non-Car Behavioural Responsiveness

Response	LGV	HGV	Taxi	Bus
Pay CAZ Charge	48%	11%	0%	0%
Avoid Zone (Change Route)	27%	27%	0%	0%
Cancel Trip	0%	0%	0%	0%
Replace Vehicle	25%	62%	100%	100%
Total	0%	0%	0%	0%

2022 CAZ D FBC Scheme (with high charge)

3.38 This version of the model has:

- CAZ Charge
  - £12.50 - car, LGV, taxi
  - £100 – HGV, Bus, Coach
- Additional Measures (Including removal of free on-street parking)
- Exemptions
- Mitigations

Figure 3.9: Cordon Crossings CAZ D High (OBC)

	CAZ D FBC					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	134,200	9,400	14,500	5,800	5,500	169,400
Non-compliant	10,600	0	6,100	900	0	17,700
Total	144,800	9,400	20,600	6,700	5,500	187,000
	CAZ D FBC High Charge					
Compliance	**Car**	**Taxi**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	151,500	9,200	19,200	6,900	5,500	192,300
Non-compliant	1,600	0	3,000	100	0	4,700
Total	153,100	9,200	22,200	7,000	5,500	197,000
	Difference (High Charge – FBC)					

Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	2,600	0	500	100	0	3,200
Non-compliant	-1,000	0	-500	-100	0	-1,600
Total	1,600	0	0	0	0	-1,600

	% Difference (High Charge – FBC)					
Compliance	Car	Taxi	LGV	HGV	Bus	Total
Compliant	2%	0%	3%	1%	0%	2%
Non-compliant	-38%	0%	-15%	-61%	0%	-26%
Total	1%	0%	0%	0%	0%	1%

Table 3.32: Compliant Car Response to Removal of Free Parking

Response	Compliant Car Response (With Free Parking)	Response as Proportion of Total Car Fleet
Pay Parking Charge	72%	8.5%
Avoid Zone (Change Destination)	3%	0.4%
Cancel Trip	11%	1.3%
Replace Vehicle	0%	0.0%
Mode Shift	14%	1.6%
Total	**100%**	**11.9%**

Table 3.33: Non-Compliant Car Response

Response	Response of Non-Compliant Vehicles	Response as Proportion of Total Car Fleet
Pay CAZ Charge	5%	0.1%
Pay CAZ Charge and Parking	0%	0.0%
Avoid Zone (Change Route)	16%	2.5%
Avoid Zone (Change Destination)	7%	1.1%
Cancel Trip	15%	2.4%
Replace Vehicle (No Parking Change)	32%	4.9%
Replace Vehicle and Pay Parking	4%	0.6%
Mode Shift	21%	3.3%
Total	**100%**	**15.5%**

Table 3.34: Non-Car Behavioural Responsiveness

Response	LGV	HGV	Taxi	Bus
Pay CAZ Charge	42%	4%	0%	0%
Avoid Zone (Change Route)	27%	27%	0%	0%
Cancel Trip	0%	0%	0%	0%
Replace Vehicle	31%	69%	100%	100%
Total	0%	0%	0%	0%

4 Model Results

Overview

4.1 This section describes the impact of the forecasts described in the proceeding chapters on the SATURN assignment models. A summary of the model runs are as follows:

- The models have been run for the following time periods:
  - AM Peak Weekday Average Hour (07:30-09:30)
  - Inter Peak Weekday Average Hour (08:30-16:30)
  - PM Peak Weekday Average Hour (16:30-19:00)
- And the following scenarios
  - 2016 Base Year
  - 2020 Do Minimum
  - 2020 CAZ D High with Additional Measures, Exemptions and Mitigations (FBC)
  - 2022 CAZ D High with Additional Measures, Exemptions and Mitigations (FBC)

4.2 The detailed reporting in this chapter focuses on the AM Peak hour as the effects are similar across the time periods. Network plots and changes in network statistics are included in appendices for all scenario.

4.3 The key metrics we have used to assess the impacts of the CAZ are as follows:

- Annual Average Daily Flows (AADT) entering the CAZ for compliant and non-compliant flows. This shows the numbers of vehicles driving across the CAZ boundary each day by vehicle type in the different scenarios.
- Network Plots – Showing change in flows graphically across the modelled links to see where flows are increasing and decreasing. Also includes analysis of change in link delay.
- Key Link Analysis – Tables showing changes in flows at key network links at the all day level
- Network Statistics – Change in vehicle kilometres and average network speed. This provides an aggregate measure of change in network conditions and has been provided by different modelled areas.

4.4 An important caveat when analysing these results is that the model detailed is focused on the City Centre. Changes to the model outside of the CAZ should be treated with caution.

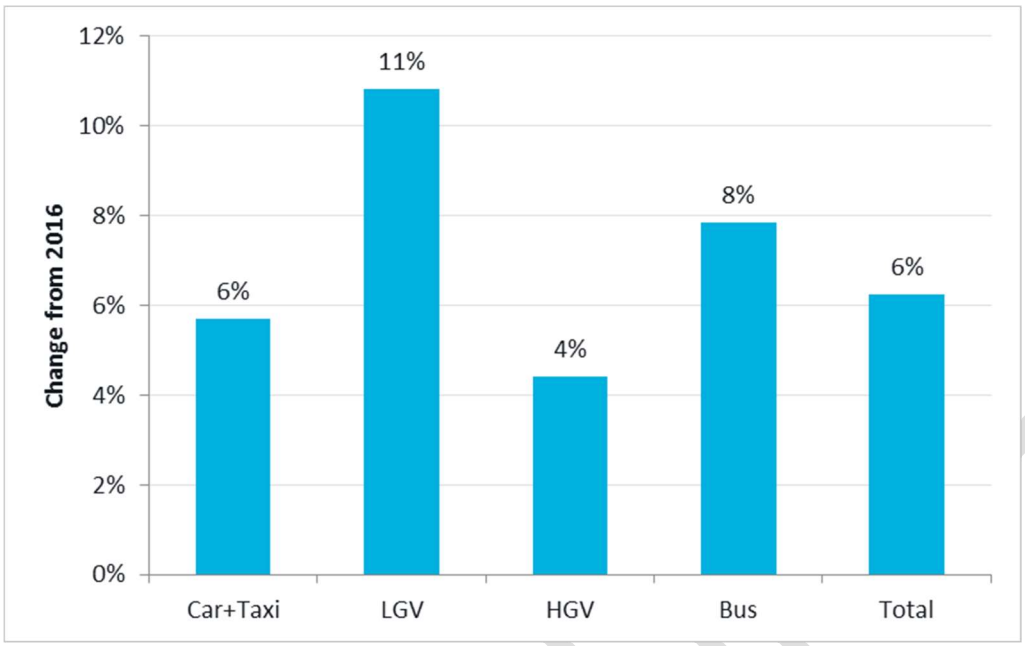
Base Year to 2020 Do Minimum Changes

Clean Air Zone

4.5 Figure 4.1 shows the forecast growth in vehicles entering the CAZ between 2016 to 2020, including both through trips and those with a destination in the City Centre. Overall traffic

growth is 6% with the largest increase in LGVs, with an increase of 11%. This is line with recent trends showing rapid growth in "white van" traffic.

Figure 4.1: Growth by Vehicle Type – Average Annual Daily Traffic



4.6 Figure 4.2 below, shows the changes in compliance rates for the different vehicle classes, supported by the detailed information in Table 4.1 to Table 4.4 below. Overall there is an increase in 12,000 vehicles entering the zone, but with a reduction in non-compliant vehicles of around 42,000 vehicles.

Figure 4.2: Growth by Compliance Rate

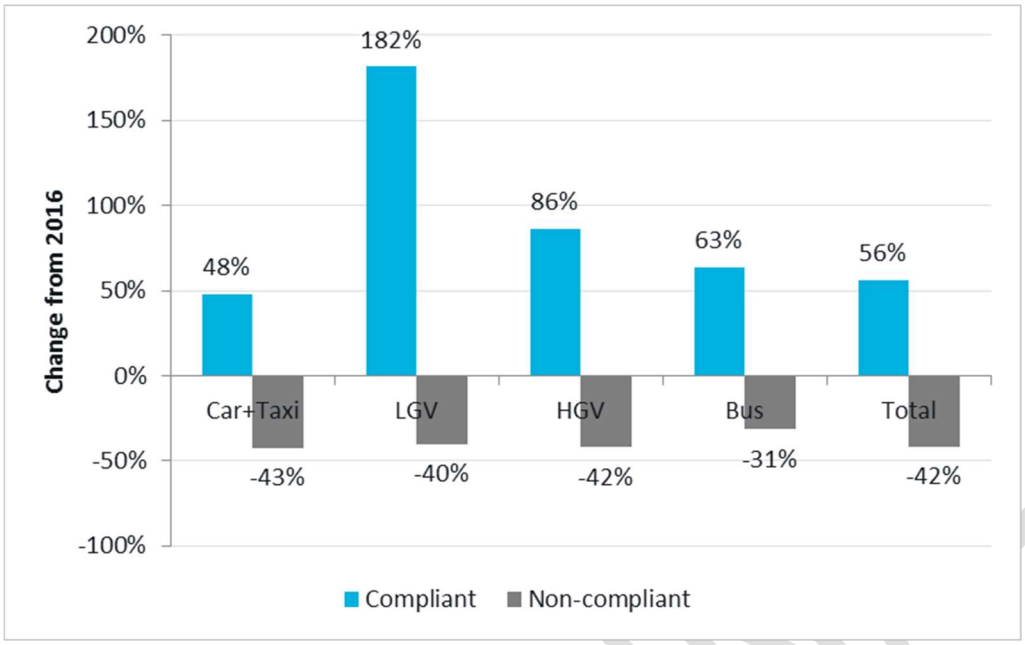


Table 4.1: Screenline AADT Flows – 2016 Base Year

Compliance	Car+Taxi	LGV	HGV	Bus	Total
Compliant	87,700	4,700	2,500	2,000	96,800
Non-compliant	76,800	15,600	4,300	3,200	99,900
Total	164,500	20,300	6,800	5,100	196,700

Table 4.2: Screenline AADT Flows - 2020 Do Minimum

Compliance	Car+Taxi	LGV	HGV	Bus	Total
Compliant	129,800	13,200	4,700	3,300	151,000
Non-compliant	44,100	9,300	2,500	2,200	58,000
Total	173,900	22,500	7,100	5,500	209,000

Table 4.3: Screenline AADT Flows Difference (2020 Do Minimum – 2016 Base Year)

Compliance	Car+Taxi	LGV	HGV	Bus	Total
Compliant	42,143	8,532	2,151	1,269	54,196
Non-compliant	-32,746	-6,301	-1,804	-1,004	-41,856
Total	9,397	2,231	346	365	12,339

Table 4.4: Screenline AADT Flows % Difference (2020 Do Minimum – 2016 Base Year)

Compliance	Car+Taxi	LGV	HGV	Bus	Total
Compliant	48%	182%	86%	63%	56%
Non-compliant	-43%	-40%	-42%	-31%	-42%
Total	6%	11%	5%	7%	6%

Network Changes

4.7 Figure 4-3 to Figure 4-5 illustrate changes in AM peak city centre traffic flows between the 2016 Base Year and the modelled 2020 Do-Minimum, with:

- Green links showing an increase in traffic with the thicker the line the bigger the increase
- Blue links showing a decrease in traffic with the thicker the line the bigger the decrease

4.8 Figure 4-3 shows the change in total traffic, with impacts varying depending on the location of new developments and the impact of changes to the road network. Outside of the CAZ zone there is general increase in traffic reflecting the forecast growth in background traffic. Decreases in traffic can be seen to the East of the City Centre with traffic reducing due to road closures associated with HS2 construction, and the closure of Moor Street Queensway to general traffic.

4.9 Significant increases in traffic are seen on the A38 through the City Centre as traffic diverts from the corridors described above, and following the completion of the Paradise Circus scheme which reopens the link to Summer Hill Road increasing accessibility to the corridor compared to 2016 conditions. This also increases traffic on Summer Hill Road while reducing rat-running traffic on the side streets in the area.

4.10 Figure 4-5 shows the changes in compliant and non-compliant vehicle traffic respectively. This demonstrates the reduction in non-compliant vehicles due to the natural upgrading of the vehicle fleet, despite the general increases in total traffic.

Figure 4-3: Total Flow Change (2020 Do Minimum – Base) - AM

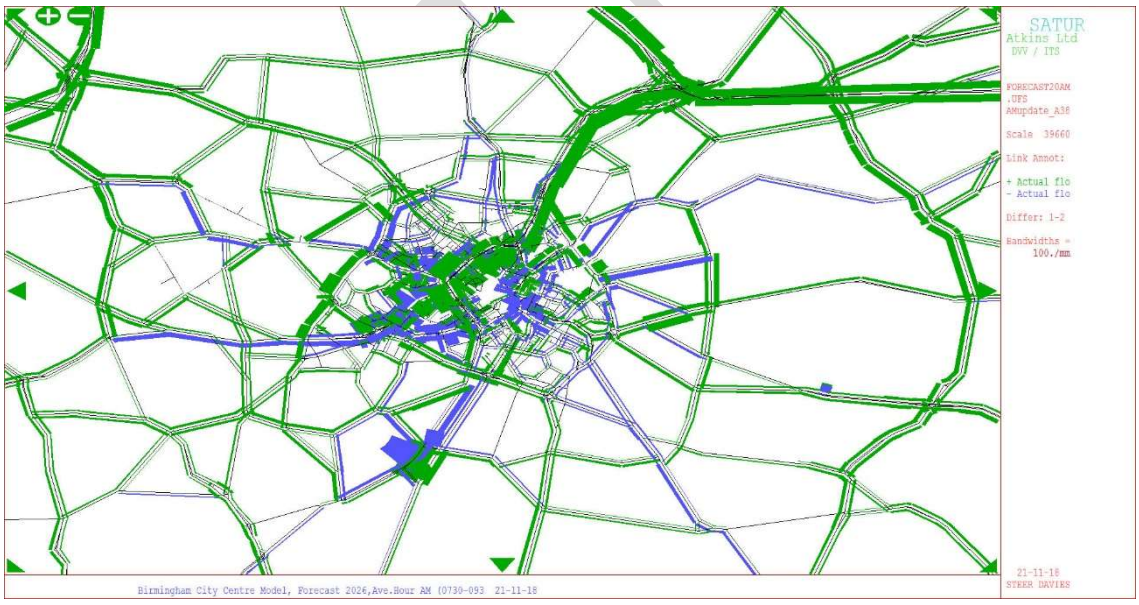


Figure 4-4: Compliant Flow Change (2020 Do Minimum – Base) – AM

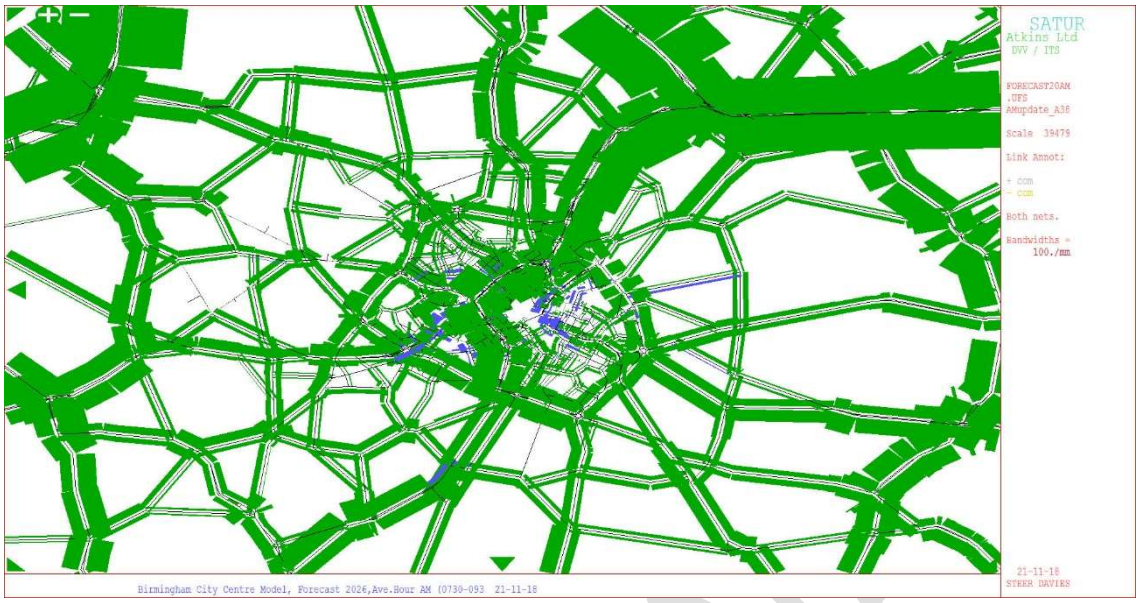
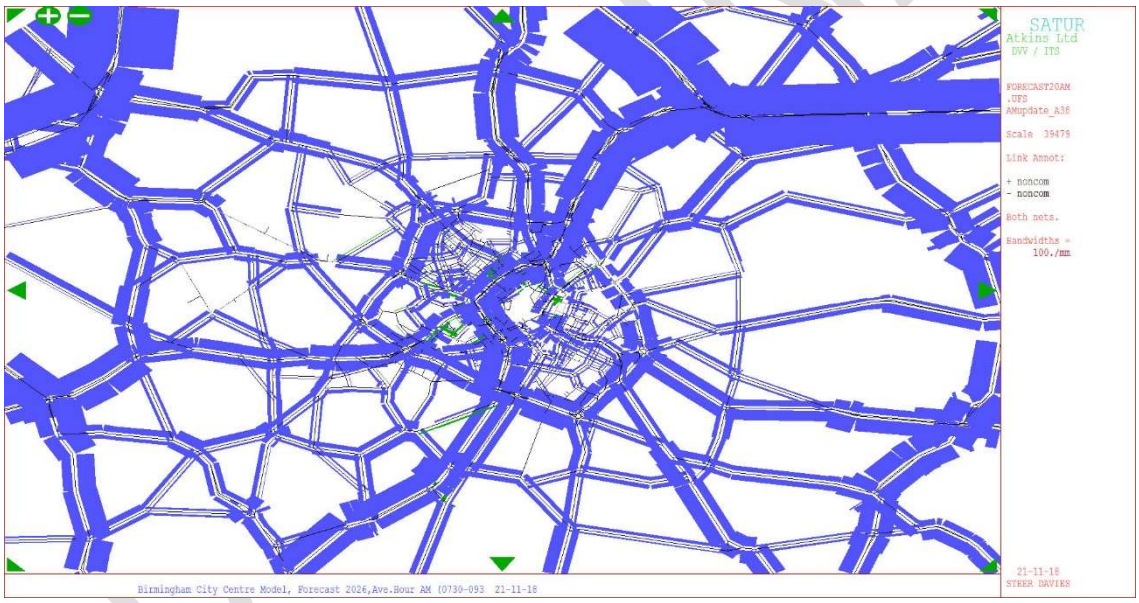


Figure 4-5: Non-compliant Flow Change (2020 Do Minimum – Base) - AM



2020 CAZ D FBC Scenario

4.11 Under CAZ Scenario D, non-compliant vehicles (excluding exemptions) are subjected to charges as described in the table below.

Table 4.5: CAZ Charges

CAZ	CAZ FBC
Car	£8.00
Taxi	£8.00
LGV	£8.00
HGV	£50.00
Bus/ Coach	£50.00

4.12 The change in compliance for car, LGV and HGV traffic entering the CAZ is shown in the table below. Overall compliance rates increases from 72% to 97% of all vehicles entering the CAZ as a result of the scheme.

Table 4.6: Compliance Rates for CAZ D – Crossing the CAZ Cordon

		Car	Taxi	LGV	HGV	Bus	Total
DM	Compliant	77%	30%	59%	65%	60%	72%
	Non-compliant	23%	70%	41%	35%	40%	28%
High	Compliant	93%	100%	70%	87%	100%	91%
	Non-compliant	7%	0%	30%	13%	0%	9%

4.13 Table 4.7 below shows the forecast CAZ cordon crossing flows. Within the model Private Hire Vehicles (PHVs) are included within the car matrices with adjustments to the compliance rates made to account for the differing response rates outside of the model for presentation purposes. Because it is an out of model adjustment the balance between car and PHV in the tables may not be 100% accurate, however in terms of total compliance and the fleet mix in the AQ model these numbers are correct.

4.14 The following impacts are shown in the model results:

- A reduction of over 40,000 non-compliant vehicles entering the CAZ
- A total reduction of around 22,000 vehicles

Table 4.7: CAZ D Screenline AADT flows by Vehicle Type

Do Minimum	Car	Taxi and PHV	LGV	HGV	Bus	Total
Compliant	127,200	2,700	13,200	4,700	3,300	151,000
Non-compliant	37,600	6,500	9,300	2,500	2,200	58,000
Total	164,700	9,200	22,500	7,100	5,500	209,000
High	**Car**	**Taxi and PHV**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	134,200	9,400	14,500	5,800	5,500	169,400
Non-compliant	10,600	-	6,100	900	-	17,700
Total	144,800	9,400	20,600	6,700	5,500	187,000
Change from Do Minimum (Abs)	**Car**	**Taxi and PHV**	**LGV**	**HGV**	**Bus**	**Total**

Compliant	7,000	6,700	1,300	1,100	2,200	18,400
Non-compliant	-27,000	-6,500	-3,200	-1,600	-2,200	-40,300
Total	-19,900	200	-1,900	-400	0	-22,000
Change from Do Minimum (%)	**Car**	**Taxi and PHV**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	6%	248%	10%	23%	67%	12%
Non-compliant	-72%	-100%	-34%	-64%	-100%	-69%
Total	-12%	2%	-8%	-6%	0%	-11%

4.15 Figures 4.13 to 4.15 illustrate changes in AM peak city centre traffic flows between the modelled 2020 Do-Minimum and CAZ D FBC scenario with:

- Green links showing an increase in traffic in CAZ D compared to the Do Minimum with the thicker the line the bigger the increase.
- Blue links showing a decrease in traffic in CAZ D compared to the Do Minimum with the thicker the line the bigger the decrease.

4.16 In total, there is decrease crossing the city centre with a clear reduction trips on the A38. Increases can be seen on sections of the Ring Road as well as some additional parallel roads further out from the CAZ, which are used as a detour for through trips entering the zone.

Figure 4.6: Total Flow Change (CAZ D High – Do Minimum) – AM Peak

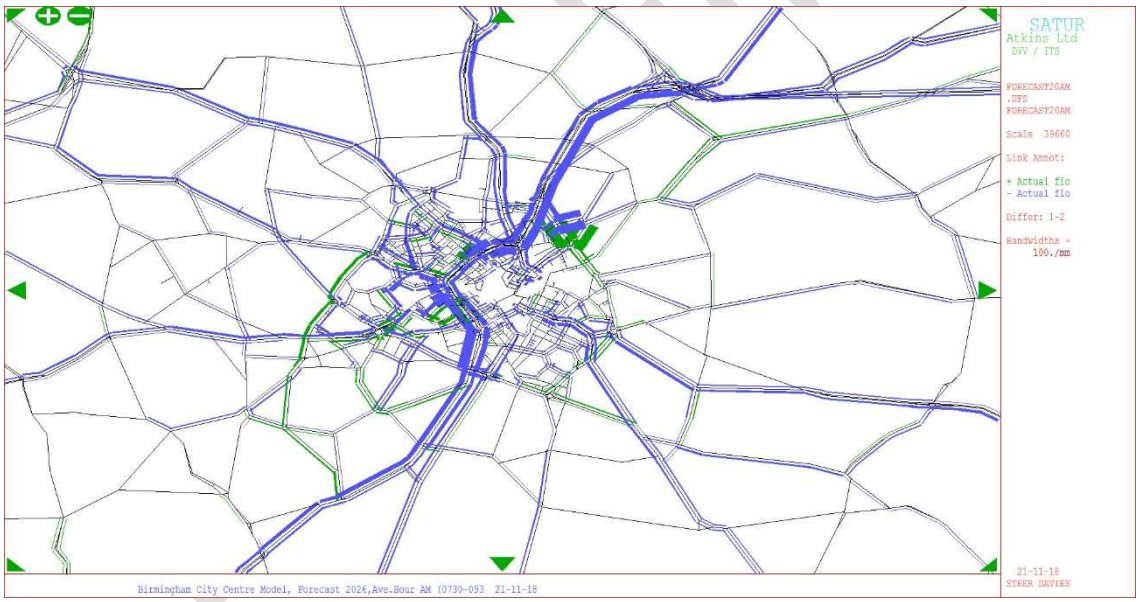


Figure 4.7: Compliant Flow Change (2020 CAZ D FBC – Do Minimum) – AM Peak

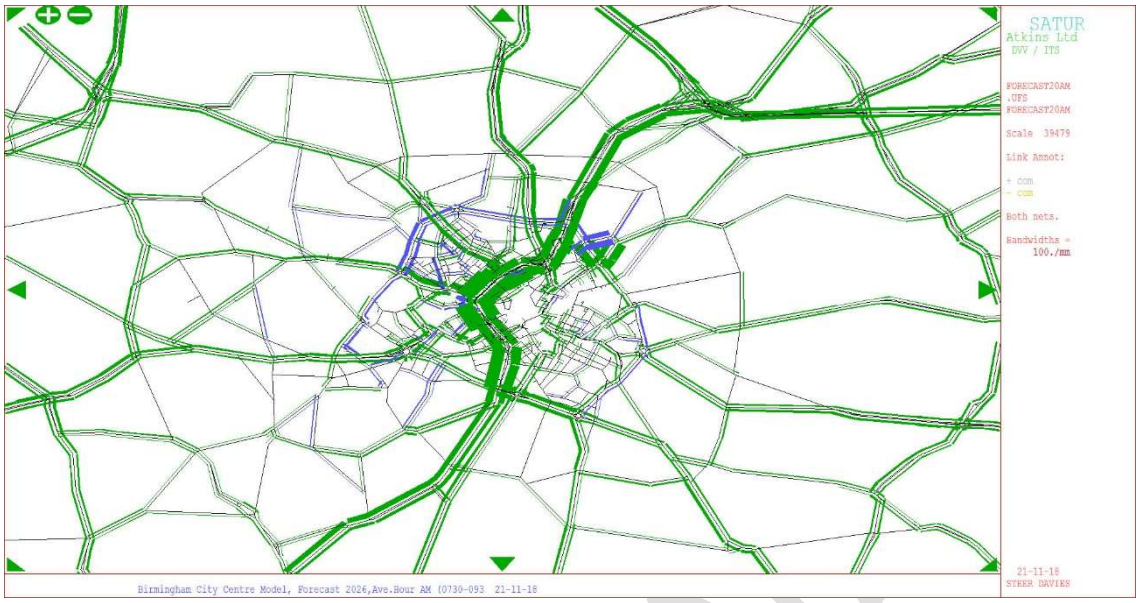
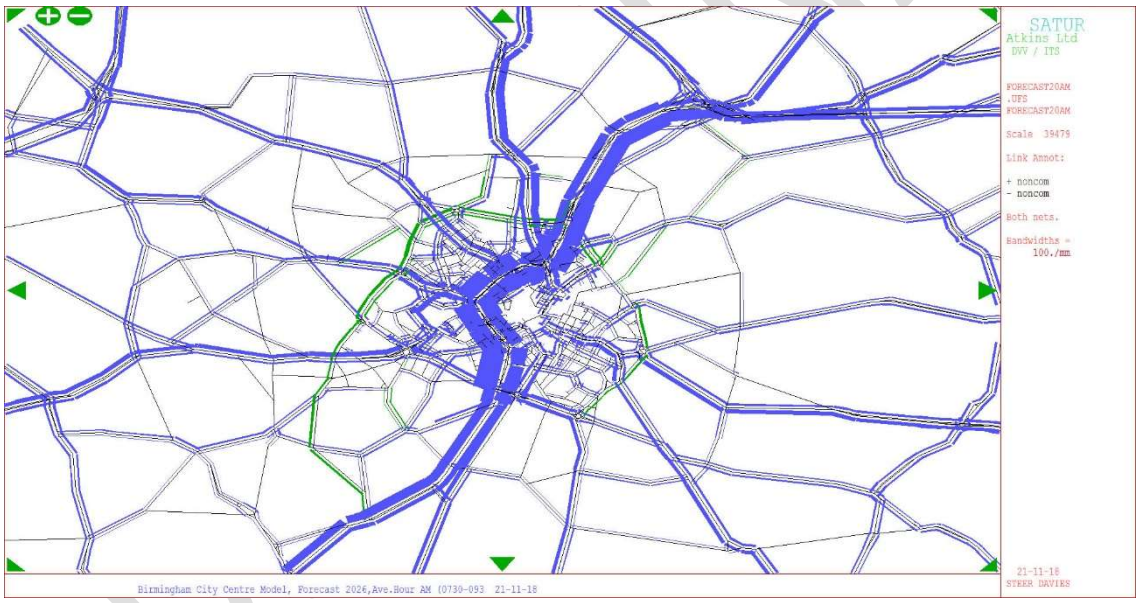


Figure 4.8: Non-compliant Flow Change (2020 CAZ D FBC – Do Minimum) – AM Peak

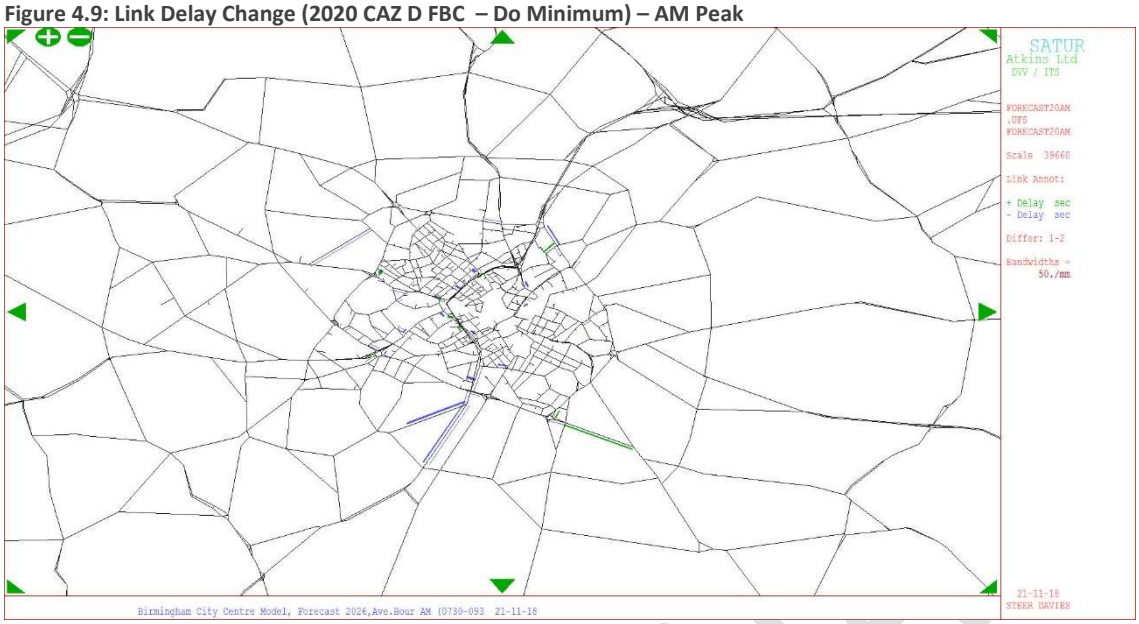


4.17 CAZ FBC does not have a significant impact on links delays, as can be seen in Figure 4.10 below, with:

- Green links showing an increase in delay in CAZ D compared to the Do Minimum with the thicker the line the bigger the increase.
- Blue links showing a decrease in delay in CAZ D compared to the Do Minimum with the thicker the line the bigger the decrease.

4.18 There have been minor reductions in delays across many City Centre links and on radial routes into the CAZ reflecting the reduction in traffic levels caused by cancelled trips. The effects of diversion have caused minimal increases in delay at a small number of links on parallel routes.

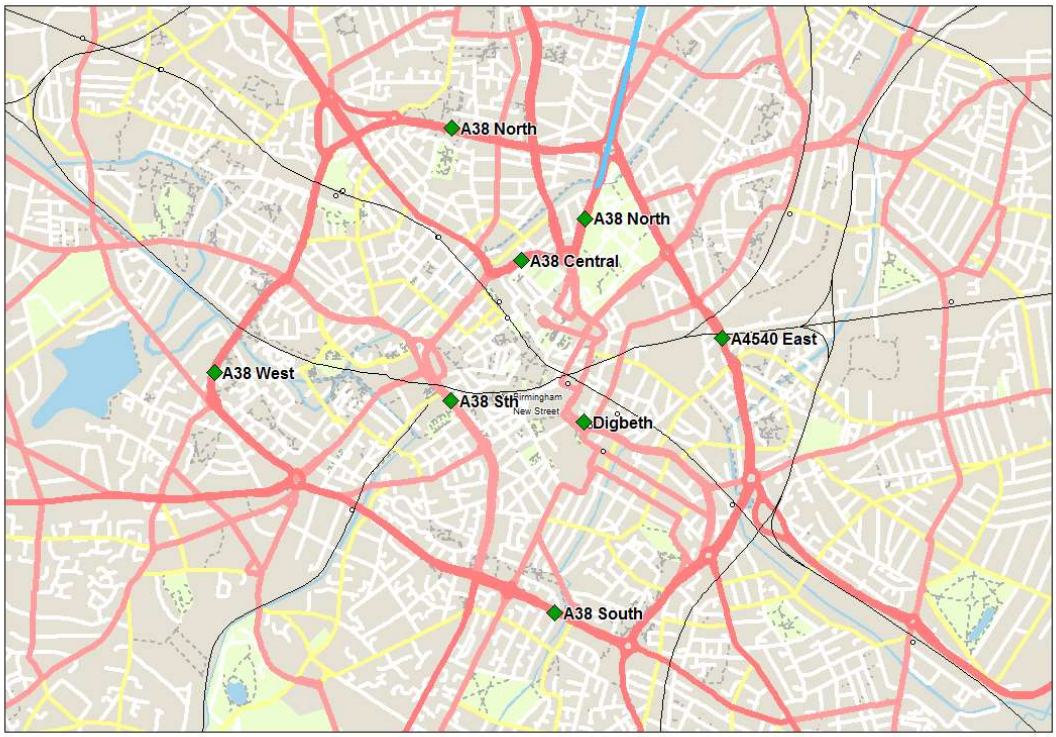
Figure 4.9: Link Delay Change (2020 CAZ D FBC – Do Minimum) – AM Peak



Key Link Analysis

4.19 To have a more detailed understanding of changes to the network a set of individual links have been analysed. The worst links in the City Centre in terms of Air Quality have been identified as well as selecting four links on the ring road, and change in flows between scenarios analysed. Figure 4.10 shows the links chosen for analysis.

Figure 4.10: Key City Centre Links



4.20 Table 4.8 below shows changes in total vehicles, with the following observations on traffic changes between base year and the Do Minimum:

- The A38 links show significant increase due to parallel road closures (described at the start of this chapter) due to:
  - HS2 Curzon Street construction;
  - Edgbaston Metro;
  - Moor Street Queensway Closure

4.21 The changes between CAZ D and the Do Minimum shows:

- There are significant reductions on each of the roads identified, with flows on the A38 forecast to reduce to below 2016 levels, except for the central section which still shows a 9% reduction from the Do Minimum.

Table 4.8: City Centre Links AADT All Vehicles

Road	2016 Base	2020 Do Minimum	Growth (DM-Base) (Abs)	Growth (Base to DM %)	CAZ D High	CAZ D Change (CAZ D - DM)	CAZ D Change (DM to CAZ D %)
Digbeth Gyratory	17,500	18,900	1,400	8%	17,500	-1,400	-7%
A38 South	56,400	63,600	7,200	13%	55,200	-8,400	-13%
A38 Central	61,500	72,900	11,400	19%	66,400	-6,500	-9%
A38 North	84,000	87,800	3,800	5%	82,900	-4,900	-6%

4.22 For the ring road, changes in traffic levels are as shown in Table 4.9:

- In terms of traffic growth between the base year and the Do Minimum, overall growth is in line the with general traffic growth across the model, although is flatter in the northern section.
- For CAZ D to Do Minimum changes, the impacts are generally neutral but with some significant increases on the Western section of the ring road.

Table 4.9: Ring Road City Centre Links AADT All Vehicles

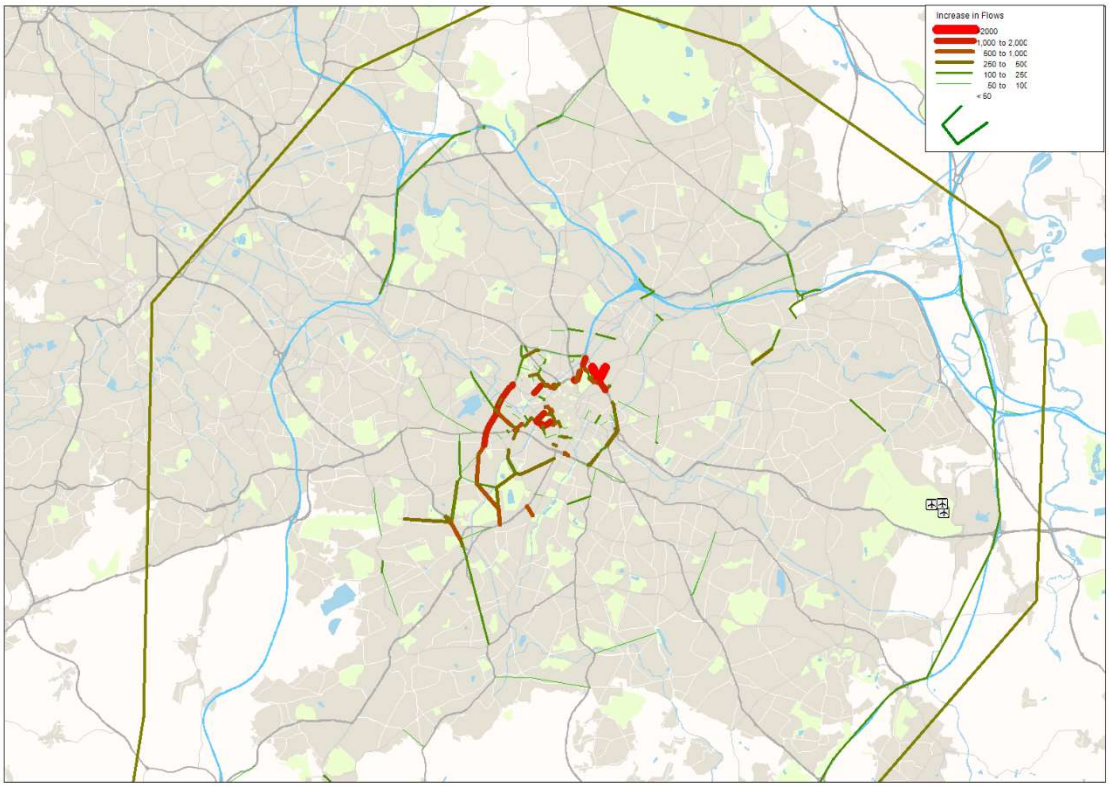
Road	2016 Base	2020 Do Minimum	Growth (DM- Base) (Abs)	Growth (Base to DM %)	CAZ D High	CAZ D Change (CAZ D - DM)	CAZ D Change (DM to CAZ D %)
Ring Road North	32,800	33,000	200	1%	32,900	-100	0%
Ring Road South	59,600	63,300	3,700	6%	62,500	-800	-1%
Ring Road West	30,900	33,000	2,100	7%	34,900	1,900	6%
Ring Road East	54,900	58,300	3,400	6%	58,400	100	0%

In terms of the wider network the impact of diversion away from the CAZ area is shown in Figure 4.18 below which highlights roads where the daily increase in traffic is great than 50. This shows:

- The most significant increases occur on the Ring Road
- There is diversion to the South East of the City as through trips avoid the A38 and find alternative routing to the Ring Road.
- There are increases on some sections of the motorway box, but generally the impacts are not seen beyond links close to the City Centre

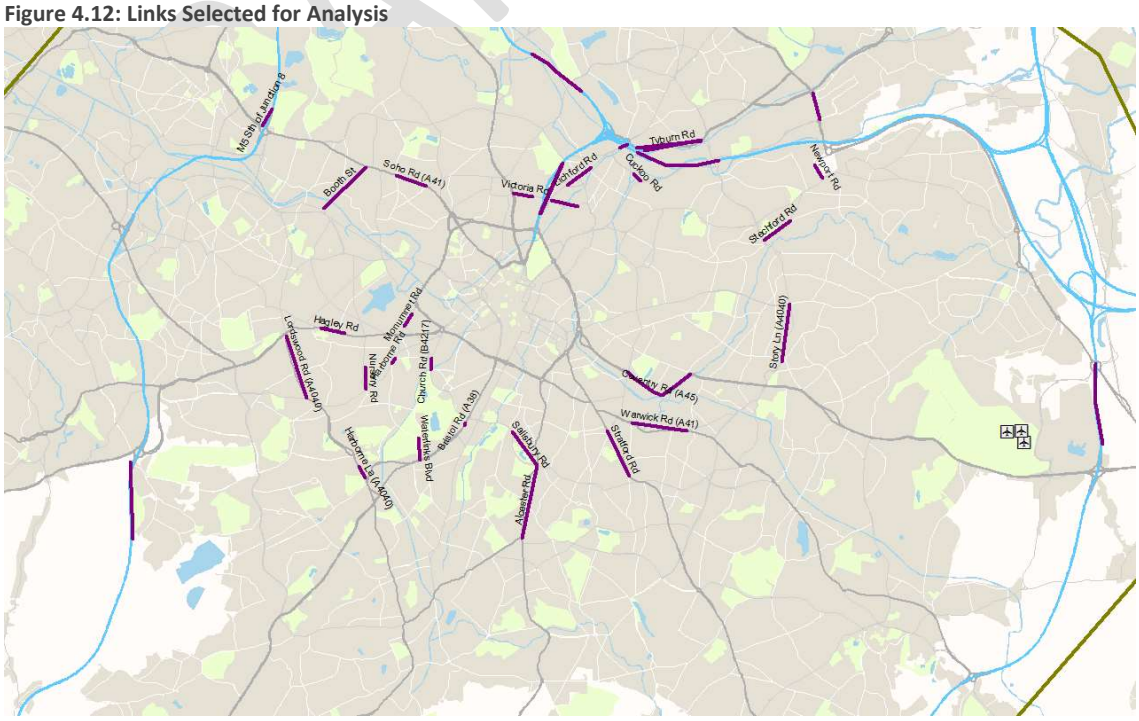
- Other than the A4050 ring road and Monument Rd, no link increases by more than 1000 vehicles a day, with typical values less than 250 a day

Figure 4.11: Change in AADT Vehicle Flows DM to CAZ D High



4.23 The links with the largest changes in flows in the CAZ D scenario have been identified along with some other selected links in the wide network have been analysed. The links selected are shown in Figure 4.12.

Figure 4.12: Links Selected for Analysis



4.24 Traffic changes on the motorway box links selected for analysis are shown in Table 4.10 below.

- For traffic growth between the base year and the Do Minimum:
  - Is in line or slightly higher than for general traffic. The M42 south of the M6 which forecast to have higher levels of growth of 8%.
- For CAZ D compared to Do Minimum
  - The impact of CAZ D high is minimal with below 1% change in flows, with the M6 east of the A38(M) showing a slight reduction in vehicles indicating that this section carries significant numbers of trips accessing the City Centre.

Table 4.10: Motorway Box Links AADT All Vehicles

Road	2016 Base	2020 Do Minimum	Growth (DM- Base) (Abs)	Growth (Base to DM %)	CAZ D High	CAZ D Change (CAZ D - DM)	CAZ D Change (DM to CAZ D %)
M5 Sth of Junction 3	125,100	130,900	5,800	5%	130,400	-500	0%
M5 Sth of Junction 8	166,000	173,400	7,400	4%	173,500	100	0%
M42 East of M40	140,300	148,600	8,300	6%	148,900	300	0%
M6 East of A38 (M)	115,800	122,400	6,600	6%	120,800	-1,600	-1%
M42 Sth of M6	131,800	141,800	10,000	8%	141,700	-100	0%

4.25 For the wider road network within the motorway box the traffic numbers for all traffic are shown in Table 4.24 below.

4.26 For the base year to Do Minimum traffic growth, growth rates vary across the network but are generally in line with general traffic levels, except on B4124 Monument Rd where there are some significant traffic increases. There is a reduction in traffic on the A38 Bristol Road which is due to network changes outside of the City Centre allowing a new access route for local traffic in the Edgbaston area.

4.27 The impact of CAZ D FBC compared with Do Minimum, shows that for most of links there will be a small reduction in traffic. The three links below are the only roads identified with more than a 500 vehicle increase in AADT traffic flows and are all in the area to the South West of the City Centre:

- Monument Rd
- Edgbaston Park Rd
- Harborne La (A4040)
- Church Rd (B4217)

Table 4.11: Wider Network Links AADT All Vehicles

Road	Growth (Base to DM %)	CAZ D Change (CAZ D - DM)	CAZ D Change (DM to CAZ D %)
Tyburn Rd	7%	- 1,900	-2%
Chester Rd	5%	200	0%
A38 (M)	7%	- 6,000	-6%
Edgbaston Park Rd	3%	1,000	4%
Nursery Rd	8%	100	1%
Monument Rd	21%	1,200	7%
Harborne Rd	6%	-	0%
Church Rd (B4217)	2%	600	5%
Harborne La (A4040)	2%	700	2%
Bristol Rd (A38)	-23%	- 2,900	-6%
Lordswood Rd (A4040)	2%	-	0%
Hagley Rd	-5%	- 1,800	-5%
Soho Rd (A41)	6%	- 1,500	-6%
Alcester Rd	3%	- 500	-1%
Salisbury Rd	6%	- 300	-2%
Stratford Rd	-3%	- 1,100	-2%
Warwick Rd (A41)	2%	- 900	-4%
Coventry Rd (A45)	3%	- 1,500	-3%
Victoria Rd	3%	200	1%
Litchford Rd	7%	- 600	-7%
Cuckoo Rd	11%	-	0%
Story Ln (A4040)	5%	- 300	0%
Newport Rd	8%	100	0%
Booth St	5%	- 300	-2%
Stechford Rd	6%	300	1%
Waterlinks Blvd	5%	200	5%
Harborne La (A4040)	2%	700	2%

Network Statistics

4.28 Table 4.25 to Table 4.28 display the total vehicle kilometres for the Do-Minimum and CAZ D FBC, across the different vehicle types. This provides an aggregate network wide assessment of the impact of CAZ D FBC on the road network. It should be noted that PHVs are included within cars in the assignment model, so their responses are included within this data.

4.29 The analysis has been split to look at four separate areas:

- Across the entire network:
  - Low reduction in overall vehicle KMs of less than 1%
  - Around 11% reduction in non-compliant vehicle KMs
- Clean Air Zone only:

  - A reduction of 9% in overall traffic
  - A reduction in total LGV and HGV traffic of around 6% and 4% respectively
  - Significant reduction in total non-compliant traffic of 67%
- the area outside the CAZ:
  - The Ring Road,
    - Total traffic increases by less than 0.5%
    - There is a total reduction in car and taxi traffic
    - LGV and HGV traffic increases in total with LGV non-compliant trips increasing by over 6%
    - The overall impact on non-compliant vehicles is a reduction of around 8%
  - Outside the Ring Road,
    - Total traffic is flat with less than 0.5% reduction
    - A reduction of 5% in non-compliant cars
    - An overall reduction in non-compliant vehicles of almost 9%.

4.30 Changes in overall vehicle kilometres travelled across the modelled area is low. This is because there is a reduction in car trips caused by the CAZ, which offsets any diversion caused by the charge. In addition, the majority of trips in the model do not go through or into the CAZ, so are not affected by the scheme.

Table 4.12: Change in Vehicle KMs (whole network)

Do Minimum	Car	Taxi	LGV	HGV	Total
Compliant	21,719,261	322,979	3,295,276	4,682,913	30,020,429
Non-compliant	6,599,908	822,129	2,299,391	2,498,692	12,220,120
Total	28,319,169	1,145,108	5,594,667	7,181,605	42,240,550
CAZ D FBC	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	21,834,724	1,145,087	3,308,537	4,719,542	31,007,889
Non-compliant	6,165,451	0	2,288,351	2,460,843	10,914,645
Total	28,000,174	1,145,087	5,596,888	7,180,385	41,922,534
(CAZ D FBC – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	115,463	822,107	13,261	36,629	987,460
Non-compliant	-434,458	-822,129	-11,039	-37,849	-1,305,476
Total	-318,995	-22	2,221	-1,221	-318,016
(CAZ D FBC - Do Minimum) %	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	0.5%	254.5%	0.4%	0.8%	3.3%
Non-compliant	-6.6%	-100.0%	-0.5%	-1.5%	-10.7%
Total	-1.1%	0.0%	0.0%	0.0%	-0.8%

Table 4.13: Change in Vehicle KMs (CAZ)

Do Minimum	Car	Taxi	LGV	HGV	Total
Compliant	472,435	7,180	44,499	34,018	558,132
Non-compliant	145,119	18,275	31,340	18,304	213,039
Total	617,554	25,455	75,840	52,323	771,171
CAZ D High	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	511,797	26,498	49,236	43,163	630,693
Non-compliant	41,513	0	21,915	6,934	70,362
Total	553,310	26,498	71,150	50,097	701,055
(CAZ D High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	39,362	19,318	4,736	9,145	72,561
Non-compliant	-103,606	-18,275	-9,425	-11,371	-142,677
Total	-64,244	1,043	-4,689	-2,226	-70,116
(CAZ D High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	8.3%	269.1%	10.6%	26.9%	13.0%
Non-compliant	-71.4%	-100.0%	-30.1%	-62.1%	-67.0%
Total	-10.4%	4.1%	-6.2%	-4.3%	-9.1%

Table 4.14: Change in Vehicle KMs (Ring Road)

Do Minimum	Car	Taxi	LGV	HGV	Total
Compliant	302,417	4,258	34,638	35,569	376,882
Non-compliant	91,174	10,839	24,024	18,817	144,854
Total	393,591	15,097	58,662	54,385	521,736
CAZ C High	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	300,675	14,867	34,599	38,562	388,703
Non-compliant	85,193	0	28,559	19,592	133,344
Total	385,868	14,867	63,158	58,153	522,047
(CAZ C High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	-1,742	10,608	-39	2,993	11,820
Non-compliant	-5,982	-10,839	4,535	775	-11,510
Total	-7,723	-231	4,496	3,768	310
(CAZ C High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	-0.6%	249.1%	-0.1%	8.4%	3.1%
Non-compliant	-6.6%	-100.0%	18.9%	4.1%	-7.9%
Total	-2.0%	-1.5%	7.7%	6.9%	0.1%

Table 4.15: Change in Vehicle KMs (Outside CAZ)

Do Minimum	Car	Taxi	LGV	HGV	Total
Compliant	20,971,917	311,952	3,218,460	4,615,211	29,117,540
Non-compliant	6,371,979	794,060	2,245,647	2,462,566	11,874,252
Total	27,343,897	1,106,012	5,464,107	7,077,776	40,991,792
CAZ C High	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	21,198,154	1,105,171	3,227,172	4,640,180	30,170,677
Non-compliant	6,041,623	0	2,239,327	2,434,817	10,715,767
Total	27,239,776	1,105,171	5,466,500	7,074,997	40,886,444
(CAZ C High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	226,236	793,219	8,712	24,970	1,053,137
Non-compliant	-330,357	-794,060	-6,319	-27,749	-1,158,485
Total	-104,120	-841	2,393	-2,779	-105,348
(CAZ C High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	1.1%	254.3%	0.3%	0.5%	3.6%
Non-compliant	-5.2%	-100.0%	-0.3%	-1.1%	-9.8%
Total	-0.4%	-0.1%	0.0%	0.0%	-0.3%

4.31 The introduction of CAZ D High will increase speeds within the City Centre, particularly in the PM peak which is the most congested time period. There are also minor increases in speeds on the Ring Road, but this only causes relatively small changes in average speeds.

Table 4.16: Change in average speed

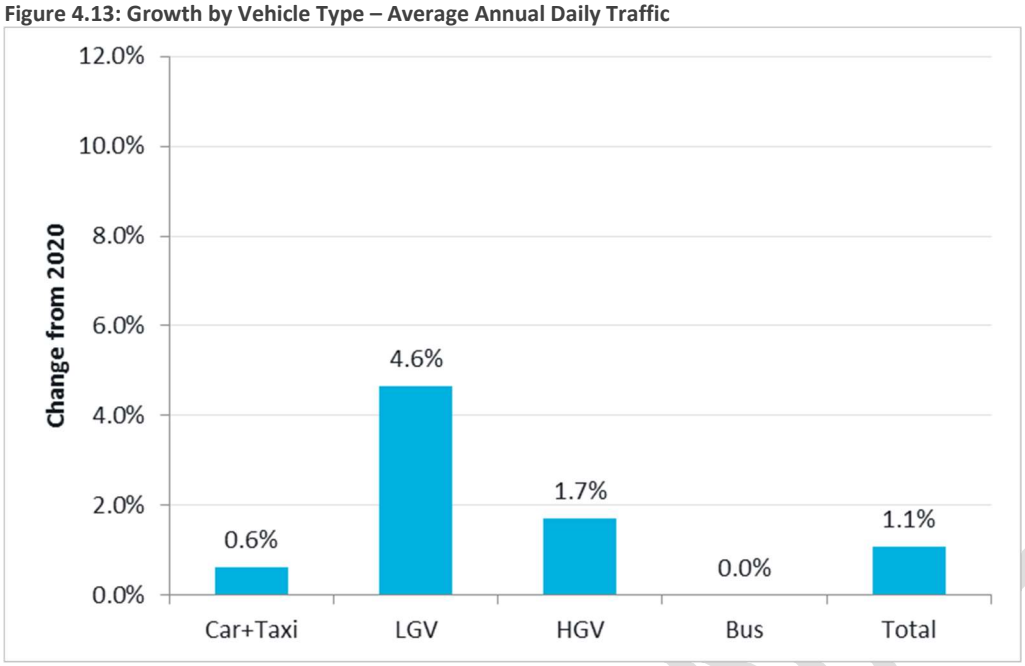
Scenario	AM				IP				PM			
	Whole Network	CAZ	RING	REST	Whole Network	CAZ	RING	REST	Whole Network	CAZ	RING	REST
DM	58.2	23.7	25.8	60.8	58.8	25.7	26.7	61.2	55.7	17.1	25.5	59.1
CAZ D	58.5	24.5	25.8	62.1	59.2	26.8	27.0	61.4	56.3	19.1	26.0	59.2
Change %	1%	4%	0%	2%	1%	4%	1%	0%	1%	12%	2%	0%

Do Minimum 2020 to 2022 Do Minimum Changes

Clean Air Zone

4.32 Figure 4.13 shows the forecast growth in vehicles entering the CAZ between 2020 and 2022, including both through trips and those with a destination in the City Centre. Overall traffic growth is 1% with the largest increase in LGVs, with an increase of 5%. This is line with recent trends showing rapid growth in “white van” traffic.

Figure 4.13: Growth by Vehicle Type – Average Annual Daily Traffic



4.33 Figure 4.14 below, shows the changes in compliance rates for the different vehicle classes, supported by the detailed information in Table 4.17 to Table 4.4 below. Overall there is an increase in 12,000 vehicles entering the zone, but with a reduction in non-compliant vehicles of around 42,000 vehicles.

Figure 4.14: Change in Compliance Rate

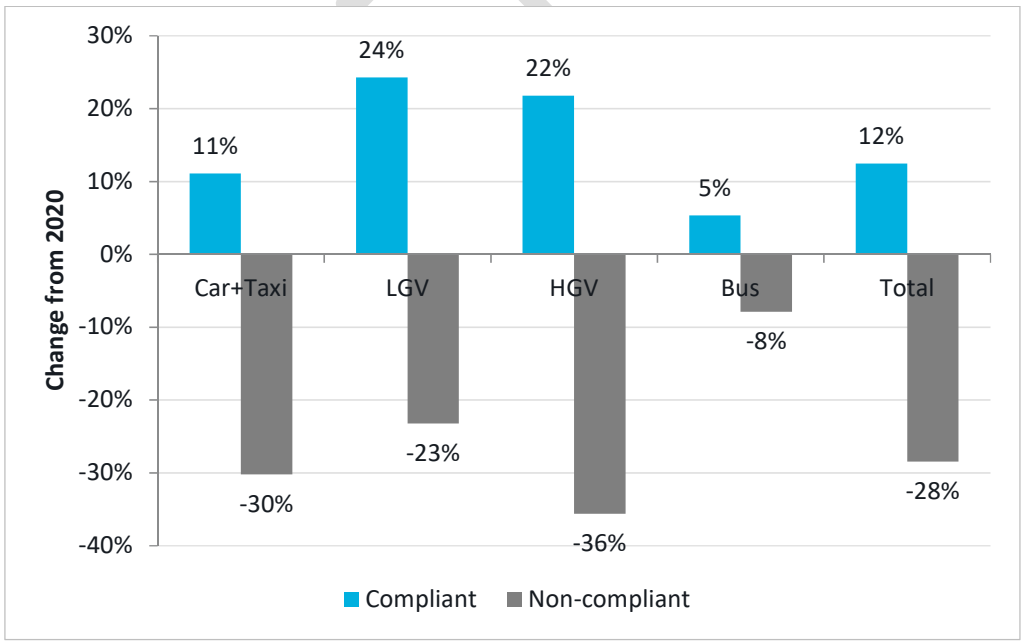


Table 4.17: Screenline AADT Flows – 2020 Do Minimum

Compliance	Car+Taxi	LGV	HGV	Bus	Total
Compliant	129,800	13,200	4,700	3,300	151,000
Non-compliant	44,100	9,300	2,500	2,200	58,000

Total	173,900	22,500	7,100	5,500	209,000

Table 4.18: Screenline AADT Flows - 2022 Do Minimum

Compliance	Car+Taxi	LGV	HGV	Bus	Total
Compliant	144,300	16,400	5,700	3,400	169,800
Non-compliant	30,700	7,100	1,600	2,000	41,500
Total	168,300	23,600	7,300	5,500	211,300

Table 4.19: Screenline AADT Flows Difference (2022 Do Minimum – 2020 Do Minimum)

Compliance	Car+Taxi	LGV	HGV	Bus	Total
Compliant	42,143	8,532	2,151	1,269	54,196
Non-compliant	-32,746	-6,301	-1,804	-1,004	-41,856
Total	9,397	2,231	346	365	12,339

Table 4.20: Screenline AADT Flows % Difference (2022 Do Minimum – 2020 Do Minimum)

Compliance	Car+Taxi	LGV	HGV	Bus	Total
Compliant	11%	24%	23%	4%	12%
Non-compliant	-30%	-24%	-36%	-9%	-29%
Total	1%	5%	2%	1%	1%

Network Changes

4.34 The figures below illustrate changes in AM peak city centre traffic flows between the 2020 and 2022 Do-Minimum, with:

- Green links showing an increase in traffic with the thicker the line the bigger the increase
- Blue links showing a decrease in traffic with the thicker the line the bigger the decrease

4.35 Figure 4-3 shows the change in total traffic, with impacts varying depending on the location of new developments and the impact of changes to the road network. Outside of the CAZ zone there is general increase in traffic reflecting the forecast growth in background traffic.

4.36 Traffic growth is more moderate in the City Centre, with only the A38 showing significant increases in traffic. There are no significant changes to the road network between 2020 and 2022 so there are no noticeable rerouting affects as seen when comparing to the 2016 base year.

4.37 Figure 4-5 and 4-17 and shows the changes in compliant and non-compliant vehicle traffic respectively. This demonstrates the reduction in non-compliant vehicles due to the natural upgrading of the vehicle fleet, despite the general increases in total traffic.

Figure 4-15: Total Flow Change (2022 Do Minimum - 2020 Do Minimum) - AM

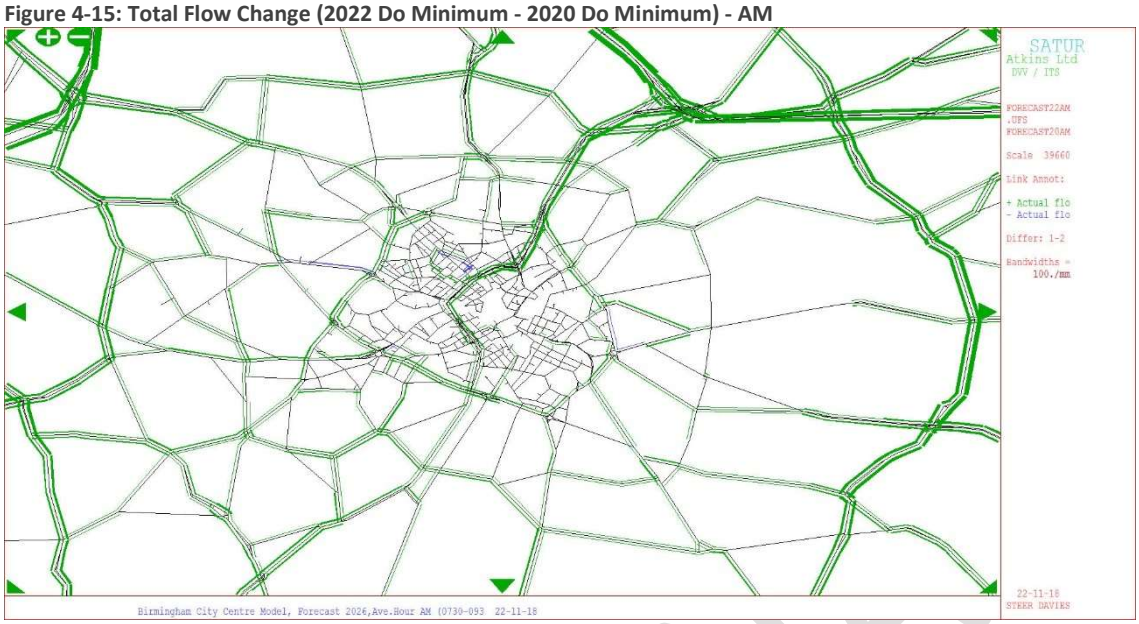


Figure 4-16: Compliant Flow Change (2022 Do Minimum - 2020 Do Minimum) – AM

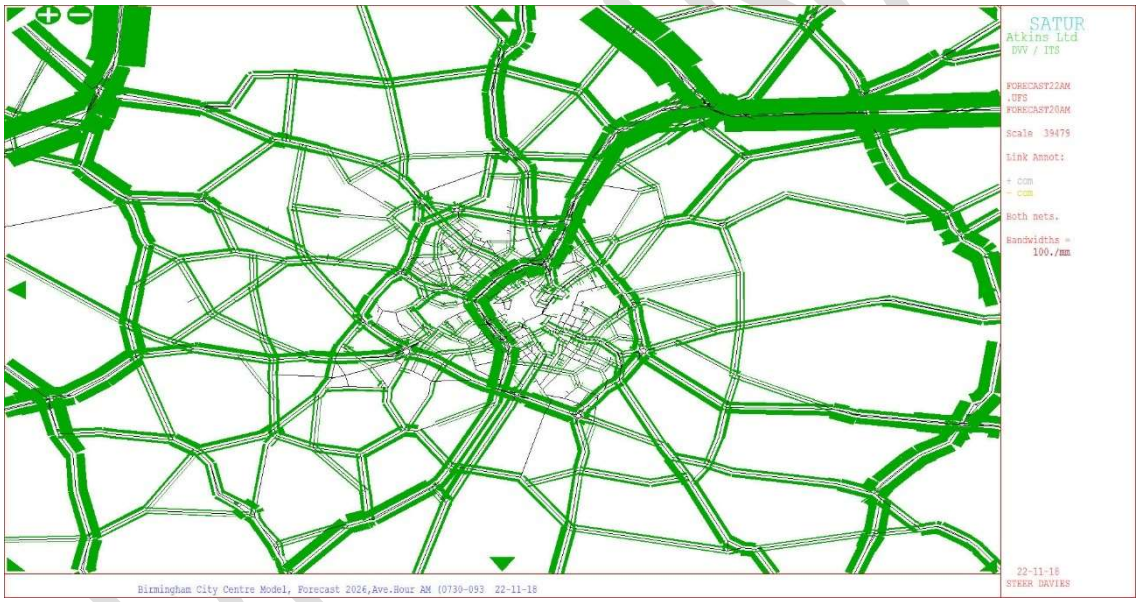
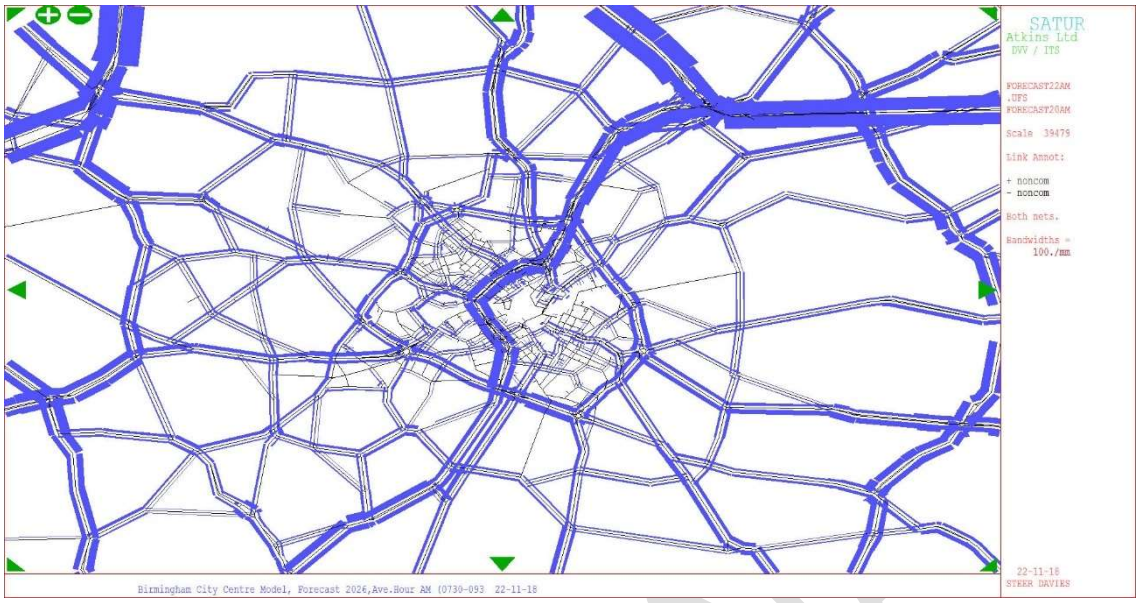


Figure 4-17: Non-compliant Flow Change (2022 Do Minimum - 2020 Do Minimum) - AM



2022 CAZ D FBC Scenario

4.38 Under CAZ Scenario D, non-compliant vehicles (excluding exemptions) are subjected to charges as described in the table below (as in 2020).

Table 4.21: CAZ Charges

CAZ	CAZ FBC
Car	£8.00
Taxi	£8.00
LGV	£8.00
HGV	£50.00
Bus/ Coach	£50.00

4.39 The change in compliance for car, LGV and HGV traffic entering the CAZ is shown in the table below. Overall compliance rates increase from 80% to 97% of all vehicles entering the CAZ, as a result of the CAZ measures.

Table 4.22: Compliance Rates for CAZ D – Crossing the CAZ Cordon

		Car	Taxi	LGV	HGV	Bus	Total
DM	Compliant	85%	43%	69%	78%	60%	80%
	Non-compliant	15%	57%	30%	22%	40%	20%
High	Compliant	98%	100%	84%	97%	100%	97%
	Non-compliant	2%	0%	16%	3%	0%	3%

4.40 Table 4.7 below shows the forecast CAZ cordon crossing flows. The model Private Hire Vehicles (PHVs) are included within the car matrices with adjustments to the compliance rates made to account for the differing response rates outside of the model for presentation purposes. Because it is an out of model adjustment the balance between car and PHV in the tables may not be 100% accurate, however in terms of total compliance and the fleet mix in the AQ model these numbers are correct.

4.41 The following impacts are shown in the model results:

- A reduction of over 35,000 non-compliant vehicles entering the CAZ
- A total reduction of around 15,000 vehicles

Table 4.23: CAZ D Screenline AADT flows by Vehicle Type

Do Minimum	Car	Taxi and PHV	LGV	HGV	Bus	Total
Compliant	140,300	3,900	16,400	5,700	3,300	169,600
Non-compliant	25,700	5,100	7,100	1,600	2,200	41,700
Total	166,000	9,000	23,600	7,300	5,500	211,300
High	**Car**	**Taxi and PHV**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	148,900	9,200	18,600	6,800	5,500	189,100
Non-compliant	2,600	-	3,500	200	-	6,300
Total	151,500	9,200	22,200	7,000	5,500	195,400
Change from Do Minimum (Abs)	**Car**	**Taxi and PHV**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	8,600	5,300	2,200	1,100	2,200	19,500
Non-compliant	-23,100	-5,100	-3,600	-1,400	-2,200	-35,400
Total	-14,500	200	-1,400	-300	-	-15,900
Change from Do Minimum (%)	**Car**	**Taxi and PHV**	**LGV**	**HGV**	**Bus**	**Total**
Compliant	6%	136%	13%	19%	67%	11%
Non-compliant	-90%	-100%	-51%	-88%	-100%	-85%
Total	-9%	2%	-6%	-4%	0%	-8%

4.42 Figures 4.18 to 4.20 illustrate changes in AM peak city centre traffic flows between the modelled 2020 Do-Minimum and CAZ D FBC scenario with:

- Green links showing an increase in traffic in CAZ D compared to the Do Minimum with the thicker the line the bigger the increase.
- Blue links showing a decrease in traffic in CAZ D compared to the Do Minimum with the thicker the line the bigger the decrease.

4.43 In total, there is decrease crossing the city centre with a clear reduction trips on the A38. Increases can be seen on sections of the Ring Road as well as some additional parallel roads further out from the CAZ, which are used as a detour for through trips entering the zone. However, in general the links with increases in traffic are generally low, with the decreases outweighing the increases.

Figure 4.18: Total Flow Change (CAZ D High – Do Minimum) – AM Peak

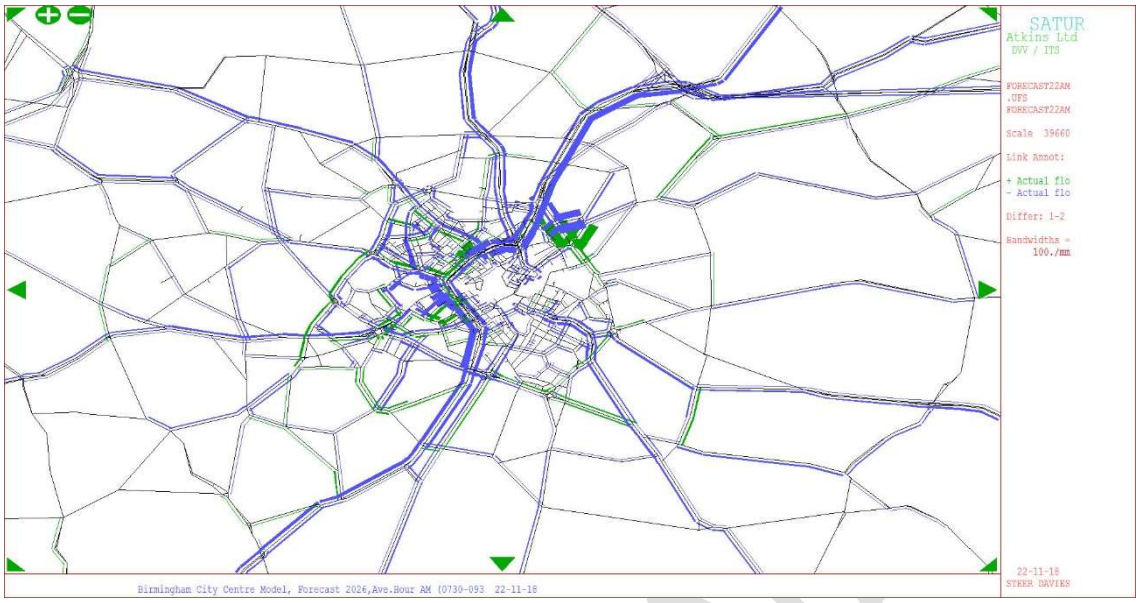


Figure 4.19: Compliant Flow Change (2020 CAZ D FBC – Do Minimum) – AM Peak

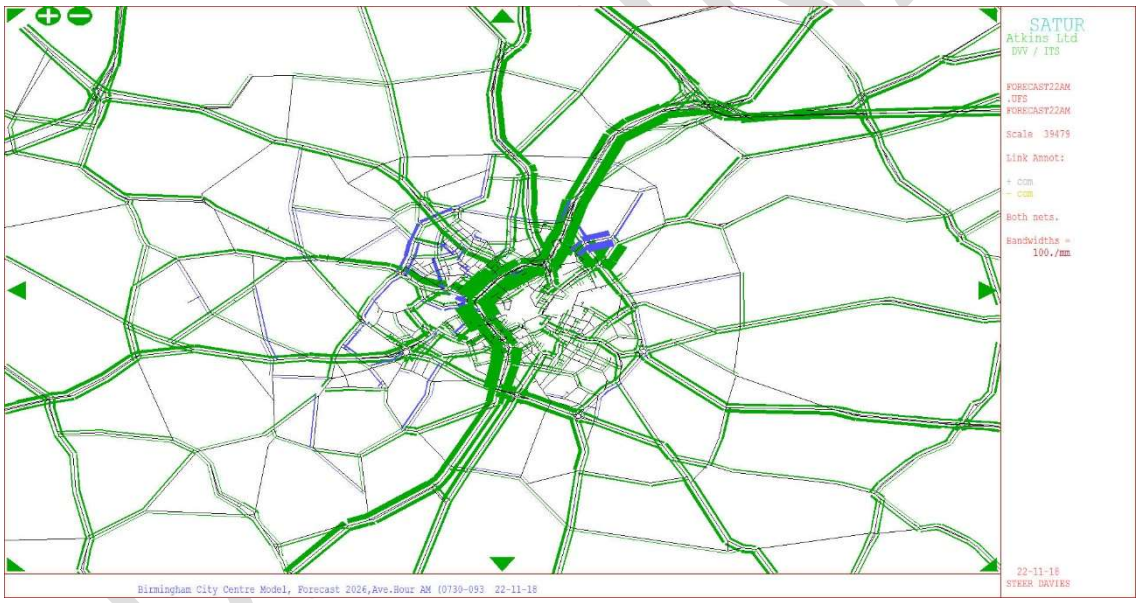
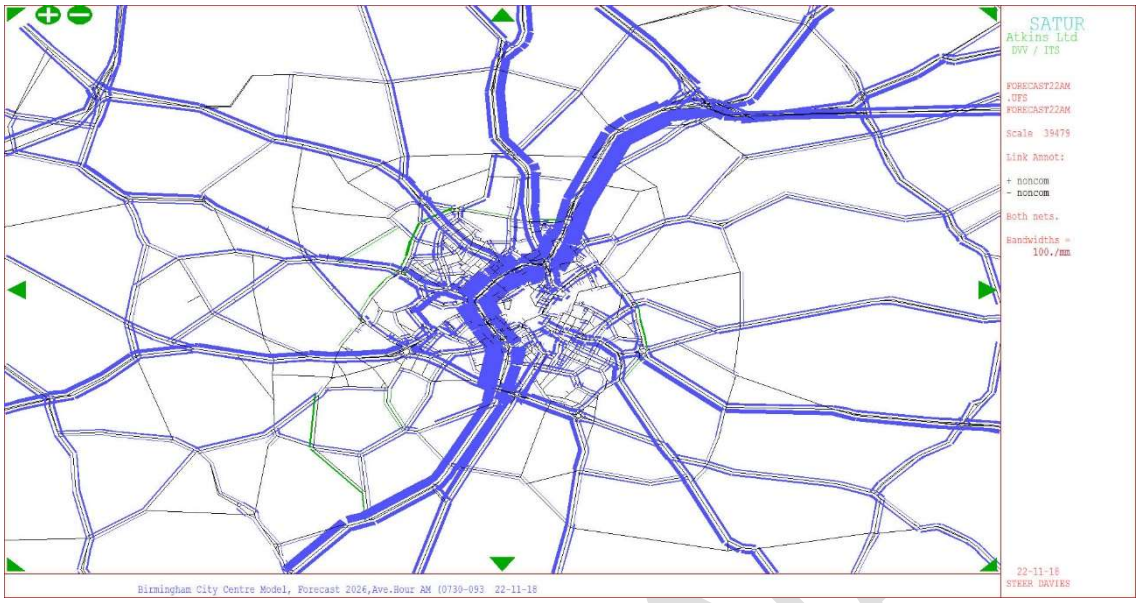


Figure 4.20: Non-compliant Flow Change (2020 CAZ D FBC – Do Minimum) – AM Peak

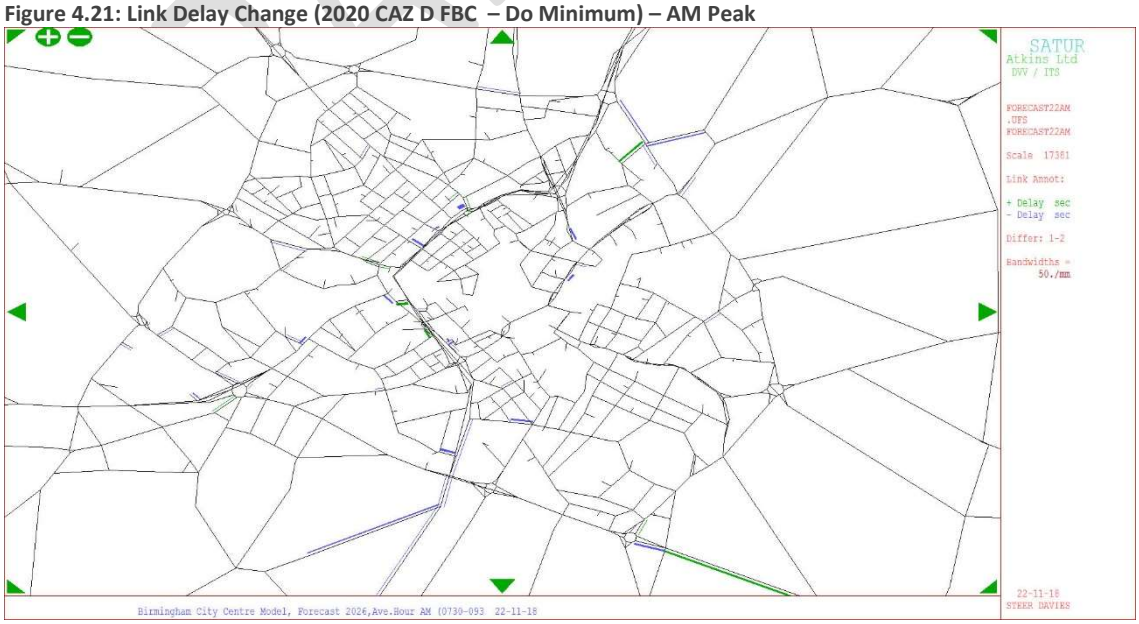


4.44 CAZ FBC does not have a significant impact on links delays, as can be seen in Figure 4.10 below, with:

- Green links showing an increase in delay in CAZ D compared to the Do Minimum with the thicker the line the bigger the increase.
- Blue links showing a decrease in delay in CAZ D compared to the Do Minimum with the thicker the line the bigger the decrease.

4.45 There have been minor reductions in delays across many City Centre links and on radial routes into the CAZ reflecting the reduction in traffic levels caused by cancelled trips. The effects of diversion have caused minimal increases in delay at a small number of links on parallel routes.

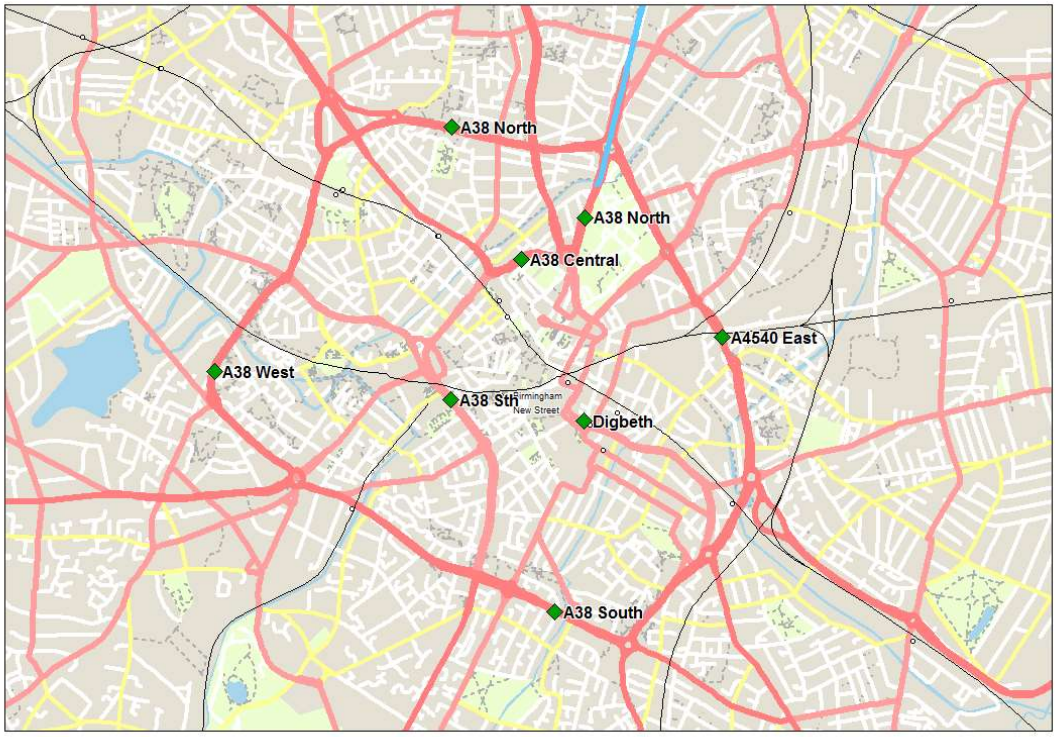
Figure 4.21: Link Delay Change (2020 CAZ D FBC – Do Minimum) – AM Peak



Key Link Analysis

4.46 To have a more detailed understanding of changes to the network a set of individual links have been analysed. The worst links in the City Centre in terms of Air Quality have been identified as well as selecting four links on the ring road, and change in flows between scenarios analysed. Figure 4.10 shows the links chosen for analysis.

Figure 4.22: Key City Centre Links



4.47 Table 4.8 below shows changes in total vehicles, with the following observations on traffic changes between the CAZ D FBC and the Do Minimum shows:

- There are significant reductions on each of the roads identified, with flows all links showing over between 1000 and 6200 less vehicles per day. The biggest reduction is seen on the southern sections of the A38 with the additional measures network schemes around Paradise Circus reducing the attractiveness of this route.

Table 4.24: City Centre Links AADT All Vehicles

Road	Do Minimum	CAZ D FBC	CAZ D Change (CAZ D - DM)	CAZ D Change (DM to CAZ D %)
Digbeth Gyratory	19,100	17,900	-1,200	-6%
A38 South	64,400	58,200	-6,200	-10%
A38 Central	74,200	69,500	-4,700	-6%
A38 North	89,200	86,700	-2,500	-3%

4.48 For the ring road, changes in traffic levels are as shown in Table 4.9:

- Most sections showing a neutral change in traffic. The reduction in traffic entering the City offsets the increase in traffic diverting around the City.
- The western section however shows some significant increases, with an increase of around 4%.

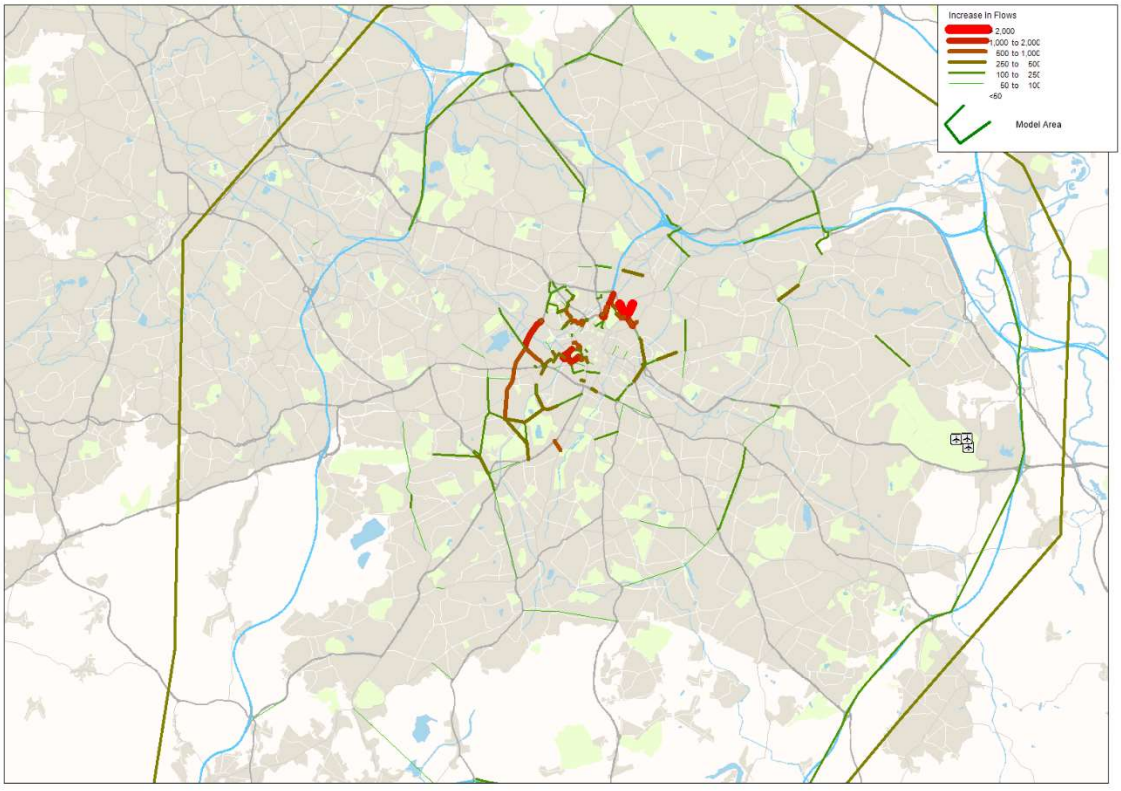
Table 4.25: Ring Road City Centre Links AADT All Vehicles

Road	Do Minimum	CAZ D FBC	CAZ D Change (CAZ D - DM)	CAZ D Change (DM to CAZ D %)
Ring Road North	33,300	33,200	-100	0%
Ring Road South	64,000	63,300	-700	-1%
Ring Road West	33,500	35,000	1,500	4%
Ring Road East	58,900	58,900	-	0%

In terms of the wider network the impact of diversion away from the CAZ area is shown in Figure 4.18 below which highlights roads where the daily increase in traffic is great than 50. This shows:

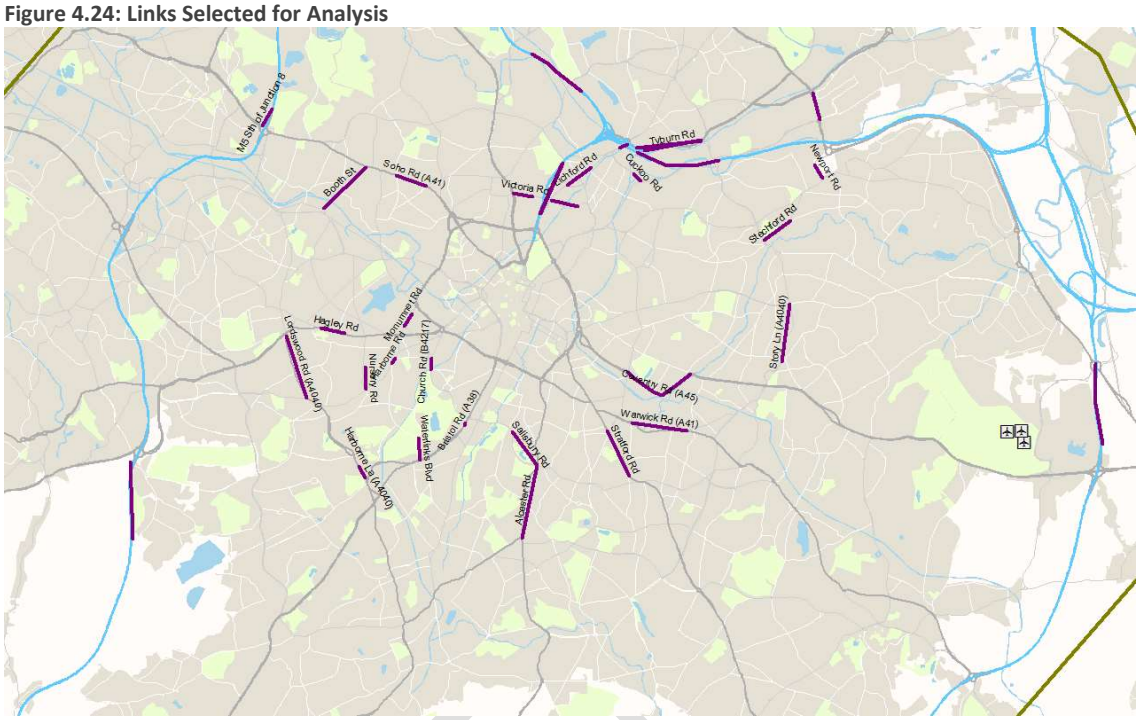
- The most significant increases occur on the Ring Road
- There is diversion to the South East of the City as through trips avoid the A38 and find alternative routing to the Ring Road.
- There are increases on some sections of the motorway box, but generally the impacts are not seen beyond links close to the City Centre
- Other than the A4050 ring road and Monument Rd, no link increases by more than 1000 vehicles a day, with typical values less than 250 a day

Figure 4.23: Change in AADT Vehicle Flows DM to CAZ D High



4.49 The links with the largest changes in flows in the CAZ D scenario have been identified along with some other selected links in the wide network have been analysed. The links selected are shown in Figure 4.12.

Figure 4.24: Links Selected for Analysis



4.50 Traffic changes on the motorway box links selected for analysis are shown in Table 4.23 below, showing the impact of CAZ D high is minimal with below 1% change in flows.

Table 4.26: Motorway Box Links AADT All Vehicles

Road	Do Minimum	CAZ D High	CAZ D Change (CAZ D - DM)	CAZ D Change (DM to CAZ D %)
M5 Sth of Junction 3	134,600	134,200	-400	0%
M5 Sth of Junction 8	178,400	178,500	100	0%
M42 East of M40	152,500	152,700	200	0%
M6 East of A38 (M)	125,500	124,400	-1,100	-1%
M42 Sth of M6	145,500	145,600	100	0%

4.51 For the wider road network within the motorway box the traffic numbers for all traffic are shown in Table 4.24 below. The impact of CAZ D FBC compared with Do Minimum, shows that for most of links there will be a small reduction in traffic. The three links below are the only roads identified with more than a 500 vehicle increase in AADT traffic flows and are all in the area to the South West of the City Centre:

- Monument Rd
- Edgbaston Park Rd
- Harborne La (A4040)

Table 4.27: Wider Network Links AADT All Vehicles

Road	CAZ D Change (CAZ D - DM)	CAZ D Change (DM to CAZ D %)
Tyburn Rd	-1,500	-2%
Chester Rd	200	0%
A38 (M)	-4,500	-4%
Edgbaston Park Rd	700	3%
Nursery Rd	100	1%
Monument Rd	1,000	6%
Harborne Rd	-300	-1%
Church Rd (B4217)	400	3%
Harborne La (A4040)	500	2%
Bristol Rd (A38)	-2,000	-4%
Lordswood Rd (A4040)	-	0%
Hagley Rd	-1,400	-4%
Soho Rd (A41)	-1,100	-4%
Alcester Rd	-500	-1%
Salisbury Rd	-400	-2%
Stratford Rd	-700	-2%
Warwick Rd (A41)	-900	-4%
Coventry Rd (A45)	-900	-2%
Victoria Rd	200	1%
Litchford Rd	-400	-4%
Cuckoo Rd	300	1%
Story Ln (A4040)	-300	0%
Newport Rd	200	0%
Booth St	-100	-1%
Stechford Rd	300	1%
Waterlinks Blvd	200	5%
Harborne La (A4040)	-1,500	-2%

Network Statistics

4.52 Table 4.25 to Table 4.28 display the total vehicle kilometres for the Do-Minimum and CAZ D FBC, across the different vehicle types. This provides an aggregate network wide assessment of the impact of CAZ D FBC on the road network. It should be noted that PHVs are included within cars in the assignment model, so their responses are included within this data.

4.53 The analysis has been split to look at four separate areas:

- Across the entire network:
  - Low reduction in overall vehicle KMs of less than 1%
  - Around 12% reduction in non-compliant vehicle KMs
- Clean Air Zone only:

  - A reduction of 6% in overall traffic
  - A reduction in total LGV and HGV traffic of around 5% and 3% respectively
  - Significant reduction in total non-compliant traffic of 83%
- the area outside the CAZ:
  - The Ring Road,
    - Total traffic increases by less than 0.5%
    - There is a total reduction in car and taxi traffic
    - LGV and HGV traffic increases in total with LGV non-compliant trips increasing by over 5%
    - The overall impact on non-compliant vehicles is a reduction of around 8%
  - Outside the Ring Road,
    - Total traffic is flat with less than 0.5% reduction
    - A reduction of 7% in non-compliant cars
    - An overall reduction in non-compliant vehicles of almost 11%.

4.54 Changes in overall vehicle kilometres travelled across the modelled area is low. This is because there is a reduction in car trips caused by the CAZ, which offsets any diversion caused by the charge. In addition, the majority of trips in the model do not go through or into the CAZ, so are not affected by the scheme.

Table 4.28: Change in Vehicle KMs (whole network)

Do Minimum	Car	Taxi	LGV	HGV	Total
Compliant	24,257,620	531,710	4,096,464	5,723,149	34,608,942
Non-compliant	4,619,431	614,217	1,763,980	1,611,935	8,609,564
Total	28,877,051	1,145,927	5,860,444	7,335,084	43,218,506
CAZ D FBC	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	24,421,804	1,146,148	4,129,450	5,763,524	35,460,925
Non-compliant	4,225,295	0	1,732,952	1,571,247	7,529,495
Total	28,647,099	1,146,148	5,862,402	7,334,772	42,990,420
(CAZ D FBC – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	164,184	614,438	32,986	40,376	851,983
Non-compliant	-394,136	-614,217	-31,028	-40,688	-1,080,069
Total	-229,952	221	1,958	-312	-228,085
(CAZ D FBC - Do Minimum) %	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	0.7%	115.6%	0.8%	0.7%	2.5%
Non-compliant	-8.5%	-100.0%	-1.8%	-2.5%	-12.5%
Total	-0.8%	0.0%	0.0%	0.0%	-0.5%

Table 4.29: Change in Vehicle KMs (CAZ)

Do Minimum	Car	Taxi	LGV	HGV	Total
Compliant	521,405	11,821	55,333	41,422	629,980
Non-compliant	100,433	13,655	24,074	11,775	149,936
Total	621,838	25,475	79,407	53,197	779,916
CAZ D High	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	564,262	26,360	63,267	50,444	704,332
Non-compliant	11,594	0	12,484	1,379	25,457
Total	575,856	26,360	75,751	51,823	729,789
(CAZ D High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	42,857	14,539	7,934	9,022	74,352
Non-compliant	-88,839	-13,655	-11,590	-10,396	-124,480
Total	-45,982	884	-3,656	-1,374	-50,127
(CAZ D High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	8.2%	123.0%	14.3%	21.8%	11.8%
Non-compliant	-88.5%	-100.0%	-48.1%	-88.3%	-83.0%
Total	-7.4%	3.5%	-4.6%	-2.6%	-6.4%

Table 4.30: Change in Vehicle KMs (Ring Road)

Do Minimum	Car	Taxi	LGV	HGV	Total
Compliant	332,861	6,950	42,796	43,207	425,814
Non-compliant	62,844	8,029	18,298	12,068	101,239
Total	395,705	14,979	61,093	55,275	527,053
CAZ D FBC	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	336,155	14,800	44,555	46,539	442,049
Non-compliant	53,961	0	20,265	11,405	85,631
Total	390,116	14,800	64,820	57,944	527,680
(CAZ C High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	3,294	7,849	1,759	3,332	16,235
Non-compliant	-8,884	-8,029	1,968	-663	-15,608
Total	-5,589	-180	3,727	2,669	627
(CAZ C High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	1.0%	112.9%	4.1%	7.7%	3.8%
Non-compliant	-14.1%	-100.0%	10.8%	-5.5%	-15.4%
Total	-1.4%	-1.2%	6.1%	4.8%	0.1%

Table 4.31: Change in Vehicle KMs (Outside CAZ)

Do Minimum	Car	Taxi	LGV	HGV	Total
Compliant	23,433,619	513,615	4,001,225	5,640,811	33,589,270
Non-compliant	4,461,923	593,314	1,722,855	1,588,735	8,366,827
Total	27,895,541	1,106,929	5,724,080	7,229,547	41,956,097
CAZ C High	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	23,719,170	1,106,437	4,024,898	5,669,346	34,519,851
Non-compliant	4,160,673	0	1,701,037	1,558,577	7,420,287
Total	27,879,844	1,106,437	5,725,935	7,227,922	41,940,138
(CAZ C High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	285,552	592,822	23,673	28,535	930,581
Non-compliant	-301,249	-593,314	-21,818	-30,159	-946,540
Total	-15,698	-492	1,855	-1,624	-15,959
(CAZ C High – Do Minimum)	**Car**	**Taxi**	**LGV**	**HGV**	**Total**
Compliant	1.2%	115.4%	0.6%	0.5%	2.8%
Non-compliant	-6.8%	-100.0%	-1.3%	-1.9%	-11.3%
Total	-0.1%	0.0%	0.0%	0.0%	0.0%

4.55 The introduction of CAZ D High will increase speeds within the City Centre, particularly in the PM peak which is the most congested time period. There are also minor increases in speeds on the Ring Road, but this only causes relatively small changes in average speeds.

Table 4.32: Change in average speed

Scenario	AM				IP				PM			
	Whole Network	CAZ	RING	REST	Whole Network	CAZ	RING	REST	Whole Network	CAZ	RING	REST
DM	58.1	23.4	25.2	60.8	58.8	25.5	26.5	61.2	55.7	17.0	25.3	59.1
CAZ D	58.4	24.2	25.6	62.2	59.1	26.5	26.7	61.4	56.2	18.4	25.7	59.2
Change %	0%	4%	1%	2%	0%	4%	1%	0%	1%	8%	1%	0%

Convergence

4.56 The models converge to WebTAG standards, with details found in appendix C

5 Summary

5.1 The key conclusions from the traffic modelling are as follows:

- There are some significant changes to the network and traffic demand in Birmingham City Centre between 2016 and 2020 which affects the traffic levels at some key links and particularly on the A38.
- The CAZ D scheme with additional measures results in significant reductions in traffic entering the zone and in particular a reduction in non-compliant vehicles, even with some exemptions in the early years.

Conclusion

5.2 The modelling approach applied has resulted in a WebTAG compliant 2020 and 2022 baseline model that incorporates agreed land use and network changes in Birmingham. In addition, we have developed and applied a modelling methodology to forecast the impact of CAZ charging and additional measures in line with the guidance issued by JAQU incorporating forecasts of:

- Vehicle Upgrade
- Mode Shift
- Cancelled journeys: and
- Avoiding the zone

5.3 Data from these models have been supplied to the AQ, economic and IA teams in the format they require to demonstrate the impacts of the CAZ schemes.

5.4 The model therefore provides robust forecasts of changes in vehicle flows and network conditions for compliant and non-compliant vehicles and can be reasonably used to develop and assess the CAZ FBC.

5.5 As in all models there are various uncertainties with the assumptions underpinning the results, and some key issues with these assumptions are discussed in 'Appendix A – Caveats' below. In addition, a set of sensitivity tests have been developed to provide further assurance that the results of the model are robust and to further highlight any risks in the modelling process, these are also reported in Appendix A. In addition, a set of sensitivity tests have been carried and are reported in Appendix D below.

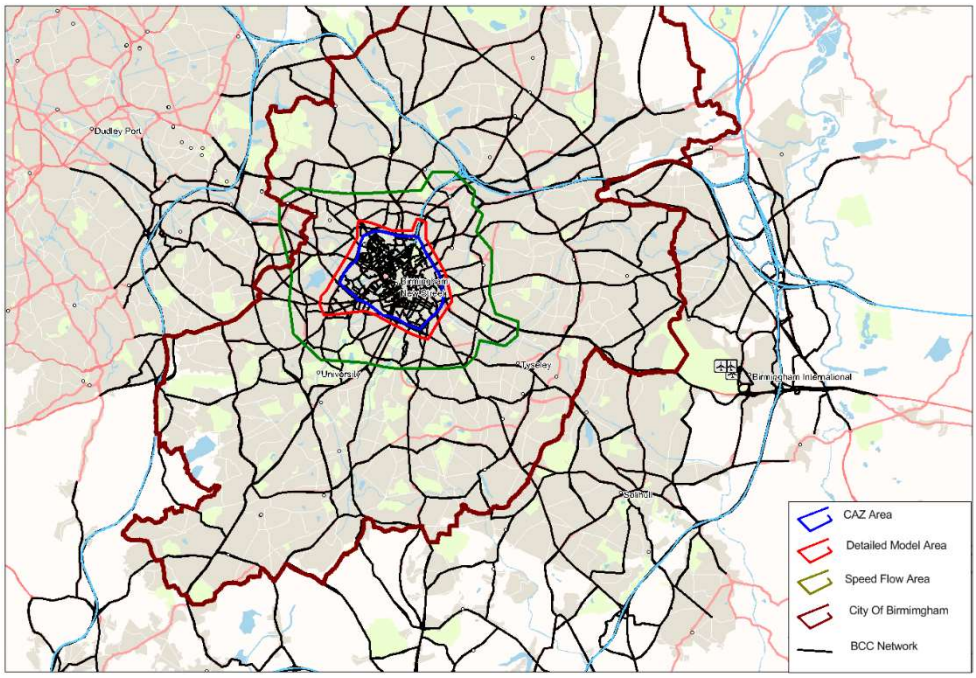
steer davies gleave

Appendices

A Caveats

Figure A.1: Birmingham City Centre Clean Air Zone - Feasibility Study Traffic Modelling Caveats

Issue	Description

Network Detail:
• Detail
• Responsiveness
• Bus
	Overview
	The model is designed to focus on the City Centre, with less detail in terms of the network and calibration data as the model moves further out from the City Centre. The fiigure below shows the extent of the road network, with:
	BCC – Network Structure
	 
	• Detailed Model Area, within the red area (covers the ring road):
	  • Simulation coding – detailed junction coding (lane allocations, junction types, queing represented)
	  • Fine zoning system to reprsent where traffic accesses the network in more detail
	  • Fully calibrated/ validated, with counts, screenlines and journey time surveys
	  • Buses coded along fixed routes
	• Speed Flow Curve Area, within the green area
	  • No junction modelling, but network speeds respond to changes in flow on links.
	  • Zoning less fine but still reasonably detailed, taken from the strategic PRISM model
	  • Calibration not detailed, no screenlines or journey time surveys, but individual counts included in the matrix estimation and calibration statistics.
	  • Buses coded along fixed routes
	• Fixed Speed Area, outside the green area:
	  • Speeds are fixed and will not respond to changes in flows.
	  • Average speeds are based on congested speeds from the Higways England model
	  • No bus route coding
	  • Zoning less fine but still reasonably detailed, taken from the strategic PRISM model
	Issues
	• Forecasts are less reliable outside of the simulation area.
	• Where diversion of traffic to the fixed speed area occurs, changes in network conditions are not modelled so could overesimate the network capacity and underestimate the dis-benefits of the scheme.
	• Bus flows are not represented outside the speed flow area

	Mitigation • Areas of exceedence and policy levers are focused on the City Centre and therefore in the area of detail, with full responsiveness • Diversion is fairly limited, minimal change in vehicle kilometers outside of the simulation area is flat between scenarios, so unlikely that the model is underestimating dis-benefits of the CAZ to a significant degree. • While the model is not calibrated outside of the speed flow curve area the demand matrices are sourced from the PRISM model which has been calibrated across the West Midlands so the overall demand and distribution can be replied upon. • Bus flows tend to be a lower proportion of total flows outside of the Central area so impact on the AQ results are limited • Opportunity to carry out corridor studies at specific areas of concern. • Model detail can be extended if required in reasonabe timescales
Vehicle Upgrade • Cost • Frequency • Timescales	**All Users** **Timescales** *Issue* The modelled year of the CAZ for the central scenario reported here is 2020 so in less than 2 years. The assumptions for users is that they will have time to assess their options and prioritise their spending towards buying a new car. Given that there still needs to be a consultation, and agreement on whether a charge should be implemented and what the level of the charge would be, it may be difficult for people to make these decisions in time for 2020. This is particularly relevant for LGV and HGV users, where engagement with users as part of this study indicates that many will pass the costs onto their customers in the short term and may not have the capacity to upgrade their vehicle. Mitigation In developing the Clean Air Zone, local and central Government needs to ensure that users are well informed of the changes proposed. Any incentives, for example scrappage schemes, will aid the ability and likelihood of people upgrading. **Frequency** *Issue* Frequency of journey into the CAZ zone is a key criterion in whether users will upgrade. The data used to define trip frequency is based on the ANPR survey data which was undertaken over one week and is therefore limited in the number of observations, particularly for the vehicles only captured once in the week. These users could potentially be entering the CAZ 52 times in a year or just once, and therefore the average trip frequency over a longer period is an assumption and not observed. *Mitigation* For car and LGV users the input to the choice model is low, medium or high frequency, in line with the groupings within the Stated Preference exercise underpinning the model, so the one week of data allows a reasonable estimate of frequency within these groupings. For HGVs assumptions were made to distribute the frequencies across the year. **Non-City Centre Trips** Changes to the fleet are only applied to the City Centre trips and not to through trips without an origin or destination in the City Centre. However, users who upgrade their vehicle are also likely to make trips that are not to or from the City Centre. This is therefore a conservative assumption, so as not to overestimate the impact of upgrade rates beyond the CAZ.

B Transport Model Forecasting Methodology

C Convergence

Ass. - DELTA FUNCTION (%) / NUMBER OF ITERATIONS

Sim. - FINAL AVER ABS CHANGE IN OUT CFP (PCU/HR) / NUMBER OF ITERATIONS

A/S Step - Step Length used on Ass/Sim Loop / Simulation Iterations

%FLOWS - LINK FLOWS DIFFERING BY < 1% BETWEEN ASS-SIM LOOPS

%DELAYS - TURN DELAYS DIFFERING BY < 1% BETWEEN ASSIGNMENT & SIMULATION

%V.I. - VARIATIONAL INEQUALITY - SHOULD BE > 0

%GAP - WARDROP EQUILIBRIUM GAP FUNCTION POST SIMULATION

Table C.1: Summary of Convergence Measures and Acceptable Values in WebTAG 5

Measure of Convergence	Base Model Acceptable Values
Delta and %GAP	**Less than 0.1% or at least stable with convergence fully documented and all other criteria met**
Percentage of links with flow change (P)<1%	**Four consecutive iterations greater than 98%**
Percentage of links with cost change (P2)<1%	**Four consecutive iterations greater than 98%**
Percentage change in total user costs (V)	**Four consecutive iterations less than 0.1%b(SUE only)**

Table C.2: Convergence statistics of last 4 iterations - DM AM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
45	0.0028/10	0.000/ 3	0.050/ 8	98.6	99.8	0	0.0031
46	0.0019/10	0.000/ 3	0.102/ 5	99	99.8	0.00011	0.004
47	0.0027/10	0.000/ 3	0.017/ 9	98.8	99.8	0.00005	0.0049
48	0.0025/10	0.002/ 4	0.343/ 2	99	99.8	0.00001	0.0061

Table C.3: Convergence statistics of last 4 iterations - DM IP

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
17	0.0004/12	0.000/ 7	1.000/ 1	98.5	99.8	0.00004	0.0022
18	0.0004/ 5	0.000/ 4	0.718/ 2	99.1	99.9	0	0.00039
19	0.0003/16	0.000/ 7	1.000/ 1	99.4	99.9	0.00004	0.0016
20	0.0006/16	0.000/ 7	1.000/ 1	99.1	99.9	0	0.00043

Table C.4: Convergence statistics of last 4 iterations - DM PM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
40	0.0020/ 7	0.001/ 7	1.000/ 1	99	99.7	0	0.0037
41	0.0018/10	0.001/ 7	1.000/ 1	99	99.7	0.00003	0.0031
42	0.0017/12	0.001/ 7	1.000/ 1	99	99.8	0.00004	0.0047
43	0.0019/12	0.000/ 3	0.084/ 8	98.8	99.7	0	0.0024

Table C.5: Convergence statistics of last 4 iterations - CAZ C Low AM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
39	0.0026/ 9	0.000/ 3	0.025/ 9	98.7	99.7	0	0.0031
40	0.0019/ 9	0.000/ 3	0.054/ 6	99	99.7	0.00002	0.0072
41	0.0023/ 9	0.000/ 3	0.038/ 9	98.8	99.7	0.00001	0.0031
42	0.0033/ 9	0.001/ 4	0.342/ 2	99.1	99.8	0.00001	0.014

Table C.6: Convergence statistics of last 4 iterations - CAZ C Low IP

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
20	0.0006/15	0.000/ 7	1.000/ 1	99	99.9	0.00006	0.00033
21	0.0002/10	0.000/ 7	1.000/ 1	99.2	99.8	0.00001	0.00034
22	0.0002/15	0.000/ 7	1.000/ 1	99.4	99.9	0.00002	0.0002
23	0.0001/11	0.000/ 7	1.000/ 1	99.6	99.9	0.00001	0.00016

Table C.7: Convergence statistics of last 4 iterations - CAZ C Low PM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
30	0.0041/ 8	0.001/ 7	1.000/ 1	99.2	99.8	0.00015	0.0037
31	0.0032/ 8	0.006/ 7	1.000/ 1	98.9	99.7	0.00014	0.0053
32	0.0036/ 8	0.001/ 7	1.000/ 1	99.2	99.7	0.00005	0.0058
33	0.0037/ 8	0.001/ 3	0.568/ 4	98.6	99.7	0	0.0042

Table C.8: Convergence statistics of last 4 iterations - CAZ C Medium AM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
41	0.0021/ 9	0.001/ 3	0.203/ 5	98.6	99.7	0.00001	0.0045
42	0.0023/ 9	0.001/ 7	1.000/ 1	99.3	99.9	0.0001	0.0032
43	0.0019/ 9	0.001/ 4	0.419/ 2	99.4	99.8	0.00006	0.013
44	0.0026/ 9	0.000/ 3	0.033/ 7	98.8	99.8	0.00039	0.011

Table C.9: Convergence statistics of last 4 iterations - CAZ C Medium IP

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
18	0.0003/17	0.000/ 7	1.000/ 1	99.1	99.8	0.00006	0.00042
19	0.0002/13	0.000/ 7	1.000/ 1	99.3	99.9	0.00003	0.00028
20	0.0002/17	0.000/ 7	1.000/ 1	99.2	99.8	0.00001	0.00057
21	0.0001/16	0.000/ 7	1.000/ 1	99.5	99.9	0.00001	0.00031

Table C.10: Convergence statistics of last 4 iterations - CAZ C Medium PM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
34	0.0028/13	0.001/ 7	1.000/ 1	99.2	99.8	0.00013	0.0024
35	0.0026/13	0.002/ 7	1.000/ 1	99.1	99.7	0.0001	0.0021
36	0.0015/13	0.001/ 7	1.000/ 1	99.2	99.8	0.00009	0.0027
37	0.0015/13	0.001/ 7	1.000/ 1	99.3	99.7	0.00001	0.0025

Table C.11: Convergence statistics of last 4 iterations - CAZ C High AM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
54	0.0019/ 9	0.001/ 3	0.129/ 4	99.1	99.7	0.00014	0.0028
55	0.0016/ 9	0.000/ 3	0.017/ 9	99.2	99.7	0.00002	0.0069
56	0.0018/ 9	0.002/ 4	0.341/ 2	98.9	99.8	0.00003	0.0041
57	0.0029/ 9	0.002/ 4	0.256/ 2	99	99.7	0.00004	0.0052

Table C.12: Convergence statistics of last 4 iterations - CAZ C High IP

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
16	0.0003/19	0.000/ 7	1.000/ 1	98.7	99.9	0.00009	0.00036
17	0.0002/19	0.000/ 7	1.000/ 1	99.3	99.9	0.00005	0.00025
18	0.0002/19	0.000/ 7	1.000/ 1	99.4	99.9	0.00003	0.00033
19	0.0002/10	0.000/ 7	1.000/ 1	99.6	99.9	0	0.00025

Table C.13: Convergence statistics of last 4 iterations - CAZ C High PM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
36	0.0023/14	0.001/ 7	1.000/ 1	99.5	99.7	0.00008	0.0022
37	0.0022/14	0.001/ 7	1.000/ 1	99.3	99.7	0.00006	0.0043
38	0.0022/14	0.001/ 3	0.037/ 7	98.8	99.8	0.00015	0.0033
39	0.0020/14	0.001/ 3	0.348/ 5	99.2	99.7	0	0.002

Table C.14: Convergence statistics of last 4 iterations - CAZ D Low AM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
53	0.0031/ 9	0.000/ 3	0.015/ 8	98.8	99.7	0.00027	0.0075
54	0.0038/ 9	0.001/ 3	0.082/ 7	98.9	99.7	0	0.0034
55	0.0023/ 9	0.001/ 3	0.167/ 4	99.1	99.8	0.00006	0.0031
56	0.0024/ 9	0.001/ 3	0.185/ 4	99.3	99.8	0.00005	0.013

Table C.15: Convergence statistics of last 4 iterations - CAZ D Low IP

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
18	0.0002/16	0.000/ 3	0.618/ 3	98.7	99.9	0	0.00024
19	0.0002/16	0.000/ 7	1.000/ 1	99	99.9	0.00001	0.00028
20	0.0002/16	0.000/ 3	0.391/ 4	98.8	99.9	0	0.00015
21	0.0001/13	0.000/ 7	1.000/ 1	99.6	99.9	0.00001	0.0002

Table C.16: Convergence statistics of last 4 iterations - CAZ D Low PM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
29	0.0032/ 9	0.001/ 7	1.000/ 1	99.4	99.8	0.00016	0.0041
30	0.0030/ 9	0.001/ 7	1.000/ 1	99.1	99.7	0.00005	0.0058
31	0.0029/ 9	0.001/ 3	0.304/ 6	99	99.7	0.00001	0.0038
32	0.0023/ 9	0.001/ 7	1.000/ 1	99.2	99.8	0.00004	0.0057

Table C.17: Convergence statistics of last 4 iterations - CAZ D Medium AM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
53	0.0041/ 9	0.000/ 3	0.149/ 6	98.9	99.8	0	0.0034
54	0.0019/ 9	0.001/ 3	0.277/ 3	98.8	99.7	0.00008	0.0039
55	0.0025/ 9	0.002/ 4	0.329/ 2	99.1	99.8	0.00004	0.013
56	0.0022/ 9	0.001/ 3	0.046/ 6	98.5	99.7	0.0004	0.011

Table C.18: Convergence statistics of last 4 iterations - CAZ D Medium IP

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
21	0.0002/17	0.000/ 7	1.000/ 1	99.4	99.9	0.00003	0.00021
22	0.0001/13	0.000/ 3	0.098/ 7	98.9	99.9	0	0.00012
23	0.0002/ 7	0.000/ 7	1.000/ 1	99.8	100	0	0.00012
24	0.0001/18	0.000/ 7	1.000/ 1	99.5	99.9	0.00002	0.00017

Table C.19: Convergence statistics of last 4 iterations - CAZ D Medium PM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
25	0.0032/12	0.002/ 7	1.000/ 1	98.5	99.7	0.00023	0.0091
26	0.0029/ 6	0.001/ 3	0.526/ 4	99	99.7	0.00002	0.0046
27	0.0025/12	0.001/ 7	1.000/ 1	98.7	99.7	0	0.0086
28	0.0024/12	0.002/ 7	1.000/ 1	98.7	99.8	0.00022	0.0056

Table C.20: Convergence statistics of last 4 iterations - CAZ D High AM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
57	0.0039/ 9	0.000/ 3	0.098/ 5	99.1	99.7	0.00003	0.0042
58	0.0026/ 9	0.000/ 3	0.044/ 9	98.9	99.7	0.00012	0.0031
59	0.0024/ 9	0.000/ 3	0.052/ 7	99.1	99.8	0.00001	0.0089
60	0.0039/ 9	0.000/ 3	0.026/ 8	98.8	99.7	0.00002	0.0028

Table C.21: Convergence statistics of last 4 iterations - CAZ D High IP

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
19	0.0004/ 9	0.000/ 7	1.000/ 1	98.9	99.8	0.00001	0.00067
20	0.0002/ 6	0.000/ 7	1.000/ 1	99.3	99.9	0	0.00024
21	0.0001/10	0.000/ 7	1.000/ 1	99.4	99.9	0.00002	0.00022
22	0.0001/14	0.000/ 7	1.000/ 1	99.3	99.9	0	0.00032

Table C.22: Convergence statistics of last 4 iterations - CAZ D High PM

LOOP	Ass.	Sim.	A/S Step	%FLOWS	%DELAYS	%V.I.	%GAP
27	0.0024/ 8	0.001/ 3	0.506/ 4	98.7	99.7	0	0.0066
28	0.0022/ 6	0.001/ 3	0.427/ 3	99.3	99.8	0	0.0032
29	0.0024/13	0.001/ 7	1.000/ 1	99.2	99.7	0.00007	0.0059
30	0.0033/13	0.001/ 4	0.746/ 2	99	99.7	0.00001	0.0034

D Benchmarking and Sensitivity Testing

E OBC Model Report

CONTROL INFORMATION

Prepared by	Prepared for
Steer Davies Gleave 28-32 Upper Ground London SE1 9PD +44 20 7910 5000 www.steerdaviesgleave.com	David Harris

SDG project/proposal number	Client contract/project number
23013602	Click here to enter text.

Author/originator	Reviewer/approver
Caulfield, Tom	Steve Oliver

Other contributors	Distribution	
Yuqing Shi	*Client:*	*SDG*:

Version control/issue number Draft Final	Date 23/11/2018

DRAFT FINAL