Bath Clean Air Plan

Bath and North East Somerset Council

T3 Local Plan Transport Modelling Methodology Report

674726.BR.042.OBC-13 | 5

October 2018

Bath Clean Air Plan

Project No:	674726.BR.042
Document Title:	T3 Local Plan Transport Modelling Methodology Report
Document No.:	674726.BR.042.OBC-13
Revision:	5
Date:	October 2018
Client Name:	Bath and North East Somerset Council
Project Manager:	BL
Author:	KW, JB

Jacobs Consultancy Ltd.

1 The Square, Temple Quay
2nd Floor
Bristol, BS1 6DG
United Kingdom
T +44 (0)117 910 2580
F +44 (0)117 910 2581
www.jacobs.com

Document history and status

Revision	Date	Description	By	Review	Approved
1	21.12.2017	Draft	KW	CB	BL
2	23.05.2018	Revision 2	KW	JB	BL
3	10.09.2018	Revision 3	KW, JB	CB	BL
4	05.10.2018	Revision 4	KW, JB	CB	BL
5	17.10.2018	Update to Table A.2	CC	CB	RR

Contents

Acronyms and Abbreviations

ANPR	Automatic Number Plate Recognition
AQMA	Air Quality Management Area
B&NES	Bath and North East Somerset
CAZ	Clean Air Zone
Defra	Department for Environment, Food & Rural Affairs
DfT	Department for Transport
EFT	Emission Factor Toolkit
GBATH	Greater Bath Area Transport Study
HGV	Heavy Goods Vehicle
IMD	Indices of Multiple Deprivation
JAQU	Joint Air Quality Unit
LGV	Light Goods Vehicle
NTM	National Transport Model
NTEM	National Trip End Model
PT	Public Transport
(Web)TAG	Transport Analysis Guidance

1. Introduction

Poor air quality is the largest known environmental risk to public health in the UK[1]. Investing in cleaner air and doing more to tackle air pollution are priorities for the EU and UK governments, as well as for Bath and North East Somerset Council (B&NES). B&NES has monitored and endeavoured to address air quality in Bath, and wider B&NES, since 2002. Despite this, Bath has ongoing exceedances of the legal limits for Nitrogen Dioxide (NO_2) and these are predicted to continue until 2025 without intervention.

In 2017 the government published a UK Air Quality Plan for Nitrogen Dioxide2 setting out how compliance with the EU Limit Value for annual mean NO2 will be reached across the UK in the shortest possible time. Due to forecast air quality exceedances, B&NES, along with 27 other Local Authorities, was directed by Minister Therese Coffey (Defra) and Minister Jesse Norman (DfT) in 2017 to produce a Clean Air Plan (CAP). The Plan must set out how B&NES will achieve sufficient air quality improvements in the shortest possible time. In line with Government guidance B&NES is considering implementation of a Clean Air Zone (CAZ), including both charging and non-charging measures, in order to achieve sufficient improvement in air quality and public health.

Jacobs has been commissioned by B&NES to produce an Outline Business Case (OBC) for the delivery of the CAP; a package of measures which will bring about compliance with the Limit Value for annual mean NO2 in the shortest time possible in Bath. The OBC assesses the shortlist of options set out in the Strategic Outline Case3, and proposes a preferred option including details of delivery. The OBC forms a bid to central government for funding to implement the CAP.

1.1 Purpose of this Report

This document is written to support the OBC and provides the transport modelling methodology which outlines the approach taken to model the transport impacts, including base and forecast years, baseline assumptions and scheme effects. It also sets out how the Euro standards have been calculated and forecast, together with how the traffic modelling outputs will feed into the air quality modelling.

[1] Public Health England (2014) Estimating local mortality burdens associated with particular air pollution. https://www.gov.uk/government/publications/estimating-local-mortality-burdens-associated-with-particulate-air-pollution
[2] https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017
[3] Bath and North East Somerset Council Clean Air Plan: Strategic Outline Case, March 2018 (http://www.bathnes.gov.uk/sites/default/files/siteimages/Environment/Pollution/strategic_outline_case_bath_28.03.2018_with_annexes.pdf)

2. Data Collection and Use

2.1 Automatic Number Plate Recognition

The 2017 ANPR surveys were undertaken in November. The locations of the ANPR cameras in Bath are shown in Figure 2-1. The sites are as listed below;

Outer Cordon

1) Lansdown Road, north of Lansdown Lane
2) A46, north of Upper Swainswick
3) A4, east of A363 Bradford Road
4) A363 Bradford Road
5) A36 Warminster Road, east of Bathampton
6) Brassknocker Hill
7) B3110 Midford Road
8) A367, north of Odd Down P&R and south of Old Fosse Road
9) A39 Wells Road, west of junction with Bristol Road
10) A4 Bath Road, west of junction with Bristol Road
11) A431 Kelston Road

Inner Cordon

12) Lansdown Road, north of Lansdown Grove
13) Camden Road
14) A4 London Road
15) A36 Warminster Road
16) North Road
17) Bathwick Hill
18) Widcombe Hill
19) Prior Park Road
20) A367 Wells Road, north of Oldfield Road
21) Broughman Hayes
22) A36 Lower Bristol Road, east of Windsor Bridge Road
23) Upper Bristol Road, east of Windsor Bridge Road
24) Weston Road, east of Park Lane
25) Cavendish Road

City Centre Car Parks

26) Charlotte Street Car Park, entrance 1
27) Charlotte Street Car Park, entrance 2
28) The Podium Car Park - to include the entrance ramp and the 2-way entry/exit road to the rear
29) Leisure Centre Car Park
30) Manvers Street Car Park

31) Southgate Car Park

32) Avon Street Car Park

The camera locations have been selected to cover an inner cordon (capturing flows into the central area of Bath), City Centre car parks (to better understand the choices of traffic within the city centre) and an outer cordon (capturing flows into the whole city).

The cordons are not entirely watertight as some small routes have not been included in the surveys. However, based on local knowledge of the network the key routes into/through the city have been selected to capture the majority of traffic.

The surveys recorded both directions of traffic in each location. The surveys captured the number plate of each vehicle that passed the camera, along with the date/time and direction of journey. This enabled vehicles to be matched at multiple locations, providing an understanding of the movements across/within the city and how long these journeys take.

The raw data has been provided by the supplier and two 'types' of matching has also been provided;

- Matches between all pairs of cameras. This allows the fleet to be analysed on selected movements through the city in order to apply the composition to the model
- Frequency matching of individual number plates across different days to understand the frequency distribution of trips in the city.

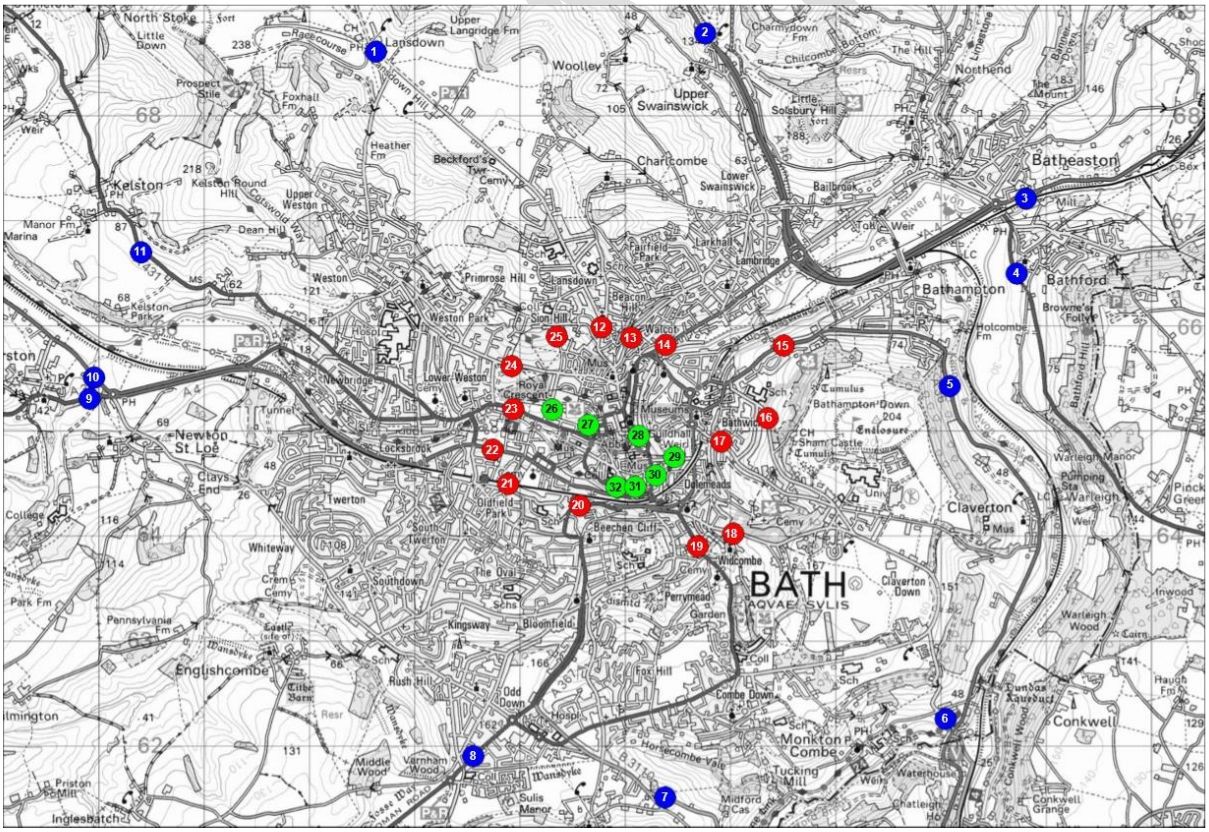

Figure 2-1: ANPR Survey Locations[4]

[4] © Crown Copyright 2018. License number 100023334

The data collected has been used to determine the compliance/non-compliance splits of the current fleet when compared to the CAZ framework criteria; namely that non-compliant vehicles are those that do not meet the required Euro standards for a CAZ (i.e. petrol must be at least Euro 4 and diesel must be at least Euro 6). The registration data from the ANPR surveys has been cross referenced with data purchased from Carweb to gain information on vehicle type, fuel type and Euro standard. Both the base year and baseline (future year) splits have been determined from the 2017 ANPR data, adjusted to the assessment year using the fleet projection tool in the Emission Factor Toolkit. These splits have been applied to the model matrices for each user class (Cars, Taxis, LGVs, Coaches and HGVs).

The GBATH transport model was not originally developed with separate taxi or coach user classes. Therefore, the ANPR data has also been used to split the taxi fleet from the car matrices and the coaches from the HGV matrices, by applying global factors for each time period.

The data collected has also been used to determine the fuel type splits and Euro standard fleet mix for the base year and baseline year models. Therefore, in addition to splitting each user class by compliance within the transport model, this data has been used to add more detail to the modelled outputs via post processing to yield inputs into the air quality model.

We have considered Euro standards compliance segmentation on a geographical basis, based on a review of compliance by area and trip pattern e.g. trips through or to the city centre. Hence the 2017 ANPR data has also been used to identify the relationship between fleet composition and movements through the city, by matching registration number plates between cameras and identifying the vehicle details.

Further details are provided in the OBC-14 ANPR Analysis and Application technical note in Appendix B of this document.

2.2 Bus Operators

B&NES has held conversations with bus operators about the fleet composition by service for the base year, baseline and options to be assessed. They have provided information based on what they believe will be the likely response to a charging Clean Air Zone (CAZ).

The bus fleet composition has been handled outside the transport model via post processing of model outputs. This has enabled vehicle details for particular routes to be accounted for in both the current and future fleet.

2.3 Stated Preference Surveys

Stated preference surveys have been undertaken to determine local behavioural responses to the implementation of a CAZ. This will provide Bath based proportions for non-compliant cars in terms of the response to a CAZ.

The main part of the survey are two stated preference exercises. The first asks the respondent to consider their most recent trip through the zone and how they would have responded from the following choices:

- Paid the charge and travelled as before;
- Made the same journey but changed mode;
- Not have made the journey at all;
- Made the same journey purpose but changed the destination;
- Made the same journey but changed route to avoid the zone; or,
- Made the same journey but switched to another compliant vehicle in their household (this option will only be shown if the respondent has indicated in an earlier question that such a vehicle exists).

Each respondent was asked to make this choice for one of two subgroups of 4 different charge levels.

The second exercise asks respondents the longer term choice of whether they would continue to pay the charge to travel in the zone or would pay to replace their vehicle with a compliant one for a given hypothetical cost.

When completed, the survey data has undergone a cleaning process to identify and discard nonsensical questionnaires.

Statistical models have been fitted to the data and then combined in order to allow predictions to be made on behavioural changes to feed into the highway transport model. Specifically, of the non-compliant car userclass that travels in the zone it has allowed the proportions to be established as follows:

- Travel as is (and pay the charge);
- Still travel as a non-compliant vehicle but reroute or change destination (to avoid the charge);
- Be moved to the compliant car userclass (due to replacing their non-compliant vehicle with a compliant one); and,
- Be removed from the highway matrix entirely (due to no longer making the car journey).

The survey also asks questions about respondents' existing vehicle replacement plans to inform both the likely average replacement cost and the base change in vehicle fleet compliance rate regardless of the introduction of a Charging Zone.

Further details are provided in OBC-30 Stated Preference Survey Report in Appendix L of the OBC.

3. Base Year Model

3.1 2014 Model

B&NES commissioned Mott MacDonald to update an existing version of the GBATH model, primarily to assess the Park and Ride schemes. The GBATH transport model is a large strategic model covering Bath and the surrounding area in the simulation model and key external routes within the buffer area. The GBATH model consists of:

- A Highway Assignment Model representing vehicle based movements across Bath and surrounding area for a 2014 autumn weekday morning peak hour (08:00-09:00), an average inter-peak hour (10:00-16:00) and an evening peak hour (17:00-18:00);
- A Public Transport (PT) Assignment Model representing bus and rail based movements across the same area and time periods; and
- A five-stage multi-modal incremental Variable Demand Model (VDM) that forecasts changes in trip frequency and choice of main mode, time period of travel, destination, and sub-mode choice, in response to changes in generalised costs across the 24-hour period.

3.1.1 Highway Model

The GBATH highway model included an update of the trip matrices using roadside interview data, automatic/manual traffic counts and manual classified turning counts collected in autumn 2014, together with 2011 census journey to work data and TrafficMaster 2013/2014 data.

The model was validated using the guidance, measures and criteria recommended in WebTAG Unit M3.1. The following comparisons between modelled and observed data were reported in the Access to Bath from the East – Highway Model - Local Model Validation Report:

- Total flows for cordons and screenlines, lights and all vehicles;
- Traffic Flows on individual links, lights and all vehicles; and
- Journey times (both cruise and net) for a range of key routes.

The analysis showed that the three models meet the acceptability guidelines:

- Regarding matrix estimation changes;
- For traffic flows on links across the total cordon and screenlines and at the individual calibration, and independent validation sites; and
- For journey times.

All three models (AM, inter-peak and PM) achieve acceptable levels of convergence and are stable based on delay/cost. Full details of the highway model update are detailed in the ‘Access to Bath from the East – Highway Model - Local Model Validation Report’, included in Appendix E of the OBC.

The light and heavy goods vehicles were not previously validated in short screenlines, using grouped counts. This has been checked as part of this study and reported separately in the technical note: OBC-15 GBATH Highway Model Local Model Validation Report: Addendum: LGV and HGV Validation in Appendix C of this document.

3.1.2 Public Transport Model

The GBATH PT model is closely integrated with the GBATH Highway model. The two models use different software packages (EMME and SATURN, respectively) but are identical in terms of road network structure, and zone system. The bus routes and frequencies in the PT model are used in the Highway model.

The validation process was carried out in-line with current guidelines as set-out in the WebTAG Unit M3.2. This states that validation should involve checks of:

- Validation of the trip matrix;
- Network and service validation; and
- Assignment validation.

Count data from a variety of sources was compared to modelled flows in all represented time-periods. This demonstrated that in the majority of cases the resulting validation has been good. Full details can be found in the Access to Bath from the East – Public Transport Model - Local Model Validation Report, included in Appendix E of the OBC.

3.1.3 Variable Demand Model

The GBATH demand model is a five-stage multi-modal incremental model that calculates trip frequency, main mode choice, time period choice, destination choice and sub mode choice with regards to changes in generalised cost for both the highway and PT models. The Variable Demand Model was originally developed following TAG guidance with respect to the structure of model, parameters used and realism tests. Full details of the demand model design methodology and calibration are outlined in the GBATH v2.3 Demand Model Report, included in Appendix E of the OBC.

3.2 2017 Model

The air quality model base year is 2017 as the air quality monitoring data was made available for the project in early 2018.

As the GBATH transport model has a base year of 2014, a 2017 highway model has been developed for consistency with the air quality model base year by applying TEMPRO v7.2 growth, adjusted for fuel and income to the 2014 model. Network changes were also added from 2014 to 2017, listed in the Uncertainty Log for the time frame. It was therefore pragmatic to undertake the disaggregation of the traffic model by vehicle compliance in the 2017 model rather than 2014, since this is also the year in which ANPR data is available. The validation of the 2017 fleet composition will be reported within T4 Transport Modelling Forecast Report.

3.2.1 Matrix Compliance Splits

The base year highway model has 4 user classes: Car Non-business, Car Business, LGV and HGV. These have been split into 12 user classes using the following methodology:

- Split the Car user classes into Car and Taxi user classes;
- Split the HGV user class into HGV and Coach user classes;
- Split Car, Taxi, LGV and Coach matrices into compliant and non-compliant using the time period splits; and
- Split HGV matrices into compliant and non-compliant using the corridor splits.

For further details and splits used please refer to OBC-14 ANPR Analysis and Application technical note in Appendix B of this document.

4. Baseline Model

4.1 Compliance Year

The compliance year was initially calculated using the model runs of each of the options undertaken within the Strategic Outline Case, and an understanding of the time taken to deliver each proposed scheme. This assessment has suggested that the year of compliance could be as early as 2020. However, more detailed modelling undertaken for the OBC has indicated the first year of compliance will not be until 2021. Hence the modelled compliance year is 2021, since the latest model tests found that compliance could not be achieved with a Class D CAZ in 2020.

4.2 Uncertainty Log

The existing GBATH multi-modal model future year is 2029, therefore details for a 2021 Uncertainty Log have been collated. This covers both development and scheme assumptions. The baseline model (2021) has the most recent scheme assumptions for the assessment year modelled within it based on the Near Certain and More than Likely entries in the Uncertainty Log. The Uncertainty Log is shown in Appendix A.

4.3 Model Constraints

4.3.1 Issues

We originally proposed to use the existing GBATH variable demand model for the Bath Clean Air Plan Feasibility Study. This model was updated from the original GBATH 2006 model by Mott MacDonald.

During the development of the first forecast year with the GBATH variable demand model, it was noted that the PM peak output highway matrix produced by the variable demand model was showing less than 0.5% growth in contrast to the 7-9% of the other time periods. Further, the variable demand model appeared to be moving a significant number of trips to travelling within the same zone, i.e. intrazonal rather than interzonal. When looking at trips that were actually loaded onto the highway networks, the PM peak period was showing around a 5% reduction in total trips.

We then established that the same issues were evident in the 2029 variable demand model as received. Here, total highway trips loaded onto the network showed a growth of only 3% in the PM period. This included a reduction of 3% for Commuting and Other purpose trips. AM and interpeak periods showed the same substantial transfer of trips to intrazonal movements.

The response of a variable demand model to increased congestion means some reduction in growth between the input trip ends and model output is expected. However, the level of reduction in the 2029 forecasts was greater than would be expected and an overall reduction in the PM peak is considered illogical.

We therefore undertook further checks of the spatial distribution of the changes in output trip ends. This showed a very uneven distribution, with both large increases and decreases in certain zones. This distribution also did not consistently match with development inputs with some development zones showing large decreases and some non-development zones showing large increases.

Correspondence with Mott MacDonald also established that the variable demand model was not recalibrated for their work. This may be a reason for the general level of sensitivity of the model, though it would not easily explain all the behaviours noted.

4.3.2 Revised Methodology

The variable demand model scripting that formed the Greater Bristol Modelling Framework (GBMF) of which GBATH 3 was one of a suite of models, is complex and poorly documented. From our own initial interrogation of model scripts we considered that to identify and fix the issues within the GBATH variable demand model was likely to be difficult and time consuming.

Given that, we proposed that to progress the development of the 2021 future year highway assignment model within the timescales required for the project, a future demand for 2021 would be derived using standard forecasting practices, then a simple new variable demand model developed for the 2031 baseline / reference case.

The above approach for deriving 2021 forecast highway demand matrices without the use of a variable demand model is considered to be suitable for the following reasons:

- The base year highway model is 2017, which needed to be projected to a 2021 baseline to reflect the compliance year. This is only a 4-year projection; therefore, the variable demand model response will be minimal.
- There are no schemes, highway or public transport, identified in the Uncertainty Log between 2017 and 2021. The Uncertainty Log is shown in Appendix A. Therefore, the only change between 2017 and 2021 would be in the traffic growth.

To build the 2021 model the developments identified in the Uncertainty Log have been added to the 2017 base matrices and the growth constrained to TEMPRO for each area. TEMPRO V7.2 car growth has been applied by area, time period and user class within the model, which can be attributed to model zones. These have been adjusted for fuel and income growth. Light and heavy goods vehicle growth has been based on forecasts produced by the National Transport Model (NTM) as advised by WebTAG.

A variable demand model was needed to generate highway matrices for 2031 since a greater response would be expected as we move further away from the base year. DIADEM has been used for this as a simple variable demand model, in conjunction with the SATURN highway assignment model.

This revised methodology was presented to JAQU via Huddle in 'Bath Demand Model Issues TN v4.pdf' on 1st May 2018, and subsequently discussed during a conference call. The methodology was agreed on 8th May 2018 as the most practical solution to the problem, within the timescales available.

4.4 Matrix Compliance Splits

The outturn baseline highway model from the variable demand model has 4 user classes: Car Non-business Car Business, LGV and HGV. These have been split into 12 user classes using the following methodology, as per the base year model:

- Split the Car user classes into Car and Taxi user classes;
- Split the HGV user class into HGV and Coach user classes;
- Split Car, Taxi, LGV and Coach matrices into compliant and non-compliant using the time period splits. splits; and
- Split HGV matrices into compliant and non-compliant using the corridor splits.

The fleet projection tool within the EFT version 8 has been used to project the euro standard splits from the 2017 ANPR data to the Baseline year of 2021.

For further details and splits used please refer to OBC-14 ANPR Analysis and Application technical note in Appendix B of this docuemtn.

5. Diadem Setup and Realism Tests

5.1 Demand Model Structure

For the implementation of the Diadem model, the 4 userclasses of the SATURN model were split into 6-person types, with LGV and HGV as fixed inputs and the Non-Employer's Business and Employer's Business (EB) userclasses split into 'Incremental OD' and fixed types on the basis of trip end locations. Here, trips that were external to external movements were separated into the fixed person types where external zones were those outside of Bath and its transport catchment area - i.e. Bristol and the nearby towns to the south and east such as Radstock, Trowbridge and Melksham. This is shown in Table 5-1 below.

Table 5-1: Diadem & SATURN userclass correspondence

Diadem Person Type	SATURN Userclass	Demand Model Type
1 – Non EB	1 – Non EB (except External to External trips)	Incremental OD
2 – Non EB Fixed	1 – Non EB (External to External trips)	Fixed
3 – EB	2 – EB (except External to External trips)	Incremental OD
4 – EB Fixed	2 – EB (External to External trips)	Fixed
5 – LGV	3 – LGV	Fixed
6 – HGV	4 – HGV	Fixed

For the two incremental OD person types, two demand responses were enabled: Trip Frequency and Trip Distribution.

Diadem running parameters were largely left as default with a fixed step length of 0.5 and full model convergence target set to a relative gap of 0.2%. A sub area relative gap of 0.1% was set to cover the zones comprising the city of Bath in order to ensure this area of the model had low convergence noise.

5.2 Calibration and Realism Testing

Due to the lack of available local data and the project timescales it was decided to use the illustrative parameters described in WebTAG as the starting point. Realism testing runs were undertaken, and parameters adjusted accordingly until appropriate elasticities were obtained, with the parameters shown in in Table 5-1.

Table 5-1: Diadem Demand Model Parameters

Person Type	Frequency ϴ	Distribution λ
1 – Non EB	0.025	-0.098
3 – EB	0.001	-0.070

Cost damping was also enabled as the relatively longer trip length distribution inherent to the Bath area required a reduction in sensitivity of the longer distance trips to avoid an unrealistic spatial response to changes in cost. The power function of cost method was used with a power (β) of 0.9 set to the cost skims.

Car fuel cost elasticity was undertaken within Diadem by forecasting to a cost of distance where the fuel component was increased by 10%. This elasticity considers the change in vehicle distance against the change in fuel cost.

Journey time elasticity considers the change in numbers of trips against an increase in journey time. This is less straightforward to calculate in Diadem as it does not have the capacity to factor the journey time. As such the help file recommends estimating the journey time elasticity from the elasticity of trips against fuel cost, converting this using the total distance and time travelled in the model and the costs of distance and time used. As long as this result is not close to the recommended limit this estimation is sufficient.

The final results of these realism tests are shown in Table 5-2 and Table 5-3 below.

Table 5-2: Car Fuel Cost Elasticity

Person Type	AM	IP	PM	Total
Non-EB	-0.30	-0.30	-0.32	-0.31
EB	-0.27	-0.22	-0.24	-0.23
All				-0.29

WebTAG recommends that the average elasticity lies in the range of -0.25 to -0.35 with weaker elasticities reflecting higher income, a lower proportion of discretionary trips and shorter trip length distribution. The nature of the trips covered by the models is a mix of these criteria (trip length is relatively long, which would suggest a stronger elasticity, but income is above average – suggesting a weaker elasticity) and as such it is thought that an average close to the -0.3 mid point is reasonable.

The elasticity of employer's business trips is noticeably weaker and this is expected as these trips are less discriminatory.

Table 5-3: Car Journey Time Elasticity

Person Type	AM	IP	PM	Total
Non-EB	-0.012	-0.011	-0.012	-0.011
EB	-0.008	-0.007	-0.008	-0.007
All				-0.011

Guidance on car journey time elasticities is less prescriptive than fuel cost due to the limited data from which the target elasticities were derived. It is recommended that elasticity should not be 'very high' with a suggested maximum 'strength' of -2 and anything weaker than that as acceptable. As can be seen the model has a weaker elasticity with an average of -0.01.

It is therefore considered that the model satisfied the required realism tests and is a proportionate basis from which to derive a 2031 Baseline Scenario.

6. Option Modelling

6.1 Primary Behavioural Responses

The results from the stated preference surveys have been used to determine the local proportions for each of the four primary responses for non-compliant cars to the implementation of the CAZ, which will replace the percentages shown for cars in Figure 5-1 from the Draft UK Air Quality Plan. For non-compliant light goods vehicle, employer's business responses from the stated preference surveys were used. For heavy goods vehicles the responses have been determined by looking at the replacement cost compared to the charge on entering the CAZ. For coaches, the proportions have been used from the 'Draft UK Air Quality Plan for tackling nitrogen dioxide' May 2017, Table 4.4, as shown in Table 5-1. Bus and Taxi responses have been established based on discussions with B&NES and service providers.

Table 5-1: Table 4.4 from the Draft UK Air Quality Plan for tackling Nitrogen Dioxide – Technical Report

Table 4.4: Proportions of non-compliant trips by response to the presence of a CAZ

	Cars	LGVs	HGVs	Buses	Coaches
Pay charge	7%	20%	9%	0%	16%
Avoid zone	7%	8%	0%	0%	0%
Cancel journey / change mode	21%	8%	9%	6%	13%
Replace vehicle	64%	64%	83%	94%	72%

These primary responses have been modelled using the GBATH highway assignment model using the following methodology:

- Pay Charge – no change to the highway model
- Avoid Zone – a charge is applied to each inbound link to replicate the percentage change of non-compliant cars, LGVs and HGV's within the CAZ;
- Cancel journey / change mode – modelled by reducing the number of trips made by non-compliant vehicles to/from and within the CAZ area, to replicate the required percentage change from the baseline case; and
- Replace Vehicle – an adjustment to the matrices by extracting select cordon matrices for the non-compliant trips and switching the required proportion of replace vehicles from the non-compliant matrices to the compliant matrices.

Further detail of the calculation of the behavioural responses is provided in OBC-16 Bath Clean Air Plan: Primary Behavioural Response Calculation Methodology in Appendix D of this document.

6.2 Secondary Behavioural Responses

In addition to the primary behavioural responses, JAQU have set out some further assumptions on secondary responses for a charging CAZ for cars, which we have adopted in the analysis. JAQU's assumptions from paragraph 3.3 of the Evidence Package are as follows:

- The 'replace vehicle' response will result in 75% replacing their non-compliant vehicle to a second-hand complaint vehicle;
- 25% will scrap their vehicle and buy a new compliant one of the same fuel type; and

- For those replacing with a second-hand vehicle, 75% will switch from diesel and petrol while the remainder will keep the same fuel type.

These secondary responses have been applied during the calculation of the upgrade costs and post-processing of the extracted link-based flow data from the Transport Model for the replace vehicle response.

6.3 CAZ Response Rates

6.3.1 Upgrade Costs

In order to determine the primary response rates over a range of CAZ charges from the stated preference surveys, an upgrade cost is required. The HGVs methodology for determining response rates also requires an estimation of an upgrade cost. The upgrade costs of other vehicle types (Taxi, Bus and Coaches) were not used to calculate the primary response rates. The primary response rates were determined by other information collated.

The methodology for calculating the upgrade costs for all vehicle types is discussed fully in 674726.BR.042.OBC-13 Bath Clean Air Plan: Primary Behavioural Response Calculation Methodology in Appendix D of this document and is summarised as follows:

- Cars - The cost of a new car was calculated by determining the most popular car models. A national list was obtained from the SMMT website, which is comparable with the most popular car models identified from the ANPR data. New car prices for Petrol and Diesel models of the list of popular cars were extracted from the Parkers database;
- LGVs and HGVs -The cost of a new LGV, rigid HGV and artic HGV have been calculated from the Publication by Road Haulage Association on the LGV and HGV operating costs, 2018;
- Depreciation Rates - A non-compliant vehicle will not always be replaced with a new compliant vehicle; therefore, depreciation rates were used to calculate the value of vehicles by age. Depreciation rates from the National data inputs for Local Economic Models, provided by JAQU for this project have been used, since no locally derived depreciation values were available;
- Average upgrade cost by vehicle type - Upgrade costs for each vehicle type and Euro Standard (and fuel type for cars) were calculated using the depreciated vehicle values. To derive an average upgrade cost by vehicle type, the upgrade costs by vehicle type and Euro Standard were weighted by trip frequency. The trip frequency of each vehicle type was calculated from the ANPR survey data for Bath, split by Euro standard. It was necessary to also account for 'secondary' behavioural responses within these calculations, as discussed above.

6.3.2 Proposed charge rates

The methodology for determining the proposed charge rates for all vehicle type is discussed fully in 674726.BR.042.OBC-13 and Table 6-1 shows the final proposed charges. These are selected as the minimum charges required to address the air quality exceedances within Bath and are expected to bring about compliance with the European Limit Value for annual mean nitrogen dioxide in the shortest time possible (2021), based on the traffic and air quality modelling.

Table 6-1: Bath CAZ Proposed Charges

Charge Class	Charge
Cars	£9.00
Taxis	£9.00
LGVs	£9.00
HGVs	£100.00
Buses	£100.00
Coaches	£100.00

6.3.3 Calculated Response Rates

The methodology for calculating the primary response rates for all vehicle types is discussed fully in 674726.BR.042.OBC-13 and is summarised as follows:

- Cars - The upgrade cost has been used to determine a range of primary responses for different charge rates using the stated preference survey responses;
- LGVs - The primary response rates are calculated from the stated preference survey responses which were identified as an 'Employers Business' trip purpose. Again, the upgrade cost is used to determine a range of primary responses for different charge rates;
- HGVs - The primary behavioural responses rates for HGVs were determined by comparing the cost to upgrade with the cost of paying the charge throughout a 5-year time period using trip frequency data from the ANPR surveys, with a tipping point of upgrading the vehicle when paying the charge becomes more expensive;
- Taxis - The taxi response rate is based on B&NES enforcing an 100% compliance for Taxis through their licensing agreements with taxi operators. An exception has been made for wheelchair accessible taxi vehicles (WAVs) which are likely to be exempted from CAZ charges in order to ensure the continued provision of these services in the face of substantial vehicle upgrade costs;
- Coaches - The initial response rates for coaches were taken from 'Table 2 – Behavioural responses to charging Clean Air Zones' in the Evidence Package, provided by JAQU. An adjustment for school coaches has been made to reflect ongoing discussions with operators of school coach trips;
- Buses - The response rates for buses were determined through discussions between B&NES and bus operators. These identified that approximately half the bus fleet could be expected to be fully replaced by 2021, and the remaining buses could largely be retrofitted with financial assistance. It is possible that some services may stop running if they are deemed financially unviable. Whilst B&NEs is working closely with the bus operators to minimise that risk, it is considered prudent within the modelling to assume a scenario where a small number of services are removed. Therefore, the percentage of trips cancelled for buses has been taken from 'Table 2 – Behavioural responses to charging Clean Air Zones' in the JAQUs Evidence Package.

An adjustment for foreign vehicles has been applied to the responses rates calculated from the methodology set out above, as foreign vehicles cannot be reliably charged (their details are not captured in the DVLA database in order to determine if the vehicle is compliant and so enforcement can only occur through a manual process with limited powers). The final response rates will assume a 'worst case', i.e. that these vehicles continue to drive within the zone but do not pay the charge. In reality it is unlikely that this will be the case for all foreign vehicles.

Table 6-2 shows the final primary behavioural response rates by vehicle type produced the methodology set out above and the charge rates in Table 6-1. These are the response rates that have been applied to the core modelling scenarios within the traffic model.

Table 6-2: Final Primary Behavioural Response Rates

Response	Cars	Taxis	LGVs	HGVs	Buses	Coaches
Pay Charge / Excluded	4.9%	4.1%	18.4%	13.8%	0.0%	20.1%
Avoid Zone	19.6%	0.0%	11.7%	4.4%	0.0%	0.0%
Cancel Journey / Change Mode	18.3%	0.0%	3.6%	1.4%	6.4%	11.5%
Replace Vehicle	57.2%	95.9%	66.3%	80.4%	93.6%	68.4%

6.4 Non-charging measures

We planned to model the non-charging measures by estimating the level of traffic that will be impacted by the measure and adjusting the highway traffic model accordingly. The judgement of the level of traffic affected will be based on first principle calculations, benchmarking against other local schemes and/or evidence from other schemes in the UK/Europe, depending on the measure in question.

To date, no non-charging measures have been identified that will have a significant impact on the level of traffic within B&NES. As such, no further traffic modelling of these schemes has been undertaken.

7. Interim Years

The Evidence Package guidance states that projection for all years between the base year and the compliance year should be included, via interpolation methods. This is to show a clear pathway to compliance in the shortest time possible. However, where infrastructure changes are expected to have a significant impact on air quality there may be a need to model additional interim years.

We have focussed our analysis on the earliest year of expected compliance (2021) as we have demonstrated that compliance is unlikely to be achieved prior to this. Additional modelling of interim years would provide a more detailed understanding of the air quality projections over the next few years but will not assist in identifying the scheme most likely to achieve compliance in the shortest timescales possible.

For interim years between 2017 and 2021 linear interpolation has been applied to the air quality modelling results to provide concentrations of NO_2 in each interim year. Traffic model results have not been interpolated.

8. Assessment Year Plus 10

JAQU have advised emissions of the baseline and each options assessment (NO_2, particulate matter and CO_2) should also be calculated for 10 years after the compliance year. This is needed to compare the long-term costs and benefits of options that are equally effective in terms of achieving compliance in the shortest time possible.

To produce traffic flows, for the baseline and options, for the assessment year plus 10 (2031) we have:

- applied growth to the base matrices using development data from the Uncertainty Log
- constrained the overall growth to TEMPRO v7.2
- used the DIADEM model in conjunction with the SATURN highway model to produce a 2031 baseline highway assignment model.

For interim years between 2021 and 2031 traffic and air quality model results were calculated for each interim year in order to undertake a full economic assessment. This has been undertaken using Tempro growth forecasts for the West of England area to adjust the traffic and air quality model outputs. Factors to split by fuel type, HGV type (rigid or artic) and euro classes were interpolated by localising DfT databook fuel splits and EFT euro class splits to the study area based on data from the ANPR survey.

9. Links to Air Quality Model

9.1 Baseline Data Use

Link based data from the baseline highway assignment model has been output for Cars, Taxis, LGVs, Coaches and HGVs split by Euro standards compliance into a spreadsheet. The highway model outputs also include buses (not split by compliance) and net speeds by link. Buses are split into compliant / non-compliant during post processing of highway model outputs before being input to the Emissions Factor Toolkit (EFT). The peak hourly flows (AM, IP and PM) have been converted into AADT using factors derived from local ATC data. Percentages of cars (by fuel type using ANPR data), Taxis, LGVs, HGVs (rigid and artic) and Buses and coaches have been calculated from the flow data by link from the highway model. Separate spreadsheets for compliant and non-compliant vehicles were produced and run through separate EFT's so that different varying proportions of compliant / non-compliant vehicles could be reflected spatially across the modelled area by link.

Further disaggregation of the link-based data was undertaken via post processing before input into the air quality model. This was achieved using the following methodology:

- Buses split using information provided to us by First Bus, using Euro Standard of vehicle by service, which can then be applied to links;
- Cars and LGVs split by fuel type derived from the ANPR data;
- HGVs split by rigid and artic from the ANPR data;
- Motor cycles excluded due to limited information;
- Separate EFT's for compliant and non-compliant vehicles populated from the transport model;
- Within each EFT, Euro Standard splits for the assessment year for complaint and non-compliant vehicle types are overwritten with those calculated from ANPR data projected to the modelled year.

The base and baseline year splits have been derived from the 2017 ANPR data, adjusted to the required assessment years. For full details please refer to OBC-14 ANPR Analysis and Application technical note in Appendix B of this document.

9.2 Option Data Use

A similar approach has been taken to the baseline data processing for the option processing insofar as there are separate EFT input tables for compliant and non-compliant vehicles containing the required link-based data.

The secondary behavioural responses of what type of car the replacement has been applied via post processing with changes applied to the Euro Standard splits input into the EFT's.

Appendix A. Uncertainty Log

A.1 Scheme Uncertainty Log

Scheme	Type	Year	Level of Uncertainty	Included	Comment
A39/B3116 Two Headed Man	Junction improvement – signals	2013	Built	N	Not in the simulation area
A39/A368 Marksbury	Junction improvement – filter lane	2020	Hypothetical	N	-
Lower Bristol Road/ Midland Road, Bath	Junction improvement - signals	2020	Hypothetical	N	-
A39/B3355, Hallatrow	Junction improvement – mini roundabout	2017	Reasonably Foreseeable	N	Not in the simulation area
North Road/ Ralph Allen Drive, Bath	Junction improvement – mini roundabout	2015	Built	Y	-
Bath Hill/ Temple Street, Keynsham	Highway & public realm improvements	2015	Built	N	Not in the simulation area
20mph zone at Westmoreland, Oldfield, Lyncombe & Widcombe	Speed limit	2014	Built	Y	-
A4 Saltford	Toucan crossing	2017	Reasonably Foreseeable	N	Not in the simulation area
A4 Globe Roundabout	Toucan crossing	2015	Built	N	Not modelled
Stall Street, Bath	Highway & public realm improvements	2015	Under Construction	N	Not modelled
London Road regeneration, Bath	Highway & public realm improvements	2015	Built	Y	-
Keynsham regeneration	Highway & public realm improvements	2015	Built	N	Not in the simulation area
Paulton	Speed limit	2015	Built	N	Not in the simulation area
Hallatrow	Speed limit	2015	Built	N	Not in the simulation area
Hallatrow	Weight Limit	2015	Built	N	Not in the simulation area
Seven Dials, Bath	Highway & public realm improvements		Built	N	No need to change in the model
Darlington Street, Bath	Pelican to toucan crossing conversion	2016	Reasonably Foreseeable	N	Not modelled
A4 Newbridge P&R expansion	Signal & expansion	2015	Built	Already included	-
A36 Rossiter Road/ Widcombe Parade	Check	2015	Built	Y	-
Stall street & access restriction to Lower Borough Walls		2015	Under Construction	N	Not modelled
Enterprise Area	New bus route		More than likely	Y	-
Cold Ashton Roundabout	New Roundabout	2016	More than likely	N	Not in the simulation area
A350 Yarnbrook/ West Ashton relief road	Road scheme	2017	More than likely	Y	-
Improvements to A350 north of Chippenham	Road scheme	2015	Built	Y	-
Improvements to A350 (dualling) at Chippenham between Badger and Chequers roundabouts	Road scheme	2017	Near certain	Y	-
A350 Farmers roundabout	Road signalisation	2016	Near certain	Y	-
Improvements to M4 J17	Road scheme	2016	Near certain	N	Not in the simulation area
Corsham Station	Rail	2021	Reasonably foreseeable	N	No need to change in the model

Scheme	Type	Year	Level of Uncertainty	Included	Comment
Link Road east of Chippenham (betw een A350 & A4)	Road scheme	2026	More than likely	Y	-
Bath Quays - Avon Street / Green Park Road	Road scheme	2017	built	Y	-
St James Parade - new lining and signing as part of the Bus Gate scheme	Road scheme	2016	built	Y	-
A36 Windsor Bridge Road, junction improvments	Road scheme	2016	bulit	Y	-
Charlotte Street Car Park Extension	Road scheme	2017	built	Y	Increase from 1056 to 1166 spaces. Final matrix adjustment.
Avon Street Car Park	Road scheme	2019	Near certain	Y	Reduction from 639 to 414 spaces. Final matrix adjustment.
Avon Street Car Park	Road scheme	2025	More than likely	Y	Reduction from 414 to 320 spaces. Include in 2030 model. Final matrix adjustment.
Saw Close Car Park Closure	Road scheme	2015	built	Y	Final matrix adjustment.
Royal United Hospital Car Park Extension	Road scheme	?	Reasonably foreseeable	N	
Increase Car Parking charges	Road scheme	2018	Near certain	Y	See Appendix 1- Proposed Parking Charges Feb18 for changes
Review residents parking zone (expansion)	Road scheme	2021	Reasonably Foreseeable	N	
Differential parking charges based vehicle emissions	Road scheme	2019	Reasonably Foreseeable	N	Possible addition to CAZ
Car Parking Reductions across the city	Road scheme		Reasonably Foreseeable	N	
Expansion of existing P&R (excluding Lansdow n	Road scheme		Reasonably Foreseeable	N	Funded by WECA
Coach Parking	Road scheme	2019	Near certain	Y	Riverside 43 to 13 spaces and 29 new spaces at Odd Dow n. Final matrix adjustment
MetroWest	Public transport scheme	2021	Near certain	N	

A.2 Development Uncertainty Log (Residential)

Development	Policy Area	Ref	Ward	OSGR (X)	OSGR (Y)	Planning Status	Development Status	Certainty	Dwelling Totals 2013-2036	Dwelling Totals 2013-2021	Dwelling Totals 2022-2026	Dwelling Totals 2027-2031	Dwelling Totals 2032-2036
BWR: B3, B4, B10, B10a, B10b, B7, B8	Bath	Wes 1	Kingsmead	374051	164918	Full Permission	Under Construction	UC	93	93			
BWR: B17	Bath	Wes 1	Westmoreland	373719	164984	Full Permission	Under Construction	NC	55	55			
BWR: B1 & B2	Bath	Wes 1	Westmoreland	374165	164923	Full Permission	Under Construction	NC	26	26			
BWR: B6, B12	Bath	Wes 1	Westmoreland	373945	164945	Full Permission	Under Construction	NC	38	38			
BWR: B11, B13,B15a, B15b	Bath	Wes 1	Westmoreland	373945	164945	Full Permission	Under Construction	NC	259	259			
BWR: B10c	Bath	Wes 1	Westmoreland	373945	164945	Full Permission	Under Construction	NC	11	11			
BWR: B5	Bath	Wes 1	Westmoreland	373945	164945	Outline Permission	Not Started	NC	45	45			
BWR: B16	Bath	Wes 1	Westmoreland	373945	164945	Outline Permission	Not Started	NC	53	53			
BWR: OPA.1 Unsecured Land	Bath	Wes 1	Westmoreland	373719	164984	Outline Permission	Not Started	ML	1460	492	605	363	
MoD Ensleigh 1	Bath	Lan 5a	Lansdown	374106	167610	Full Permission	Not Started	NC	40		40		
MoD Ensleigh 2	Bath	Lan 5a	Lansdown	374106	167610	Full Permission	Not Started	NC	240	157	83		
MoD Foxhill	Bath	Cdn 3	Combe Down	375481	162769	Full Application Submitted	Under Construction	NC	700	380	320		
MoD Warminster Road	Bath	Bwk 1	Bathwick	376144	165981	Full Application Submitted	Not Started	NC	150	150			
Lambridge Harvester	Bath	Lam 4	Lambridge	376302	166559	Full Permission	Not Started	ML	50	50			
R/O 89-123 Englishcombe Lane	Bath	Odn 3	Southdown	373527	163230	Allocated Site	Not Started	NC	50	50			
Hope House	Bath	Lan 2	Lansdown	374686	165811	Full Application Submitted	Not Started	NC	50	50			
Brougham Hayes	Bath	Wid 2	Widcombe	374066	164684	Full Permisison	Not Started	NC	50	50			
Roseberry Place	Bath	Wes 5	Twerton	373489	164903	Application Imminent	Not Started	NC	170	170			
Bath Press	Bath	Wes 2	Westmoreland	373738	164780	Application Imminent	Not Started	ML	200	200			
Odd Down/Southstoke	Bath	B3A	Bathavon South	373661	161411	Allocated Site	Not Started	NC	300	300			
SW Keynsham 1	Keynsham	K2	Keynsham South	364906	167310	Full Permission	Under Construction	NC	285	285			
SW Keynsham 2	Keynsham	K2	Keynsham South	364336	167337	Full Application Submitted	Not Started	NC	266	266			
Somerdale	Keynsham	K1	Keynsham North	365626	169256	Part Outline/Part Full Permission	Not Started	NC	700	350	350		
Riverside	Keynsham	K4	Keynsham South	365530	168337	None	Not Started	ML	90	90			
East of Keynsham	Keynsham	KE3A	Keynsham East	366673	167967	Allocated Site	Not Started	NC	250	250			
SW Keynsham 3	Keynsham	KE4	Keynsham South	364253	167044	Allocated Site	Not Started	NC	150	150			
Cautletts Close	Somer Valley	MSN 19	MSN Redfield	365960	153582	Full Permission	Under Construction	NC	109	109			
Alcan	Somer Valley	MSN 10	Westfield	366863	153868	Full Permission	Under Construction	NC	169	169			
Radstock Railway Land	Somer Valley	Rad 1	Radstock	368984	154792	Part Oultine/Part Full Permission	Not Started	NC	190	190			
Fosseway South	Somer Valley	MSN 31a	MSN Redfield	366655	152917	Outline Permission	Not Started	NC	165	165			
Monger Lane	Somer Valley	MSN 28	MSN North	365978	155219	Outline Permission	Not Started	NC	135	135			
Knobsury Lane	Somer Valley	Rad 27	Radstock	370186	154338	Outline Permission	Not Started	NC	53	53			
Paulton House	Somer Valley	MSN 25	Paulton	365161	155120	Prior Approval Change of Use	Not Started	NC	58	58			
R/O St Peters Factory	Somer Valley	MSN 15	Westfield	367665	153828	Pre app Submitted	Not Started	NC	90	90			
Polestar	Somer Valley	Pau 1	Paulton	364780	156784	Part Outline/Part Full Permission	Under Construction	NC	528	528			
Wellow Lane	Somer Valley	Pea 1	Peasedown	370260	156941	Full Permission	Complete	NC	89	89			
Greenlands Road	Somer Valley	Pea 7	Peasedown	370267	157629	Outline Permission	Not Started	NC	89	89			
Temple Inn Lane	Rural	TC 4a	Temple Cloud	362311	158024	Outline Application Submitted	Not Started	ML	70	70			

A.3 Development Uncertainty Log (Employment)

Address	Policy Area	Ward	OSGR (X)	OSGR (Y)	PlanningStatus	Development Status	Certainty	2014-2021			2022-2026				2027-2031			
								Office Floor space (sq m)	Office no. jobs	Schools no. students	Office Floor space (sq m)	Office no. jobs	Retail Floor space (sq m)	Retail no. jobs	Office Floor space (sq m)	Office no. jobs	Retail Floor space (sq m)	Retail no. jobs
Manvers Street, Bath	Bath	Abbey	375276	164542	Future Allocation	None	RF	9000	750									
Avon Street, Bath	Bath	Abbey	374911	164452	Future Allocation	None	RF	18000	1500									
South Quays, Bath	Bath	Widcombe	374611	164493	Future Allocation	None	RF	16000	1333									
South Quays II, Bath	Bath	Widcombe	374419	164568	Future Allocation	None	RF								17500	1458		
Green Park, Bath	Bath	Widcombe	374252	164785	Future Allocation	None	RF	10000	833		5000	417	10000	500			10000	500
Bath City Centre	Bath	Abbey	TBC	TBC	Future Allocation	None	H											
Bath Press, Bath	Bath	Westmoreland	373636	164813	Future Allocation	None	RF	3000	250									
Roseberry Place, Bath	Bath	Westmoreland	373404	164864	Planning Application	None	RF	5000	417									
Former MoD Foxhill	Bath	Odd Down	375516	162796	Pre-Planning Application	None	ML			200								
Somerdale, Keynsham	Keynsham	Keynsham North	365701	164434	Planning Status	Partly under construction	ML	10000	833									

Appendix B. ANPR Data Analysis and Application (OBC-14)