SHEFFIELD AND ROTHERHAM CLEAN AIR ZONE FEASIBILITY STUDY

JUNE 2019 – OBC CLARIFICATION MODELLING REPORT

1st July 2019

DOCUMENT CONTROL

Version	**Name**		**Position**	**Date**	**Changes**
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EXECUTIVE SUMMARY

Background

This document provides a response to the modelling clarifications received from JAQU following the submission of the OBC for the Sheffield and Rotherham CAZ scheme.

Those clarifications included assumptions made in the modelling of the Baseline and Preferred Option scenarios along with a series of sensitivity tests designed to test the breaking points and flexibility around elements of the proposed scheme.

The key assumptions included in the modelling of the Preferred Option have been to include a representation of the response of through trips to the scheme, and to clarify the scale and methodology relating to the 4% Hearts and Minds campaign impacts.

Within this document we present the results of the revised Baseline and Preferred Option, along with the findings from the sensitivity tests including what the consequences of not achieving elements of the scheme may be on the principle of compliance within the shortest possible time.

Headlines

The summary results from this clarification work are as follows:

- **Revised Baseline position is an improvement** on previous modelling due to inclusion of recent trends away from diesel cars;

- The **Preferred Option (CAZ C+) remains as the solution which reaches compliance within the 'shortest possible time', forecasting compliance at all locations** in mid-2021 based on implementation of CAZ C+ in 2021 Q2. Given there is a revised and more conservative approach to Hearts and Minds this reduces 'slack' compared to the version presented in the OBC;

- This Preferred Option could be implemented by 2021 Q2, at least six months in advance of a CAZ D (2021 Q4). The modelling which demonstrates compliance represents an average point in 2021 (ie end Q2 / start Q3), and as such represents the **shortest possible option to achieve compliance**;

- The response of goods vehicle trips which pass through the charging area in the Baseline situation will affect compliance as the more that upgrade rather than reroute will mean additional vehicles and hence NO_2 within the charging CAZ. **If up to 87% upgrade and continue to go through the charging area compliance is still achieved**. Given it is anticipated that at least 50% will reroute so this is not expected to be a problem. Even if 100% of through goods vehicle trips upgrade and continue to drive through the charging area it is forecast that compliance is achieved before a CAZ D could go live;

- **97% of the taxi upgrade included in the Preferred Option is required** in order to achieve compliance at all locations by mid-2021 (this represents 90% black cab and 95% PHV upgrade). Due to the current age profile of the current taxi fleet (Private Hire and Hackney) 60% will need to change their vehicle by 2021 Q1 as they become beyond the age at which they can be licensed. Changes to licencing in Sheffield and

Rotherham are proposed post FBC approval and in conjunction with incentive schemes, this is forecast to achieve compliance at the majority of locations. The remaining locations would become compliant due to changes in the background fleet faster than a CAZ D could go live;

- **The full Hearts and Minds switch of 4% from diesel is required to achieve compliance** in all locations by mid-2021, although a lower switch would achieve this at all but a handful of locations on the Sheffield Inner Ring Road. Test show that an unrealistic scenario with no changes in response to a Hearts and Minds campaign would still achieve compliance before a CAZ D could go live, but with the shortest possible time extended. It should also be note that the CAZ D option within the OBC contained the benefits of Hearts and Minds campaign;

- It has been established that **the HGV ban in the uphill direction on Wortley Road is required in order to achieve compliance** by mid-2021. However, it is not required that all HGV's obey this ban which will mean issues surrounding levels of enforcement are less vital; and

- It has also been established that the Rawmarsh Hill rerouting is required to achieve compliance in mid-2021. **At least 33% of buses need to reroute** onto the parallel route in order to achieve this.

1. INTRODUCTION

1.1 Context

1.1.1 Following the production of the OBC for Sheffield and Rotherham Clean Air Zone (CAZ), JAQU requested that some additional investigations be undertaken to further clarify the evidence base for the Preferred Option (PO).

1.1.2 These investigations are in order to further refine the Preferred Option and to undertake some sensitivity tests around it. In particular, to determine what the 'breaking-point' is around some of the assumptions in the Preferred Option, to determine the level of flexibility associated with these assumptions while still achieving compliance with the relevant air quality standard[1].

1.2 List of Tests

1.2.1 The table below shows the full list of tests undertaken in this OBC clarification workstream, including the revised Baseline and Preferred Option and all the Sensitivity Tests undertaken.

Table 1 – List of modelling tests undertaken in this OBC Clarification task

No	Description	Purpose
New Baseline		
1	As before but including reduced BaU sales of new diesel cars (capped at 2018 values) and a (capped) local 2nd hand diesel car sales effect	To establish a 2021 Baseline with the updated / agreed new BaU diesel car fleet assumptions. All sensitivity test use this new Baseline.
New Preferred Option		
2	As before but with 4% Hearts and Minds (modelled as a switch from diesel to non-diesel cars by continuing current trends in diesel reduction as a 'worse-case' scenario, but will also include some switch to cleaner modes, e.g. walk and cycle). Also includes a 'central' representation of through trips fleet effects, with **50%** of the HGV/ LGV trips which pass through the proposed charging area in the Baseline upgrading their vehicles in the same proportions as assumed for trips to/from the charging area	To ensure compliance is still achieved everywhere with new BaU fleet and new H&M assumptions.
Sensitivity Tests – Through Trips		
3	As Test 2 but with 100% of the HGV/ LGV through trips deemed to be in scope for fleet effects	As above but to establish a breaking point for numbers of through HGV / LGV trips which can / need to be effected by same fleet impacts as those trips going to / from the CAZ area.
Sensitivity Tests – Taxis		
4	As Test 2, but the proportions of taxis (black cabs and PHVs) which upgrade to ULEV reduced to	To justify financial ask around taxi upgrades and establish a breaking point proportion of taxis (black

[1] Annual average concentration of NO2 <= 40 µg/m3

	50% of the values assumed in the PO (with the other 50% returning to the BaU taxi fleet as produced by applying EFT changes to the Base Year taxi fleet).	cabs + PHV's) which we need to upgrade to achieve compliance.
Sensitivity Tests – Hearts and Minds		
5	As per test 2 but with no H&M effect	To determine a breaking point for the % shift which the Hearts and Minds campaign needs to achieve to achieve compliance.
Sensitivity Tests – Rotherham Breaking Point Tests (without through trips)		
6	Preferred Option but with no HGV ban on Wortley Road	To establish the proportion of HGV's we need to remove from Wortley Rd to achieve compliance
7	Preferred Option but with 100% of Rawmarsh Hill buses diverted to Barbers Avenue rather than 50%	To determine the proportion of buses we need to remove from Rawmarsh Hill to achieve compliance

1.3 Notes on Sensitivity Testing

1.3.1 The NO_X and NO_2 concentrations predicted by the transport model and the Air Quality model represent an average value for the 2021 year based on an average traffic flow for that year an average fleet for that year and an average expected set of background concentrations for that year. They do not necessarily relate to the exact go live date of the scheme.

1.3.2 It is expected that the Preferred Option can go live in 2021 Q2 and we know this will achieve compliance within the 2021 calendar year. As the assumptions which underpin the model are yearly averages we can assume this will be at the end of Q2 / beginning of Q3 (possibly slightly earlier). It would not be possible to go live on CAZ D any earlier than six months following the implementation of the Preferred Option and therefore the earliest possible go-live would be 2021 Q4 (Cabinet approvals and the need to undertake a new consultation dictate that CAZ D would take a minimum of six months longer).

1.3.3 In order to determine if the effects observed in the Sensitivity Tests presented in this note affect the **shortest possible time** compliance of the Preferred Option we have undertaken some trend analysis (Appendix D) taken from the last 3-4 years of data from the air quality monitors across central Sheffield. These show a steady reduction of around 2.5 $\mu g/m^3$ per annum in NO_2 concentrations which works out as a 0.2 $\mu g/m^3$ average reduction in NO_2 levels each month.

1.3.4 Generally Air Quality cannot be considered like this. It is not linear month on month and seasonal / weather impacts markedly upon these trends. However, in the absence of other evidence we will use this as an estimate of whether any issues observed in the sensitivity tests are likely to extend the expected point of compliance beyond the possible opening of a CAZ D. This will be done in order to establish what represents the shortest possible time. This doesn't, however, double count the improvements seen year on year in the modelling but aims to put an indicative value on reductions over time within a given year.

1.3.5 All of these tests are undertaken and considered in isolation, with no consideration of the interaction between the revised sensitivity test assumptions. This should be borne in mind, particularly when considering the results of the 'breaking point' tests. For example, reducing

the amount of taxi upgrades assumed will slightly increase the need to enforce the HGV bans, but this interaction of sensitivity test assumptions has not been appraised here.

1.4 Structure of this Document

1.4.1 The contents of this document are as follows:

- The updated Baseline Model is described in **Section 2**;
- The updated Preferred Option is described in **Section 3**;
- The sensitivity tests around the assumptions regarding the fleet upgrade response of through trips are described in **Section 4**;
- **Section 5** describes the taxi sensitivity tests;
- The Hearts and Minds Sensitivity Test is described in **Section 6**;
- **Section 7** describes the Wortley Road HGV ban sensitivity tests;
- **Section 8** describes the Rawmarsh Hill bus sensitivity tests; and
- The main conclusions are summarised in **Section 9**

2. REVISED BASELINE

- **Purpose:** To establish a Baseline with the updated / agreed forecast Baseline fleet assumptions (equivalent to ~16% switch from diesel to 'not-diesel' cars in 2021).
- **Methodology:** As previous Baseline but including reduced sales of new diesel cars (capped at 2018 values) and capped local 2nd hand diesel car sales effect within the proposed central Sheffield CAZ area (referred to as Charging Area 3 in the OBC) which were previously included in the OBC Preferred Option test.
- **Results:** More-robust Baseline Air Quality predictions (and reduced levels of predicted air

2.1 Introduction

2.1.1 In the OBC, we predicted within our assessment of the Preferred Option a reduction in the number of diesel cars in the Central Sheffield private car fleet, made up of a combination of a sharp decline in the sale of new diesel cars, an out-migration of older diesels via a change in the pattern of 2nd-hand car sales by those travelling regularly into the proposed charging area and as a result of a 'Hearts & Minds' campaign targeting the use of diesel cars in the areas of poor air quality.

2.1.2 The first two of these are, in fact, Business as Usual effects, but were not included in the original Baseline, which was based on the fleet profiles specified in Version 8 of the DfT's EFT model.

2.1.3 Following the submission of the OBC, it was agreed that interpretation of the modelling and appraisal results would be facilitated by updating the Baseline to incorporate the two Business as Usual diesel car fleet effects, leaving only the additional 'Hearts and Minds' portion of the fleet effects differing between Baseline and Do Something scenarios.

2.1.4 Additional fleet modelling (reported in detail in Appendix A of this note) suggested that the impact of the new car sales component will generate a 10% reduction in the share of diesel in the average 2021 private car fleet (Baseline and Preferred Option), the out-migration of diesel via changes in second-hand sales will generate a further 6% reduction (Baseline and Preferred Option). The Hearts and Minds (modelled as the continuation of the recently-observed downward trends in diesel sales) will generate a further 4% reduction (but is only included in the Preferred Option only).

2.1.5 These changes to the fleet are described further in the information note attached as **Appendix A**.

2.1.6 Applying the two Business as Usual effects to the Baseline model will lead to area-wide reductions in the NO_X emissions from the private car fleet, with corresponding improvements in the predicted average 2021 Baseline air quality.

2.2 Purpose of Test

2.2.1 The purpose of the test was twofold:

- Firstly, to test whether this new Baseline was indeed an improvement on the OBC version due to the improved fleet; and

- To establish a new more-robust Baseline against which the new Preferred Option and Sensitivity Tests could be compared.

2.3 Detailed Methodology

2.3.1 For this new Baseline run, there have been no changes in the Transport Model (SRTM3B) and therefore no changes to the assignment. Changes have been applied to the fleet and ENEVAL emissions processes, to reflect the revised assumptions about the future-year private car fleet.

2.3.2 Firstly, in the fleet model, the %diesel in new car sales effect is conservatively capped at current 2018 values. This is applied everywhere, including to motorway traffic, as the recent 'cliff edge' drop in new diesel sales is a UK-wide phenomenon. The additional 2nd hand diesel sales out-migration effect is applied to all links within the central CAZ charging area, to represent the additional impact on car drivers who regularly drive into this area and whose second-hand car purchases are influenced by the general anti-diesel sentiment affecting new car sales and the potential anticipation of future restrictions on the use of older diesel vehicles in central Sheffield.

2.3.3 The fleets predicted by the fleet model are then included in the ENEVAL input tables and applied to the outputs from the SATURN assignment models. The ENEVAL outputs are then passed to the AIRVIRO Emissions Dispersal/Air Quality Prediction model.

2.3.4 In addition to this the f-NO2 values for the test have been recalculated and incorporated into the results. These do not have much impact on the overall results.

2.4 Results

2.4.1 The results at several key points in Sheffield and Rotherham, either where the OBC 2021 Baseline predicted non-compliance or this new 2021 Baseline predicts non-compliance are presented in the two tables below.

Table 2 – Comparison of OBC and New Baseline (Rotherham) – 2021 Average

	OBC Baseline	New Baseline	Change
Parkway - Rotherham	**43.60**	**42.80**	-2%
Rawmarsh Hill	**42.20**	**44.10**	5%
Wortley Road	**41.30**	**43.20**	5%
Fitzwilliam Road	**40.80**	**41.96**	3%

NB For Rotherham modelling a new background file has been used which presents a more robust set of values. This new background data suggests much worse non-transport concentrations than the version used for OBC. Without this new file the Baseline values in Rotherham drop by ~2-3%.

Table 3 – Comparison of OBC and New Baseline (Sheffield) – 2021 Average

	OBC Baseline	New Baseline	Change
Suffolk Road	54.75	53.38	-3%
St Mary's Road	54.28	53.06	-2%
Derek Dooley Way	51.68	50.28	-3%
Shoreham Street	51.48	50.10	-3%
Shalesmoor	51.02	49.66	-3%
St Mary's Gate	50.92	49.51	-3%
Sheaf Street	50.17	49.01	-2%
Sheffield Parkway	49.89	48.23	-3%
Hawke Street	49.33	48.08	-3%
Matilda Street	48.55	47.57	-2%
Wicker	47.70	46.08	-3%
C710 Arundel Gate	46.74	45.47	-3%
Hoyle Street	45.65	44.90	-2%
Moorfields	45.58	44.41	-3%
Attercliffe Common	43.08	41.30	-4%
Fornham Street	43.03	42.76	-1%
Bawtry Road	40.99	39.38	-4%
Meadowhall Road	40.60	39.18	-3%

2.5 Conclusions

2.5.1 The table above shows that:

- The main non-compliant sites remain non-compliant in this new Baseline; and
- At all these sites emissions have improved compared to old Baseline (except Rotherham because of the new background data).

NB, it has been agreed that JAQU do not require us to update the Target Determination to reflect these changes in the Baseline model.

3. REVISED PREFERRED OPTION (PO)

- **Purpose:** To ensure that the Preferred Option under the improved modelling of the predicted private car fleet and inclusion of 'central case' through trip fleet effects still achieves area-wide compliance by mid-2021.
- **Methodology:** Preferred Option changes (including the 4% switch away from diesel due to an assumed Hearts & Minds campaign by continuing the recently-observed downward trends) applied to the revised Baseline described in the previous section and a 'central' through trip fleet effect (i.e. relevant fleet upgrades applied to 50% of LGV and HGV through trips)
- **Results:** The Preferred Option still predicted to achieve area-wide compliance by mid-2021, but with reduced 'slack' at some through route locations within the charging area, due to the effect of the set of 'dirty' goods vehicles which previously diverted round the CAZ upgrading to Euro 6 and now driving through the charging area free of charge.

3.1 Introduction

3.1.1 Following on from the updated Baseline, it was agreed that the Preferred Option should be updated to include the same fleet upgrades that were included in the Baseline, plus the additional Hearts and Minds effect (equivalent to a ~4% switch from Diesel to Petrol).

3.1.2 The Preferred Option has also been updated to take into consideration the likely fleet upgrade effects on HGV / LGV trips passing through the CAZ area.

3.1.3 In the original OBC Preferred Option, only those trips to / from the CAZ area were assumed to upgrade their vehicles in response to the CAZ charge, using upgrade factors derived from the Local Behavioural Research which was undertaken in the SCC/RMBC area. The revised version of the Preferred Option includes an estimate of a corresponding fleet upgrade responses of owners of non-compliant vehicles making trips which pass through the proposed charging area in the Baseline network.

3.1.4 The two extremes of the relevant assumption are that a) none of these Baseline through trip-makers upgrade their vehicles in response to the CAZ and b) 100% of them respond in the same way as the trips to/from the CAZ area (in the proportions predicted by the local behavioural research).

3.1.5 In the absence of any definitive evidence on what the actual response of through trip-makers will be, we have defined a '**Central**' through trips fleet effects assumption which lies midway between these two extremes, namely that **50%** of non-compliant trips (after 2021 Business as Usual upgrades) which travel through the proposed charging area in the 2021 Baseline will make the fleet responses predicted by the Local Behavioural Research, based on the owners of non-compliant goods vehicles making trips **to/from** the charging area. The remaining 50% will not upgrade their vehicles in response to the CAZ and so will then have to choose between diverting round the charging area or paying the daily charge to drive through it.

3.2 Purpose of Test

3.2.1 The purpose of this test is to ensure the new Preferred Option:

- Ensure that SCC/RMBC's Preferred Option still achieves compliance under the improved modelling of the predicted private car fleet in response the Hearts and Minds campaign and inclusion of 'central case' through trip fleet effects;
- Act as a 'point on the line' for the breaking point tests; and
- To include the JAQU suggestion that we should apply fleet upgrade effects to HGV and LGV trips travelling through the proposed charging area in the modelling of the Preferred Option.

3.3 Detailed Methodology

3.3.1 Within the fleet model the car fleet is as in the new Baseline. The Hearts and Minds campaign is to further influence car drivers to move away from diesel with a continuing decline in diesel sales affecting car traffic on all links within the proposed charging area. This results in an additional 4% Hearts and Minds switch from diesel to non-diesel cars.

3.3.2 The representation of this %switch away from diesel now takes account of a much-more-detailed fleet modelling, as reported in **Appendix A** than was the case in the OBC Preferred Option.

3.3.3 This refinement will lead to a slight deterioration in the Preferred Option, as it includes a larger decrease in the number of young (relatively clean) diesel cars and a smaller drop in older (dirtier) ones.

3.3.4 Furthermore, a representation of the fleet effects on through trips has been included in this version of the Preferred Option, which includes:

- All HGV and LGV non-compliant through trips (ie a trip which does not end or start in the CAZ area but goes through it) in the 2021 Baseline are 'in-scope' for CAZ-related fleet upgrade effects;
- Modelling analysis suggests that, of non-compliant HGV/ LGV trips in the Baseline that drive through the charging zone, between 40% and 60% will choose to continue to drive through the CAZ in the Preferred Option, the remainder will reroute to avoid the zone; and
- The (conservative) factors derived from local behavioural research and standard JAQU factors for trips to/from the CAZ (reported in a previous Technical Note[2] and summarised in the table below) are applied to this 50% of Baseline through trips. This differentiates between those through trips that upgrade and those that pay the charge.

3.3.5 This revised assumption is referred to as a **50% (or Central) Through Trip Fleet Effects** (**TTFE**).

[2] 2018-01-15 Sheffield and Rotherham Clean Air Zone Feasibility Study - Behavioural Research.pdf

Table 4 – Local behavioural research factors and JAQU fleet factors

	Local - Pessemistic			Local - Conservative			JAQU		
	Avoid zone or pay charge	Upgrade	Remove from highway matrix	Avoid zone or pay charge	Upgrade	Remove from highway matrix	Avoid zone or pay charge	Upgrade	Remove from highway matrix
Car	13%	68%	19%	8%	73%	19%	18%	64%	18%
PHV	6%	94%	0%	5%	95%	0%	N/A	N/A	N/A
Taxi	18%	82%	0%	16%	84%	0%	N/A	N/A	N/A
LGV	61%	39%	0%	43%	57%	0%	28%	64%	8%
HGV	N/A	N/A	N/A	N/A	N/A	N/A	13%	83%	4%

3.3.6 The methodology for incorporating the Through Trip Fleet Effects (TTFE) is described in **Appendix C**.

3.3.7 It is also worth noting as a reminder that with the exception of HGV (which uses JAQU values) the total fleet numbers in the transport model do not reduce to provide a 'worse case' scenario.

3.4 Results

3.4.1 Firstly, the figure below shows the impact of including the TTFE on the Preferred Option, with increased NO_x emissions in Central Sheffield and reduced emissions on orbital routes outside the Inner Ring Road.

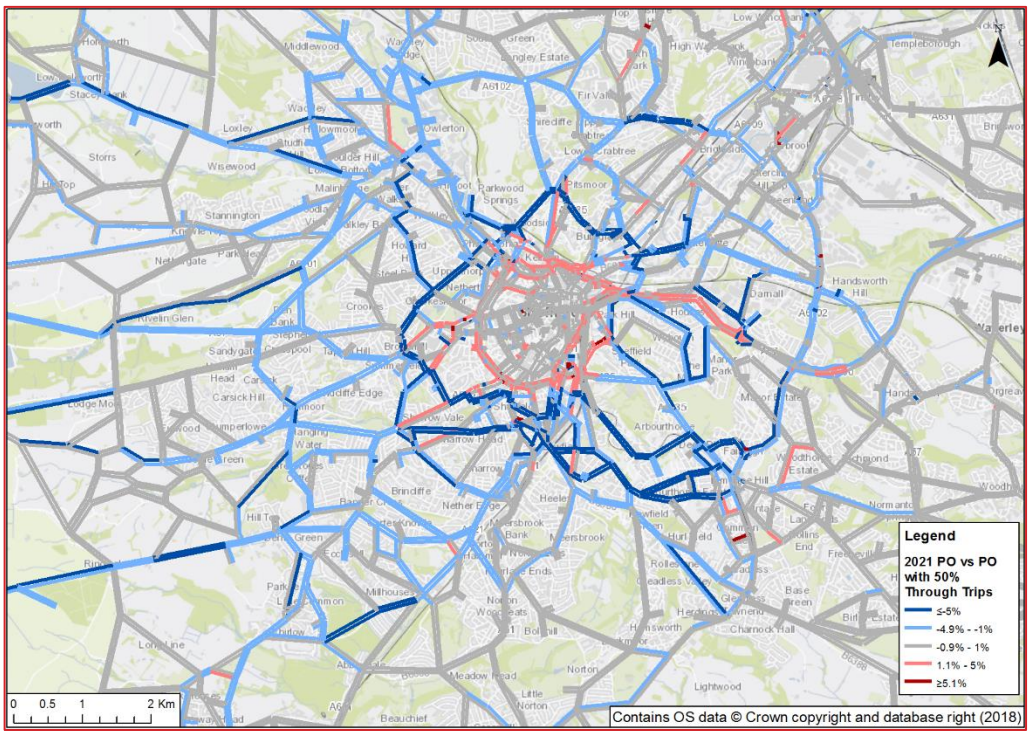

Figure 1 – Impact of including Through Trip Fleet Effects (TTFE)

3.4.2 These results combine two separate but inter-related effects of applying the TTFE, as follows:

- some non-compliant vehicles trips which previously paid to drive through the CAZ will now upgrade to cleaner (e.g. EURO VI diesel) vehicles, reducing emissions along their entire routes, with no change to traffic levels; and

- some non-compliant vehicles which previously diverted round the CAZ to avoid the charge now upgrade to compliant (e.g. EURO VI diesel) vehicles and are then able to drive through the CAZ free of charge, resulting in a reduction of their emissions on their approach and a complete removal of the vehicle and its emissions from the diversion route, but an additional set of EURO VI goods vehicle emissions and additional congestion on their chosen route through the CAZ.

3.4.3 Links outside the CAZ which are used as diversionary routes will tend to receive a net benefit from the inclusion of the TTFE, while links on popular routes through the CAZ (particularly those with an attractive alternative diversionary route and which are prone to congestion) are likely to experience more emissions as a result of the inclusion of the TTFE.

3.4.4 The tables below reports the predicted NO_2 concentrations for the previous OBC and the new Preferred Option.

Table 5 – Comparison of PO Results – OBC vs New (Rotherham)

	OBC Preferred Option	New Preferred Option	Change
Parkway - Rotherham	39.21	40.30	3%
Rawmarsh Hill	38.08	40.20	6%
Wortley Road	38.56	39.80	3%
Fitzwilliam Road	39.17	38.70	-1%

NB As for the Baseline, Rotherham modelling includes a new background file which presents a more robust set of values.

Table 6 – Comparison of PO Results – OBC vs New (Sheffield)

	OBC Preferred Option	New Preferred Option	Change
Suffolk Road	39.16	40.27	3%
St Mary's Road	39.24	40.46	3%
Derek Dooley Way	38.54	39.75	3%
Shoreham Street	38.13	39.09	3%
Shalesmoor	38.57	39.65	3%
St Mary's Gate	38.04	39.16	3%
Sheaf Street	36.27	37.19	3%
Sheffield Parkway	38.94	39.43	1%
Hawke Street	33.11	37.34	13%
Matilda Street	36.10	37.04	3%
Wicker	36.18	37.04	2%
C710 Arundel Gate	35.02	35.49	1%
Hoyle Street	35.36	35.95	2%
Moorfields	34.82	35.64	2%
Attercliffe Common	38.87	38.99	0%
Fornham Street	33.48	34.23	2%
Bawtry Road	37.36	37.20	0%
Meadowhall Road	37.56	37.29	-1%

3.4.5 The new Preferred Option is still predicted to achieve compliance at all sites by mid-2021, but in many cases the air quality is predicted to be slightly worse than in the previous (OBC) Preferred Option.

3.4.6 At St Mary's Road and Suffolk Road (parts of the Sheffield Inner Ring Road), the combined effect of the changes in the way the Hearts and Minds campaign is modelled (See **Appendix A**) and the emissions from the additional through trips by the (upgraded) goods vehicles increases the predicted NO_2 levels in to a value which is now very close to the all-important 40.5 $\mu g/m^3$ threshold value, but none the less remains compliant.

3.5 Conclusions

3.5.1 The new **Preferred Option will still achieve compliance everywhere in 2021**, but is much closer to the cut-off point of 40.5μ/m^3, at a small number of locations on the Sheffield Inner Ring Road, than the previous (OBC) Preferred Option. As the modelled values represent an average position in 2021 this suggests that compliance will be achieved later in the year than predicted in the OBC Preferred Option but still by end 2021 Q2 / start 2021 Q3. This is in advance of the earliest possible go-live of a CAZ D scheme (2021 Q4) and hence represents **compliance in the shortest possible time**.

3.5.2 From this point forward this is the Preferred Option that is used as the comparator in each of the sensitivity tests described in the following sections. *(Except for the Rotherham sensitivity tests which were undertaken before the new Preferred Option was established and where the through trip fleet effects have very little impact)*

4. THROUGH TRIPS SENSITIVITY TESTS

- **Purpose:** To determine the impact of applying the assumed fleet upgrade response proportions to 100% of non-compliant through trips (LGV and HGV) (rather than the 50% assumed in the new Preferred Option)
- **Methodology:** As per the TTFE methodology in the Preferred Option, but with the relevant fleet effect proportions applied to 100% of the non-compliant LGV and HGV through trips.
- **Results:** Results in some non-compliances on Sheffield's Inner Ring Road in mid-2021, due to more goods vehicles upgrading and then travelling through the CAZ which increases the overall NO_X emissions. Previously, in the old Preferred Option, these vehicles would have rerouted to avoid the zone and only a small proportion would have paid to pollute. The NOx from the additional 'clean' through trips outweighs the NOx from the small number of 'dirty' vehicles which 'paid to pollute'. The breaking point occurs if more than ~87% of Baseline Through Trips upgrade and drive through the charging zone. Even if more Through Trips than this experience fleet effects the non-compliances are sufficiently low that they would become compliant through background changes in the wider fleet in advance of the time scales for a CAZ D being implemented. It is also the case that through trips tend to represent lower frequency movements, so it is reasonable that a high proportion reroute rather than upgrade.

4.1 Introduction

4.1.1 This test is the same as the Preferred Option but with the fleet effect proportions in response to the CAZ applied to 100% of the non-compliant Baseline 'in scope' through trips by LGVs and HGVs. Whilst this is an unrealistic assumption it is being used to determine the breaking point of this test.

4.2 Purpose of Test

4.2.1 This test enables us to:

- Identify how changes to the Through Trip Fleet Effect (TTFE) assumptions affect the predicted air quality at different locations; and
- Estimate the' breaking point' at which the proportion of through trips which choose to upgrade in response to the CAZ creates a predicted non-compliance by mid-2021.

4.3 Detailed Methodology

4.3.1 This test was undertaken in the same way as the new Preferred Option described in Section 3.3 above, but with the relevant fleet upgrade proportions applied to 100% of the non-compliant through trips in the 2021 Baseline.

4.4 Emissions-based Results

4.4.1 When we increase the fleet upgrade responses, we expect to see:

- Significant emissions reductions on links which are used to avoid the CAZ; and
- a mix of increases and decreases on the through routes, depending on the proportion of trips which pay to pollute and the relative emission rates of 'dirty' (pre-EURO VI diesel) and compliant (EURO VI diesel or petrol or ULEV) goods vehicles.

4.4.2 For example, if there is **little or no reduction in emission rates** between compliant and non-compliant vehicles, then upgrading more of the vehicles will simply transfer their emissions from the diversionary routes back to the through routes, while if the upgraded vehicles were all **zero-emission**, then all of the emissions from the previously 'dirty' non-compliant vehicles would be removed, with those from the diverting vehicles removed from the diversionary routes and those from the previous 'pay to-pollute' subset of vehicles removed from the through routes.

4.4.3 There is also going to be a 2nd-order effect from the changing pattern of congestion on the diversionary and/or through routes created by the change of routing patterns generated by these extra fleet upgrades.

4.4.4 The figure below shows the predicted change in NO_X emissions created by moving from 50% to 100% of Baseline through trips by non-compliant vehicles considering the relevant fleet upgrade responses.

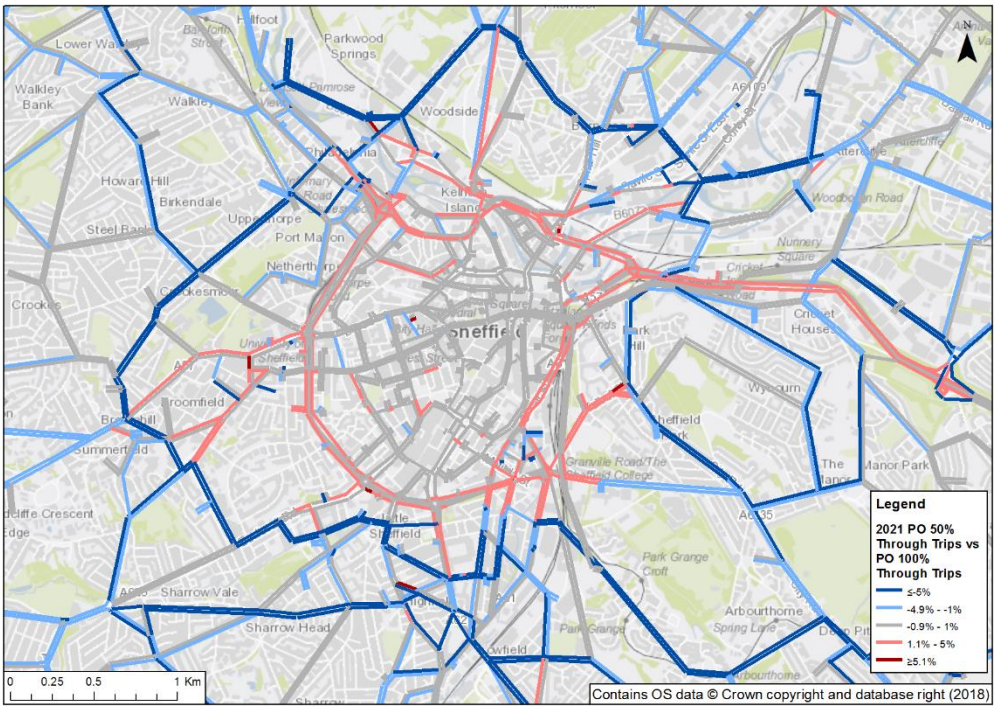

Figure 2 – Change in NO_X emissions with 100% of through trips affected by the TTFE

4.4.5 The pattern shows a) the expected reduction in emissions on the diversionary routes and b) that the extra emissions from the newly-compliant vehicles switching back to using the Inner Ring Road (and any resulting congestion effects) is predicted to be greater than the reduction from the switch of 'dirty' to 'clean' vehicles which were paying to use this route in the 50% TTFE Preferred Option.

4.4.6 The result of this test showed that one section of the Sheffield Inner Ring Road from St Mary's Road around to Suffolk Street is predicted to remain non-compliant in mid-2021.

4.5 Airviro Air Quality Results

4.5.1 The table below shows the NO2 concentrations at different levels of Through Trip Upgrade effects. This shows with 0% or 50% all links remain compliant, but at 100% TTFE stretches of the Inner Ring become non-compliant or very close to non-compliant. It is clear that the situation where no vehicles which make through trips will experience the fleet effects expected in response to the CAZ is unrealistic, but it is also unlikely that **all** the through trip vehicles would upgrade to the same level as trips to / from and within the area. Therefore the 50% level seems reasonable. *Note: the compliant breaking point for St Mary's Road occurs when approx. 87% of Through Trips experience fleet effects of the CAZ.*

Table 7 – NO_2 concentrations with different levels of Through Trip Fleet effects taking place in Sheffield

	Preferred Option (with 0%)	Preferred Option (with 50%)	Preferred Option (with 100%)
St Mary's Road	40.23	40.46	40.62
Suffolk Road	40.09	40.27	40.39
Derek Dooley Way	39.59	39.75	39.88
Shalesmoor	39.59	39.65	39.68
Sheffield Parkway	39.40	39.43	39.60
St Mary's Gate	39.06	39.16	39.13
Shoreham Street	38.98	39.09	39.05
Attercliffe Common	39.09	38.99	38.88

4.6 Conclusions

4.6.1 The response of non-compliant vehicles which travel through the proposed charging areas in the Baseline to the introduction of a daily charge was not part of the local behavioural research which was undertaken. A fleet effect response is expected, but not to the same level as trips to / from and within the CAZ area, particularly as through trips will have a higher rerouting rate.

4.6.2 The out-turn value will lie somewhere between 0% (no fleet upgrade response applied to through trips) and 100% (ie everyone making through trips upgrade their vehicles in the same way as those making trips to or from the CAZ area).

4.6.3 JAQU requires that these through trips are considered in the Preferred Option, but does not have rigid guideline for how this is done, but the applied approach has been agreed with JAQU.

4.6.4 The new Preferred Option makes a 'Central' assumption that 50% of non-compliant Baseline through trips consider the relevant vehicle upgrade responses when the CAZ is introduced. *NB this 50% is broadly in line with the proportion of non-compliant vehicles which are predicted to pay the charge to drive through the CAZ area in the Preferred Option. As described in the earlier section this new Preferred Option still achieves global compliance.*

4.6.5 However, a 'Worst Case' assumption of 100% Through Trip Fleet Effects leads to a predicted annual average NO_2 levels of 40.6 µg/m^3 on a section of Sheffield's Inner Ring Route by mid-2021. This is, as previously stated, an unrealistic scenario as through trips are likely to be lower frequency and likely to reroute. It is also the case that based on the 0.2 µg/m^3 per

month improvement detailed in section 1.3 would mean compliance would occur in advance of a CAZ D implementation at the earliest of 2021 Q4.

Note: It should also be noted that the trade-off between increased and decreased emissions inside the CAZ area as the level of through trip fleet upgrade response increases is strongly affected by the emissions rates of the new compliant vehicles. The area-wide compliance will therefore be further accelerated if vehicle owners who upgrade are encouraged to choose vehicles whose NO_X emissions are as low as possible (e.g. ULEV rather than just EURO VI, were possible).

5. TAXI SENSITIVITY TEST

- **Purpose:** To justify financial ask around taxi upgrades and establish what proportion of black cabs and PHV need to upgrade to establish a breaking point proportion of the number of taxis which must upgrade if compliance is to be achieved in mid-2021.
- **Methodology:** Only 50% of the taxi upgrades have been assumed, compared to the Preferred Option taxi upgrade assumptions
- **Results:** The breaking point for taxis in order to achieve area-wide compliance by mid-2021 has been found to be approx. 97% of the Preferred Option upgrades. This translates to 90% of black cabs and 95% PHVs need to upgrade to LPG / ULEV by mid-2021 in order to achieve compliance.

5.1 Introduction

5.1.1 In this test 50% of the Taxi (Black Cab and PHV in Sheffield; and PHV in Rotherham) upgrades have been removed from the Preferred Option tests to see what the impact is on mid-2021 compliance.

5.1.2 In the Preferred Option, 93.6% of non-compliant Black Cabs upgrade and 98.0% non-compliant of PHV's upgrade[3], in the 50% test this is 46.3% of Black Cabs upgrade and 49.0% of PHV's upgrade.

NB Due to the current age profile of the current taxi fleet (Private Hire and Hackney) 60% will need to change their vehicle by 2021 Q1 as they become beyond the age at which they can be licensed. Changes to licencing in Sheffield and Rotherham are proposed post FBC approval and in conjunction with incentive schemes.

5.2 Purpose of Test

5.2.1 The purposes of this test are to:

- establish a breaking point for the proportion of taxis which need to upgrade to achieve compliance in mid-2021; and
- help to justify the financial 'ask' required to deliver the level of taxi upgrades assumed in the Preferred Option and included in the current OBC Financial Case Model.

5.3 Detailed Methodology

5.3.1 In this test, a reduced rate of black cabs and car-based taxi upgrades is applied to the Preferred Option traffic flows via the input tables used in SYSTRA's ENEVAL emissions estimation process;

5.3.2 The resulting annual NOX emissions (by link) for the average 2021 position are then passed to SCC/RMBC's AIRVIRO models, which predict the corresponding annual average concentrations on NO_2 in 2021.

[3] The calculation of these values is included in the T4 report

5.4 Results

5.4.1 The result of this test suggest that there would still be non-compliances at various points along the Sheffield Inner Ring Road in mid-2021 if only 50% of taxis (black cabs and PHV) that the Preferred Option assumed would upgrade are upgraded to ULEV emissions standards. These predicted non-compliances in mid-2021 are predicted to occur at the southern part of the Ring Road, especially St Mary's Road and Suffolk Road. These non-compliances are shown in the table below.

Table 8 – fNO_2 values for Taxi Sensitivity Test (with interpolated 60% taxi upgrade factors)

	50% Taxi Upgrade	60% Taxi Upgrade	Preferred Option
St Mary's Road	**41.13**	**41.00**	40.46
Suffolk Road	**40.94**	**40.81**	40.27
Derek Dooley Way	40.42	40.29	39.75
Shalesmoor	40.31	40.18	39.65
Sheffield Parkway	39.64	39.60	39.43
St Mary's Gate	39.81	39.68	39.16
Shoreham Street	39.65	39.54	39.09
Attercliffe Common	39.33	39.26	38.99

5.4.2 From this result, we have been able to calculate the breaking point upgrade levels for various points around the Inner Ring Road (ie what % of the taxi fleets need to be upgraded to ULEV to achieve compliance by mid-2021.

5.4.3 The results of this 'breaking point' estimation are summarised in the figure below. The %s in this chart relate to the proportion of the Preferred Option taxi upgrades assumptions which are required to deliver compliance at the various locations by mid-2021

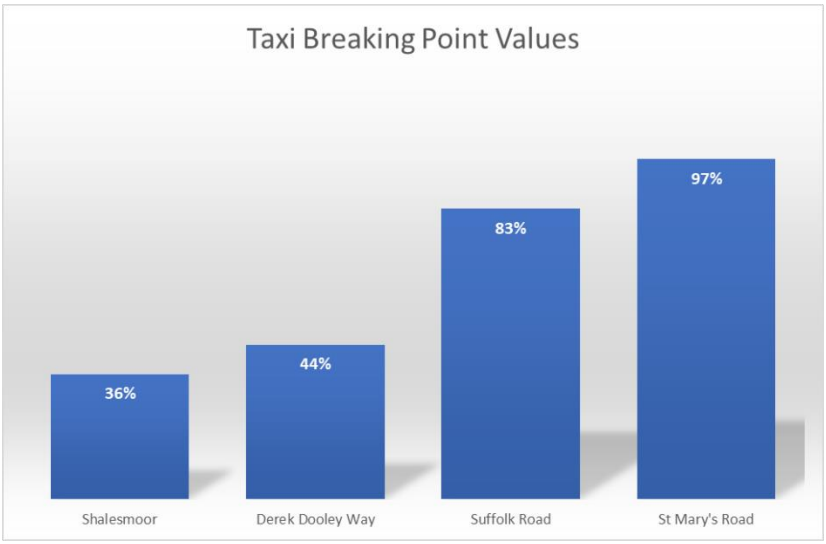

Figure 3 – Taxi breaking point values at several locations on Sheffield IRR

5.4.4 These results suggest we will require around **97%** of the taxi upgrades assumed in the new Preferred Option if we are to achieve compliance with the 40 µg/m^3 annual average limit value on St Mary's Road by mid-2021. This 97% of the upgrade is equivalent to 95% of the PHV fleet needing to upgrade and 90% of the black cab fleet needing to upgrade.

5.4.5 Due to the current age profile of the current taxi fleet (Private Hire and Hackney) 60% will need to change their vehicle by 2021 Q1 as they become beyond the age at which they can be licensed. The proposed changes to licencing in Sheffield and Rotherham post FBC approval, in conjunction with incentive schemes, are forecast to achieve compliance at all locations with the exception of St Mary's Road and Suffolk Road on the Sheffield Inner Ring Road.

5.5 Conclusions

5.5.1 This analysis has shown that the timescale for compliance at some locations on the Sheffield Inner Ring Road will be extended beyond mid-2021 if there is any significant reduction in the level of upgrades to the taxi fleets assumed in the current Preferred Option. The breaking point has been estimated to be around **97% of the Preferred Option upgrade** assumptions being required, equivalent to approx. 90% of black cabs and 95% of PHVs which regularly use Sheffield's Inner Ring Road.

5.5.2 Based on the indicative monthly change in NO_2, as described in section 1.3, a 'worst case' scenario of no additional upgrade over and above the 60% that will need to change their vehicle by 2021 Q1 as they become beyond the age at which they can be licensed, would still be expected to achieve compliance in advance of the possible introduction of a CAZ D with an average reduction of 0.2 $\mu g/m^3$ per month. **Hence the CAZ C+ even with a reduced taxi upgrade still represents compliance in the shortest possible time** and hence the financial support in the CAF bid is required to support achieving this.

5.5.3 It is also worth noting that in the local behavioural research **(Table 3),** 84% of taxi owners stated they would upgrade in response to a CAZ scheme anyway, which would represent better than the 60% licence renewals and also achieve compliance quicker than a CAZ D.

5.5.4 On this basis, all sites could be made compliant before a CAZ D could be implemented as long as **52% of the Preferred Option upgrades are achieved**. This is a realistic target than can be achieved. This was calculated using a similar interpolation, the 0.2 $\mu g/m^3$ improvement per month and assumed that a CAZ D could go live exactly six months after a CAZ C+ and that it would achieve compliance immediately (both of which are unrealistic assumptions).

6. HEARTS & MINDS SENSITIVITY TEST

- **Purpose:** To determine the breaking point for the impacts of the Hearts and Minds campaign – i.e. what additional percentage switch from diesel to petrol cars (in central Sheffield traffic) is required to achieve compliance by mid-2021.
- **Methodology:** Undertake a version of the Preferred Option but with the 4% 'diesel->non-diesel' impact of the 'Hearts and Minds' campaign removed. If this modelling predicts some remaining non-compliances in mid-2021 then linear interpolation between the new Preferred Option and this sensitivity test can be used to predict how much of this 4% Hearts & Minds effect is required to achieve area-wide compliance by the relevant target year.
- **Results:** The full 4% Hearts and Minds impact is required to achieve compliance at all locations by mid-2021. Removing all of this Hearts and Minds effect from the Preferred Option car fleet is predicted to extend timescales to achieve compliance just beyond possible implementation of a CAZ D. However any Hearts and Minds effect over 2% would achieve compliance in advance of the CAZ D timescales. More importantly the proposed Hearts and Minds effect is very much seen as achievable and therefore represent shortest possible timescales.

6.1 Introduction

6.1.1 The test undertaken has been to do a version of the new Preferred Option as described in Section 3 but with the additional 'Hearts and Minds' switch (~4%) from diesel to non-diesel cars removed.

6.2 Purpose of Test

6.2.1 The purpose of this test is to establish a breaking point between no Hearts and Minds effects and the 4% switch away from diesel included in the Preferred Option. This will aim to establish the level that needs to be reached to ensure compliance is achieved.

6.3 Detailed Methodology

6.3.1 No transport model or ENEVAL scenario has been run in this case, instead outputs from the new Baseline and the new Preferred Option have been combined to synthesise the emissions results for this scenario.

6.3.2 Since the Hearts and Minds impacts are only applied to the car fleet, the NO_X emissions from cars in the Preferred Option are simply replaced by the corresponding NO_X emissions from cars in the Baseline model, to produce the revised total link-based NO_X emissions for this sensitivity test.

6.3.3 This combined set of emissions are then input to emissions databases in SCC/RMBC's AIRVIRO air quality model, and dispersion modelling is used to predict the annual average NO2 concentrations in 2021.

6.4 Results

6.4.1 The bar chart below shows the locations within Sheffield where mid-2021 non-compliances are predicted to occur when the Hearts and Minds campaign is excluded from the Preferred Option.

6.4.2 These mid-2021 non-compliances are predicted to occur at a number of locations on Sheffield's Inner Ring Road and Sheffield Parkway.

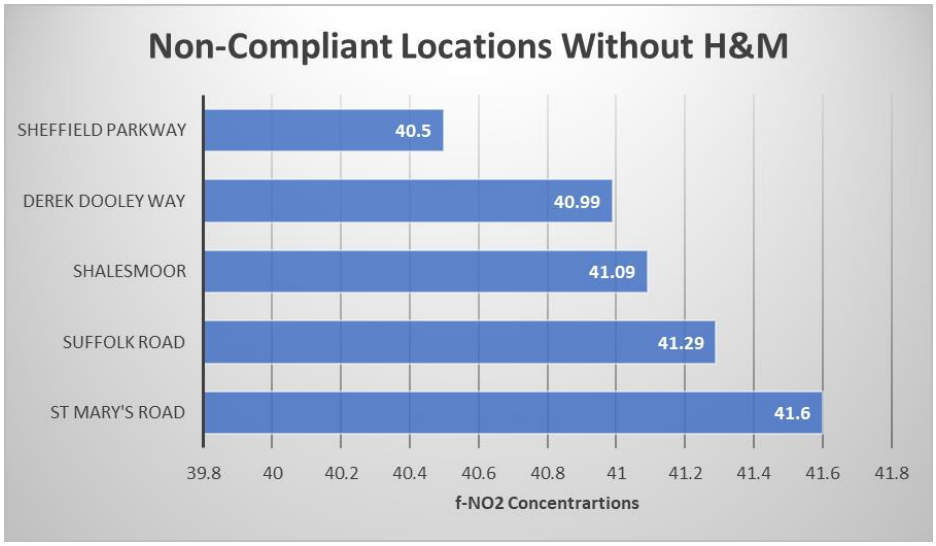

Figure 4 – Predicted 2021 NO_2 Levels at Key Locations if the H&M Effects are Excluded from the PO

6.4.3 The chart below illustrates the percentage of the Hearts and Minds effect needed at each non-compliant site to achieve compliance by mid-2021. These suggest that for the key air quality 'hot-spot' locations on the Inner Ring Road (St Mary's Road and Suffolk Road) almost all of the 4% of Hearts and Minds effects is required to achieve compliance by mid-2021.

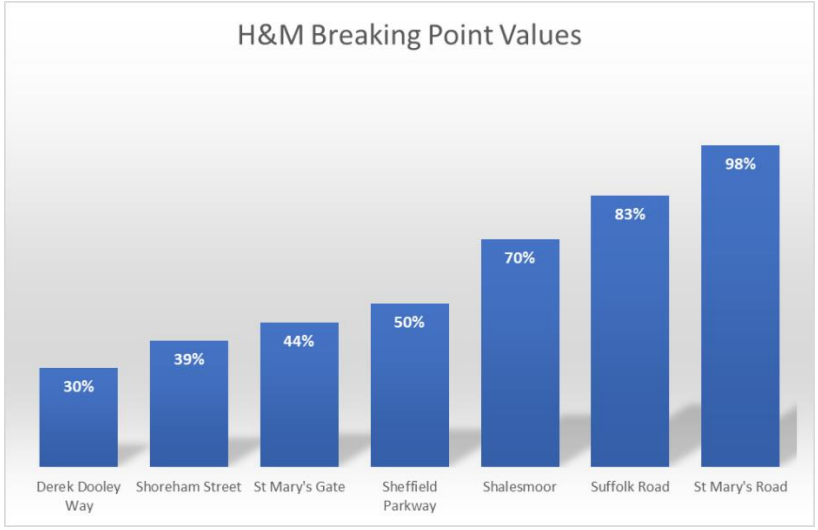

Figure 5 – Breaking Point Values for Non-Compliant Roads

6.5 Conclusions

6.5.1 All of the 4% Hearts and Minds effect assumed in the new Preferred Option is predicted to be required to achieve area-wide compliance in Sheffield in mid-2021 at St Mary's Road. Other locations will be compliant at 3.3% Hearts and Minds (Suffolk Rd) effects or lower.

6.5.2 This 4% Hearts and Minds effect is expected to be achievable. In the modelling these trends away from diesel cars as included in the new Baseline are capped at current levels (in part to deal with the effect of 2nd hand diesel sales). However, in practice this trend will continue downwards, but possibly not at the same rate without intervention. This intervention would be from the Hearts and Minds campaign which would cover a wide range of effects including work to increase walking and cycling, use public transport, flexible working etc.

6.5.3 The unrealistic outcome of a Hearts and Minds campaign having no impact on car purchases (i.e. no further drop in the %diesel in car sales beyond 2018 values) results in a predicted timescale for compliance of the CAZ C+ Preferred Option just beyond the timescales for the implementation of a CAZ D (and therefore not the shortest possible time). This assumes the month on month changes described in section 1.3. However, it has been calculated, using the same interpolation used to determine the breaking point along with the 0.2 $\mu g/m^3$ reduction per month, that a Hearts and Minds impact of 2% would achieve compliance before a CAZ D could go live.

6.5.4 It is felt that a dedicated campaign over a year and a half leading up to the launch of the CAZ C+ and then continuing when the scheme goes live can achieve a result of this magnitude. This is also of the order of magnitude of effect that is felt to be achievable by JAQU.

7. WORTLEY ROAD HGV BAN – BREAKING POINT SENSITIVITY

- **Purpose:** To establish two points on a line and undertake linear interpolation to see what proportion of HGV's needs to be removed from Wortley Rd to achieve compliance by mid-2021.
- **Methodology:** Exactly the same as the Preferred Option but with the HGV ban on Wortley Road removed (*Note – undertaken on version of Preferred Option without through trip fleet effects – therefore the results here exclude the (fairly negligible) reductions on Rotherham links created by the 50% Through Trip Fleet Effects assumption*
- **Results:** HGV ban is required to achieve compliance in mid-2021 but only 10% are required to obey the ban (based on standard modelling).

7.1 Introduction

7.1.1 The Preferred Option includes an HGV ban on Wortley Road, but for this breaking point test that ban has been removed, in order to see the impact on mid-2021 compliance in the Rotherham area.

NB The HGV ban on this road in in the transport model is only applied in the uphill (North-West) direction in the Preferred Option.

7.2 Purpose of Test

7.2.1 The purpose of this test has several purposes is to establish if removing the HGV ban results in Wortley Road becoming non-compliant and if it does what the breaking point between no ban and full ban would be.

7.3 Detailed Methodology

7.3.1 A new version of the Preferred Option networks (with no Through Trip Fleet Effects) was created in SATURN without any HGV ban on Wortley Road. The assignment process was carried out as normal and the predicted traffic flows passed through ENEVAL with no fleet change from the Preferred Option, to estimate the link-based NO_X emissions.

7.3.2 The resulting NO_X emissions were then input to an Emissions Database within the AIRVIRO model, to predict the 2021 annual average NO_2 concentrations close to Wortley Road.

7.4 Air Quality Modelling Results

7.4.1 Results expressed as concentrations of NO2 are presented in the figure below for the new 2021 Baseline, 2021 Final Preferred Option and a scenario without the HGV ban.

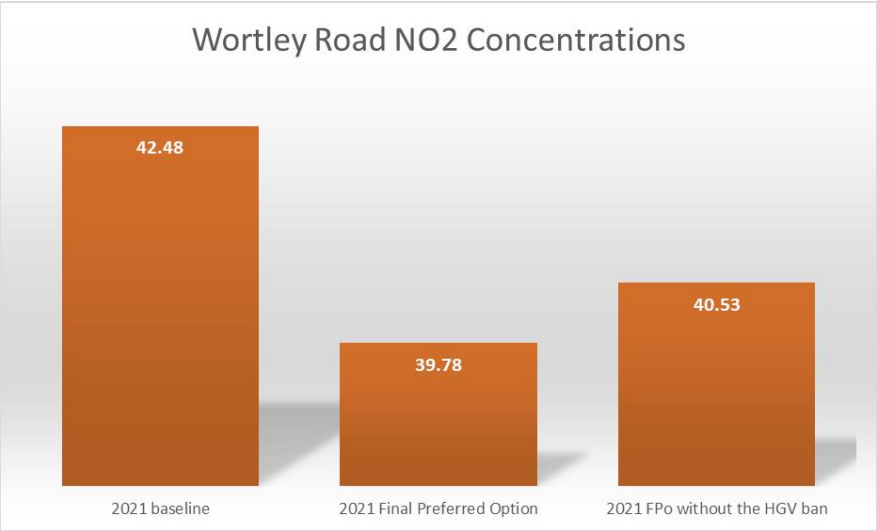

Figure 6 – NO2 Concentrations on Wortley Road

7.4.2 This shows that without the ban Wortley Road becomes just non-compliant. The breaking point for the number of HGV's required to observe the ban is **less than 10%**. However we believe this represents an underestimate of the scale of the problem as the modelling up to this point has not included any representation of the gradient on this route which is particularly steep. This means in both the Baseline and without HGV ban scenarios we are probably underestimating the size of the emissions. Given the recent release of the new Emissions Factor Toolkit (EFTv9) which includes functionality to assist with this we will try to include consideration of gradient at FBC stage.

7.4.3 We also know that in the base year calibration at this site there is around a 1.5% difference between the observed and modelled HGV flow percentages. This is within tolerable limits for model calibration but because of the specific characteristics of this route we may want to improve upon the assumptions on this route for FBC.

7.4.4 It should be noted that this gradient effect will not impact on the Preferred Option as the ban is in the uphill direction and any gradient effects will therefore not effect compliance.

7.5 Conclusions

7.5.1 The HGV ban is definitely required in order to achieve compliance on Wortley Road by mid-2021 but the modelling suggests that if **only 10% of HGV obey the ban** that would be good enough. However, we believe the model to be underestimating the size of the problem due on this route due to the issues described above and in reality, we would expect a greater proportion would need to obey the ban.

8. RAWMARSH HILL – BREAKING POINT SENSITIVITY TESTS

- **Purpose:** To establish two points on a line and undertake linear interpolation to see what proportion of Buses need to be rerouted from Rawmarsh Hill to achieve compliance by mid-2021.
- **Methodology:** Exactly the same as the Preferred Option but with all buses on Rawmarsh Hill rerouted (*Note – undertaken on version of Preferred Option without through trip fleet effects – therefore the results here exclude the (negligible) reductions on Rotherham links created by the 50% Through Trip Fleet Effects assumption*
- **Results:** At least 33% of buses need to be rerouted from Rawmarsh Hill to achieve compliance by mid-2021. It is likely to be more than this once gradient based effects (not currently included in the modelling) are taken into consideration.

8.1 Introduction

8.1.1 The Preferred Option includes the rerouting of 50% of buses which travel along Rawmarsh Hill onto the parallel Barbers Avenue route, but for this breaking point test all the buses have been rerouted, in order to establish a breaking point on mid-2021 compliance in the Rotherham area.

NB The services have been split 50/50 in the Preferred Option between Rawmarsh Hill and the alternative route. No detailed thought has been given at this point as to exactly which services that would be.

8.2 Purpose of Test

8.2.1 The purposes of the test was to establish that the bus rerouting strategy was required to achieve compliance on Rawmarsh Hill in mid-2021 and what the breaking point proposition of buses requiring rerouting would be.

8.3 Detailed Methodology

8.3.1 A new version of the Preferred Option networks (with no Through Trip Fleet Effects) was created in SATURN with all buses rerouted from Rawmarsh Hill onto Barbers Avenue. The assignment process was carried out as normal and the predicted traffic flows passed through ENEVAL with no fleet change from the Preferred Option, to estimate the link-based NO_X emissions.

8.3.2 The resulting NO_X emissions were then input to an Emissions Database within the AIRVIRO model, to predict the 2021 annual average NO_2 concentrations close to the relevant receptor points on Rawmarsh Hill.

8.3.3 It should also be noted that both the Preferred Options and this sensitivity test contain the bus upgrades (to Euro 5 retrofit or Euro 6) across the entire Rotherham fleet.

8.4 Air Quality Modelling Results

8.4.1 Results expressed as concentrations of NO2 are presented in the figure below for the new 2021 Baseline, 2021 Final Preferred Option and a scenario with 100% bus rerouting.

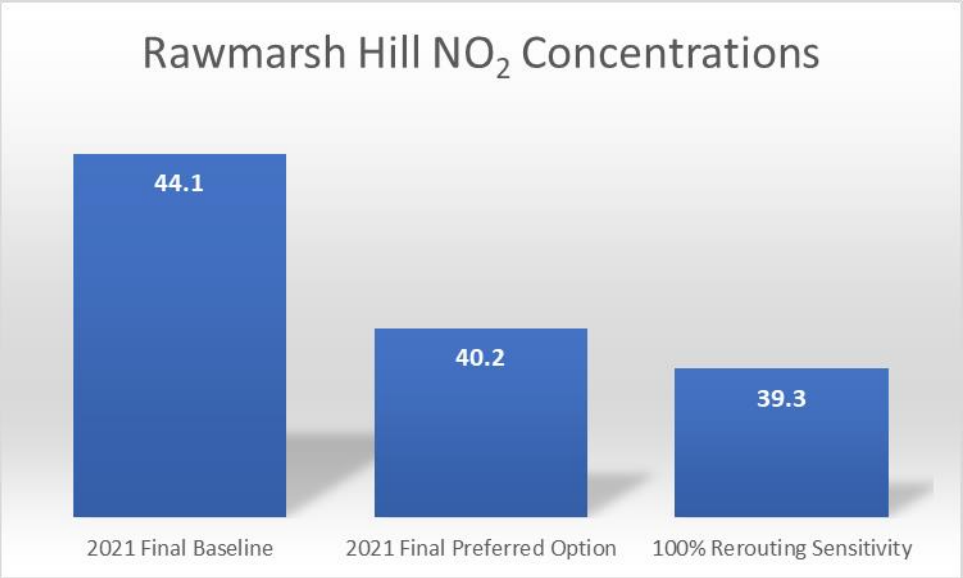

Figure 7 – NO2 Concentrations on Rawmarsh Hill

8.4.2 These tests allow us to build up a series of points between which linear interpolation can be undertaken to establish the minimum proportion of buses which need to be rerouted from Rawmarsh Hill to achieve compliance in mid-2021. The breaking point was found to be **33%**. However, similarly to Wortley Road, we believe this represents an underestimate of the scale of the problem as the modelling up to this point has not included any representation of the gradient on this route. This means in both the Baseline and the Preferred Option scenarios we are probably underestimating the size of the emissions. With the recent release of the new Emissions Factor Toolkit (EFTv9) which includes functionality to assess gradient effects, we will try to include consideration of gradient at FBC stage.

8.4.3 It is also the case that as buses are removed from Worley Road there is some re-filling of the capacity on that route by cars. This represents approx. 0.5 cars per bus removed, which slightly dampens the impact of the bus rerouting but does not remove the need for this element of the scheme.

8.5 Conclusions

8.5.1 The bus rerouting on Rawmarsh Hill is required in order to achieve compliance in that location by mid-2021 (ie the shortest possible time). This sensitivity test has demonstrated that **33%** of the buses using that route are required to reroute in order to achieve this.

8.5.2 However, as discussed in the previous section this is expected to be an underestimate as the model currently takes no account of the gradient on these links or out-of-service buses operating to Rawmarsh bus depot. Because of this and to achieve a level of 'slack' between compliance and non-compliance the **50%** rerouting included in the Preferred Option is expected to be required.

9. CONCLUSIONS

9.1 Introductions

9.1.1 In summary, the main thing to note is that the revised assessment of the Preferred Option with improved detail remains compliant everywhere, but with reduced slack between the worst performing locations and the compliant threshold.

9.1.2 The Sensitivity Tests have established breaking points for several of the features of the Preferred Option, these are summarised in the next section below.

9.2 Summary Results

Table 9 – Outcome of tests undertaken

No	Test	Results
New Baseline		
1	New Baseline	**Improved position compared to previous (OBC) Baseline** due to improved fleet expectations by 2021.
New Preferred Option		
2	New Preferred Option	Area-wide **compliance by mid-2021 still achieved**, but revised and more conservative representation of the changes to the local car fleet and the inclusion of the central Through Trip Fleet Effects assumption has eliminated most of the 'slack' in the Preferred Option, particularly at a small number of locations on the Sheffield Inner Ring Road. **This is the shortest possible time.**
Sensitivity Tests – Through Trips		
3	All possible through trips experience fleet effects	If up to **87% of HGV / LGV of the Baseline through trips** experience fleet effects similar to those which start or end in the CAZ area, then the scheme remains compliant beyond mid-2021. This is due to the additional goods vehicle traffic using this key through route. However as the modelling suggests that around **50%** of Baseline through trips will simply reroute to avoid the proposed charge it means the scheme remains compliant Even **assuming all possible through trips (ie 100%) experience the CAZ related fleet effects, the timescales for compliance would only be extended temporarily and not beyond the timescale required for the implementation of a CAZ D**.
Sensitivity Tests – Taxis		
4	Only 50% of Taxi Upgrades contained in the Preferred Option Occur.	There is a breaking point which suggests **97% of Preferred Option Taxi Upgrades** (90% of black cab fleet and 95% of PHV fleet) are required to achieve area-wide compliance by mid-2021. Reducing the upgrade to 50% of the Preferred Option level would mean that compliance would be achieved later in 2021, but still quicker than a CAZ D could be implemented. Due to the current age profile of the current taxi fleet (Private Hire and Hackney) 60% will need to change their vehicle by CAZ C+ scheme opening

		as they become beyond the age at which they can be licensed. Changes to licencing in Sheffield and Rotherham are proposed post FBC approval and in conjunction with incentive schemes. This alone is forecast to achieve compliance at the majority of locations but will require the financial assistance described in the CAF funding ask.
Sensitivity Tests – Hearts and Minds		
5	Preferred Option with no Hearts and Minds (Diesel) Effect	**All the Hearts and Minds impact on the car fleet are required to achieve area-wide compliance by mid-2021.** The unrealistic scenario of removing all the Hearts and Minds response would result in an extended compliance timescale beyond the possible introduction of a CAZ D. A Hearts and Minds impact of 2% would or above result in compliance in advance of the CAZ D timescales. **The shortest possible time is therefore still represented arising from the benefits of a Hearts and Minds switch from diesel car.**
Sensitivity Tests – Rotherham Breaking Point Tests (without through trips)		
6	Preferred Option but with no HGV ban on Wortley Road	The HGV ban is required to achieve compliance but only required around **10% to observe the ban** to achieve compliance based on the results from the transport model and the AIRVIRO outputs. However, we anticipate this being an **underestimate** of the amount of HGV's needed to observe the ban due to the lack of representation of gradient on this particular route. We will look to improve the modelling here as part of the FBC process.
7	Preferred Option but with 100% of Rawmarsh Hill buses diverted to Barbers Avenue rather than 50% in order to establish breaking point	Based on the results from the transport model and the AIRVIRO, approx. **33% of buses need to be rerouted** in order to achieve compliance on Rawmarsh Hill by 2021. However, we anticipate this being an **underestimate** of the amount that that need to reroute as this route also has gradient effects which will be explored further at FBC stage.

APPENDIX A – CHANGES TO THE DIESEL CAR FLEET

OBC Supplementary Technical Note – Predicting the %Diesel in the Sheffield Private Car Fleet in Future Years

Introduction

This note describes the analysis which supports our prediction of the drop in the proportion of diesel cars (excluding taxis and private hire vehicles) in Central Sheffield traffic between now and 2021, relative to a forecast based on the assumptions used in the current version of the Emissions Factors Toolkit (EFT).

This is important when considering NO_X emissions and NO_2 air concentrations, as a typical diesel car emits significantly more of these types of emissions into the atmosphere than a similarly-aged petrol or ultra-low emission vehicle (ULEV). Based on an average 2018 UK (non-London) fleet an average diesel car will emit nearly 8 times as much NO_X as a petrol car, when driving in typical urban conditions. Therefore, any reduction to the proportion of diesel in the car fleet will deliver a corresponding reduction in the NO_X emissions, without requiring any other change to the age profile of the car fleet. This note focuses on the Sheffield Central area, which contains the locations which our air quality modelling suggests will be most-challenging to achieve compliance with the 40 $\mu g/m^3$ limit value. However, many of the fleet profile changes described in this note will also apply to routes across the Rotherham and Sheffield area, including the currently-non-compliant A630 Parkway route.

The analysis will show that, under a set of conservative Do Nothing assumptions, the proportion of diesel in Sheffield's car traffic will fall from its current value (around 51%) to around 43% by 2021, representing a **16%** drop in the proportion of diesel cars in this central Sheffield traffic.

We then describe a set of Do Something Behavioural Change measures and assumptions which we believe will deliver a further **4%** reduction in this %diesel, to around 41% of central Sheffield car traffic in 2021.

Fleet Profile of the Private Cars Observed in Central Sheffield Traffic in 2017

The analysis starts from the profile of car traffic (excluding vehicles registered as Private Hire Vehicles[4]) observed at two clusters of ANPR cameras close to Sheffield City centre during 2017 – Clusters HS2 & HS4 shown in the map below. It should be noted that the ANPR data used in our appraisal is for the full calendar year and therefore provides a very robust understanding of the fleets across Sheffield and Rotherham.

It is worth noting that the ANPR data represents a full 12 months of traffic information, this helps us build up a high level of confidence in the traffic data, in particularly fleet split information that it is used to obtain in Sheffield.

We focus on this central Sheffield private car traffic, because it is the change in this fleet over time which will generate the corresponding change in NOX emissions at the various air quality hot-spots within the central Sheffield area.

[4] The required improvement to the PHV fleet will be affected by the introduction of the proposed CAZ and the associated incentive schemes and so needs to be treated separately from 'ordinary' cars

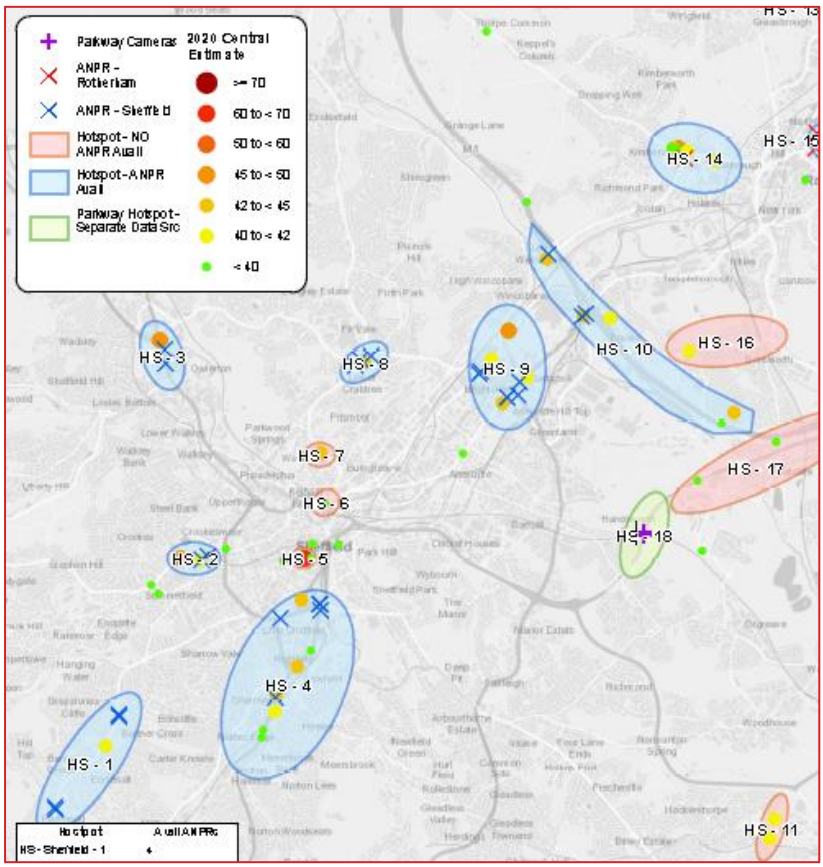

Figure 8 - Map Showing the Location of the ANPR Camera Clusters HS2 and HS4

The profile of the total set of private cars observed at these two locations by fuel type and EURO class is summarised in the table below.

Table 10 The fuel and emissions profile of private cars observed in central Sheffield in 2017

	Pre-EURO	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	EURO 6	TOTAL
Petrol	0.5%	0.2%	0.8%	9.3%	15.6%	14.1%	9.8%	50.2%
Diesel	0.0%	0.1%	0.2%	4.6%	11.3%	19.0%	12.9%	48.0%
Other	0.0%	0.0%	0.0%	0.0%	0.2%	0.6%	0.9%	1.8%
Total	0.5%	0.3%	1.0%	13.9%	27.1%	33.7%	23.5%	100.0%

The values suggest that the majority of cars are EURO 4 or above, with EURO 5 vehicles representing over 1/3 of the total car traffic. Around 48% of the total set of cars observed in 2017 were diesel, with most of these EURO 3 or above.

The table below shows the %diesel in each of the 7 EURO Classes

Table 11 %Diesel in each EURO Class Observed in Central Sheffield Car Traffic

	Pre-EURO 1	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	EURO 6	TOTAL
Petrol	93.1%	80.0%	80.2%	66.5%	57.5%	41.8%	41.7%	50.2%
Diesel	6.8%	19.1%	18.7%	33.2%	41.8%	56.3%	54.6%	48.0%
Other	0.2%	0.9%	1.0%	0.3%	0.7%	1.9%	3.7%	1.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

These figures show that less than 20% of the oldest (pre-EURO 3) fleet were diesel, rising to 56.3% of the EURO 5 and falling slightly to 54.6% of EURO 6. This pattern means that, **should** new car sales

continue to match this EURO 6 petrol/diesel/other pattern in 2018 and beyond, then the overall %diesel in the car fleet will rise over time, as the older predominantly-petrol EURO 0-4's get replaced with new vehicles with a -higher proportion of diesel. However, we will show later in this note that this expected rise in %diesel over time will be more than offset by the cumulative effects of the recent significant change in the pattern of new car sales.

The corresponding age profile of the private car traffic (excluding PHVs) observed at the two central camera clusters is compared with the age profile of the total car fleet (including PHVs), derived using data provided by the DfT (date of first registration for vehicles whose registered keepers live in Sheffield). The results are illustrated in the figure below.

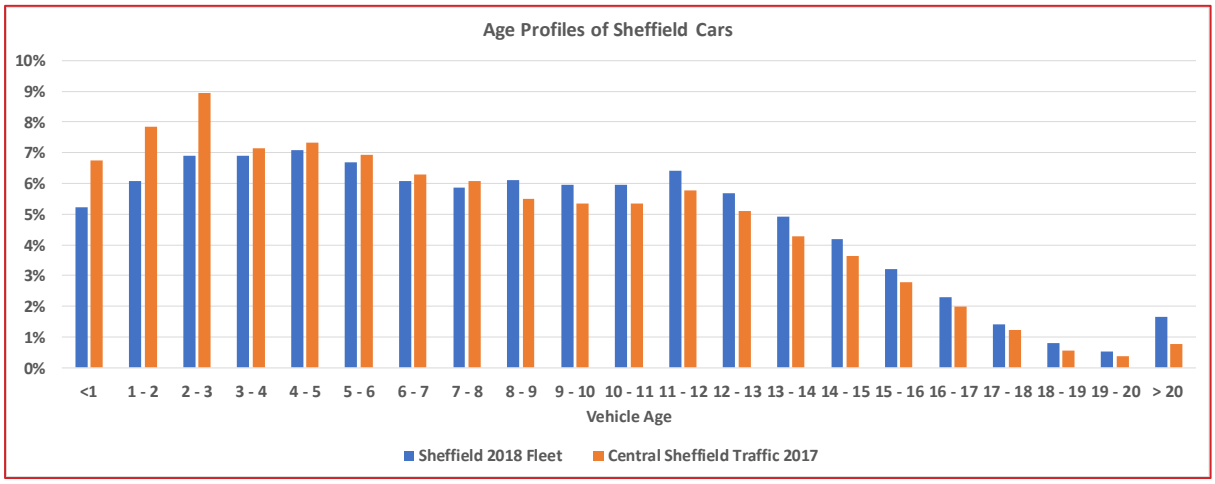

Figure 9 Age Profiles of Central Sheffield Traffic and the Sheffield-wide Car Fleet

The data suggests that central Sheffield private car traffic contains significantly more young (<3-year old) vehicles than the Sheffield-wide fleet, but is otherwise similar in profile to the set of cars registered to Sheffield owners. As a result, the overall average age of the central Sheffield private car traffic is ≈0.8 years lower than that total Sheffield car fleet.

This suggests that the central Sheffield car traffic will be slightly-more influenced by changes in new car sales than the Sheffield-wide fleet.

The EFT-based Forecast

The EFT does not include its own fleet model. Instead, it uses the vehicle fleet composition projections of the %diesel of car kms in England (excluding London) from the National Atmospheric Emissions Inventory[5].

To allow us to model the impact of changes in new car sales, changes in scrappage rates etc., we have therefore calibrated a version of our Sheffield car traffic fleet model to reproduce the %diesel projections used in the EFT.

The figure below compares the resulting change over time profile of the %diesel in Sheffield centre car traffic (calculated using our fleet model) and the vehicle fleet composition projections of the %diesel of car kms in England (excluding London) from the National Atmospheric Emissions Inventory[6], which is the default fleet composition data incorporated in the current version of the Emission Factor Toolkit, EFT v8.0 (2017).

[5] http://naei.beis.gov.uk/data/ef-transport
[6] http://naei.beis.gov.uk/data/ef-transport

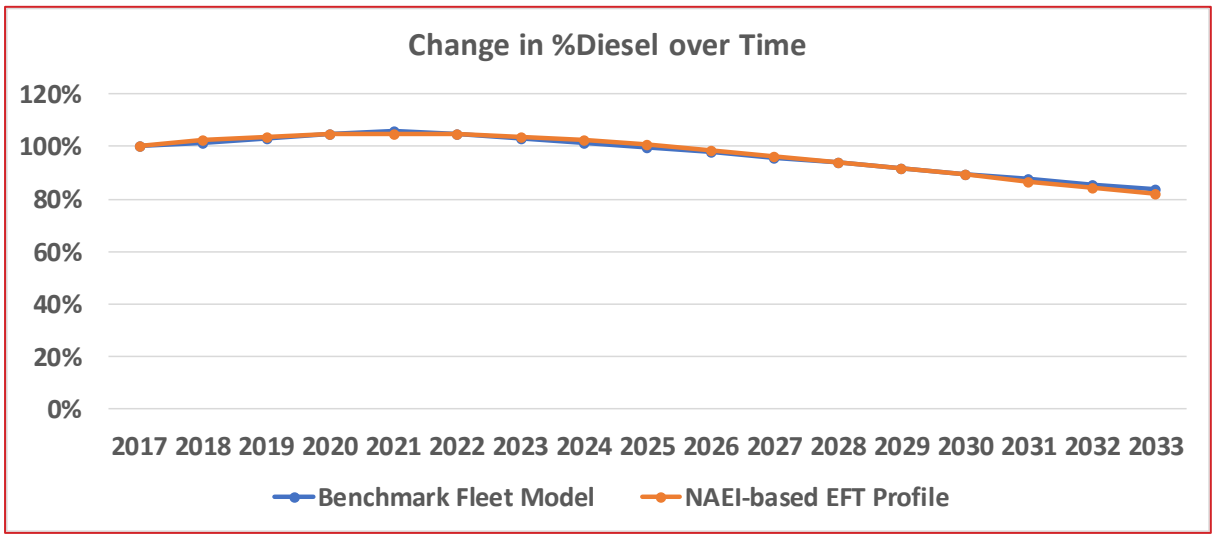

Figure 10 Comparison of Our Calibrated Benchmark with the EFT's Profile of %Diesel Over Time

The calibrated bench-mark fleet model clearly closely reproduces the diesel profile assumptions used in the current version of the EFT.

This means that this benchmark fleet model can be used to represent the **EFT-based projections** of how the %diesel in Sheffield will change over time and can therefore be used as the starting point for testing the impacts of changes in new car sales, local scrappage rates etc.

Do Nothing Scenario

New car sales

We have used DfT Vehicle Licensing Statistics – Table VEH0253 (Cars registered for the first time by propulsion / fuel type, Great Britain)[7] (2013 to 2017) and a recent report by the SMMT (2017-.2018) [8] to analyse the recent changes in the profile of new car sales in Great Britain/UK respectively.

These data, illustrated in the chart below shows that there has been a significant **35%** decline in the %diesel in new vehicle sales in the UK, dropping from around 50% in 2015 (the values used in the last update of the EFT) to less than 1/3 of new vehicle registrations in 2018, representing around a **12%** per annum reduction in the %diesel, with a **25%** drop (from 42.0% to 31.7%) in the past year alone.

[7] https://www.gov.uk/government/collections/vehicles-statistics
[8] https://www.smmt.co.uk/wp-content/uploads/sites/2/December-2018-and-YTD-cars.png

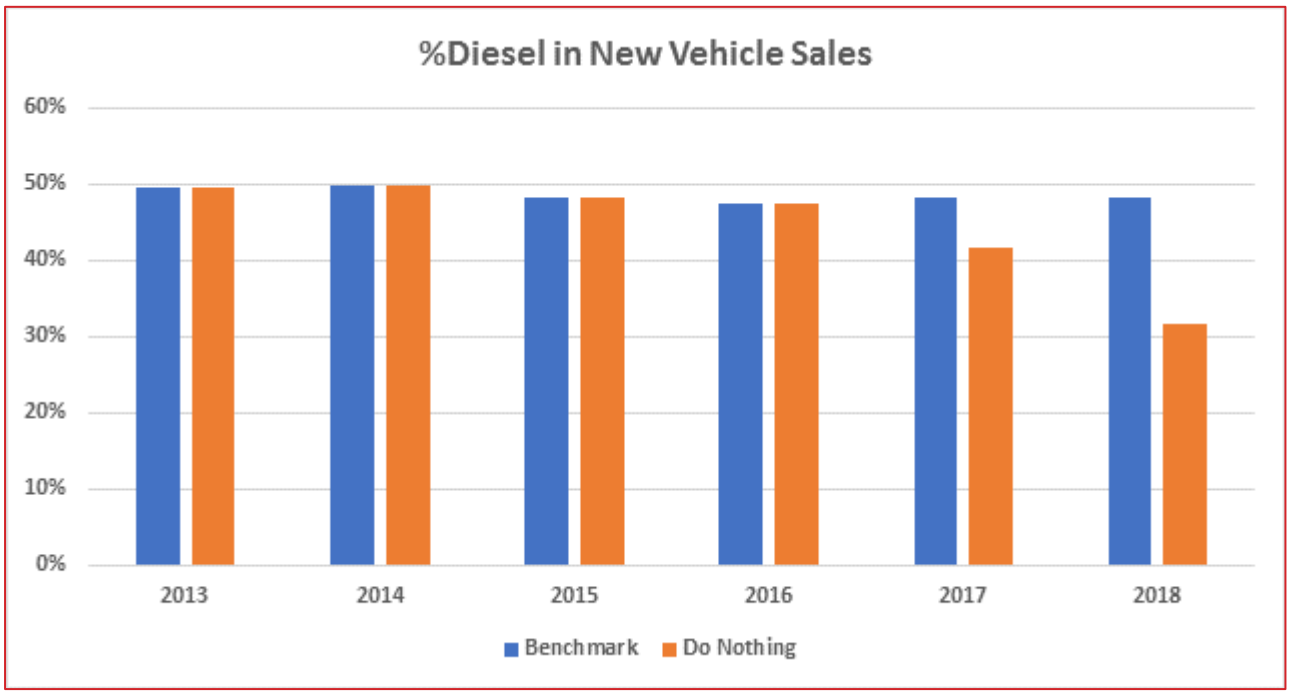

Figure 11 Recent decline in the sale of new diesel cars in the UK

Note that this drop has occurred even though these 'unpurchased' diesel vehicles would not be affected by any of the proposed CAZ or ULEZ schemes, which all treat EURO 6 diesel vehicles as compliant (and therefore not subject to any CAZ charges).

Likely Increase in %ULEVs over time – UK Government's 'Road to Zero' Policy

The Government's Road to Zero Industrial Strategy9 includes the following long-term ambition:

We want to see at least 50%, and as many as 70%, of new car sales and up to 40% of new van sales being ultra-low emission by 2030.

As the current version of the EFT pre-dates this policy, the EFT-based benchmark does not include any significant increase in the proportion of ULEVs in new vehicle sales between now and 2021.
The figure below shows two different profiles between the current level of ULEVs and the (conservative) 50% value by 2030.

9 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739460/road-to-zero.pdf

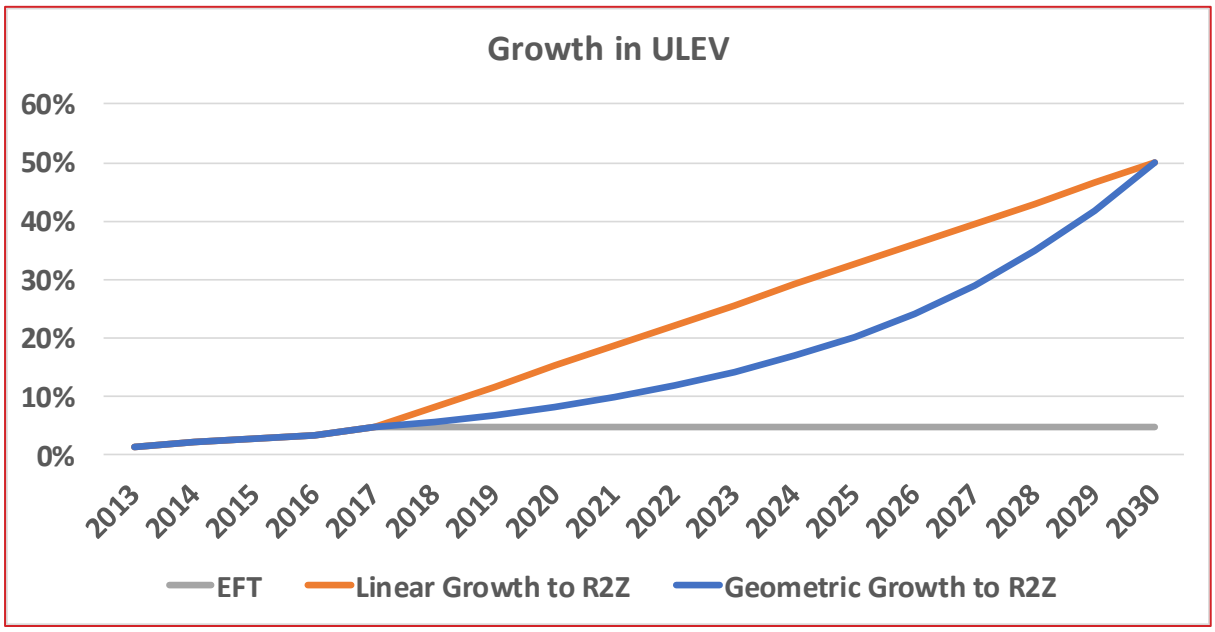

Figure 12 Different Profiles for Achieving the UK Government's 'Road to Zero' Levels of ULEV in New Car Sales by 2030

If we conservatively assume that the UK Government's lowest target value (50%) is achieved by geometric growth[10] from the 4.8% achieved in 2017, then this suggests that a 20% year-on-year growth in the market share of ULEVs in new vehicle sales will be required between now and 2030. This ULEV growth profile is shown as the blue 'Geometric' profile in the figure above.

This profile would suggest that the proportion of ULEV's will reach around 10% of new car sales by 2021. Our Do Nothing and Do Something fleet model assumes that these additional ULEVs will produce a corresponding reduction in the number of petrol and diesel new car sales in the relevant year, with this reduction applied pro rata to the petrol/diesel mix of new car sales in the relevant future year.

Our Do Nothing scenario assumes:

- the 'Road to Zero' increase in the % of ULEVs among new car sales (giving 10% ULEVs by 2021);
- no further drop in the %diesel of new car sales beyond 2018

The resulting Do Nothing profile of the %diesel among new car sales is illustrated in the chart below.

[10] Linear growth would require the %ULEV to increase faster in the early years than this geometric growth assumption

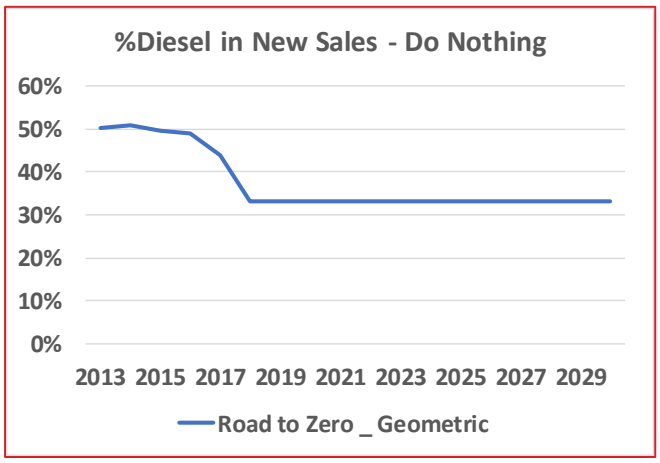

Figure 13 New Car Sales Do-Nothing

This Do Nothing profile clearly represents a **very conservative** forecast of the %diesel in new cars sales over the next few years.

2nd-hand Car Sales

A recent survey of 10 Rotherham car dealerships (see **Appendix B** for details) suggested that, on average, **41%** of new and 2nd-hand cars currently being purchased in the Rotherham area are diesel vehicles. This represents a **10%** anti-diesel bias, relative to the **46%** of diesel in the current fleet of these older (> 3-year old) cars.

The local switch away from 2nd-hand diesel is likely to be even stronger among drivers who regularly drive into central Sheffield and who will become increasingly aware of the risk that these older vehicles might be subject to CAZ-related restrictions, if Sheffield need to introduce a CAZ D at some point in the future. This fear of future CAZ schemes will obviously add to the factors influencing the sale of diesel vehicles discussed in the previous section.

This local switch away from 2nd-hand diesel among those who regularly drive into central Sheffield is assumed to apply when these owners decide to upgrade their existing diesel vehicle (assumed to be once every 5 years, on average). We have therefore **not** assumed any change to the timing of the underlying decision to replace these vehicles – ie this is not a diesel scrappage scheme, merely a reflection of the observed move away from diesel in Business as Usual car-buying behaviour.

The Do Nothing fleet model therefore applies a 10% switch to 1 in 5 of the >3-year old diesel fleet each year, resulting in a **2%** per annum switch from diesel to non-diesel within this older (>3-year old) car fleet in the Rotherham and Sheffield area.

The unsold 2nd-hand diesels are assumed to leave the pool of cars driving regularly into central Sheffield, either by being bought by owners who are less-affected by the threat of local CAZ schemes (i.e. who do not regularly drive into any potential CAZ D cities) or as a result of an increased scrappage rate at the older end of the range. At present, even with the prospect of CAZ schemes in several major cities there is no evidence that the cost of 2nd-hand diesel cars is reducing although that may change over the next few years.

In summary, our Do Nothing scenario assumes:

- the 'Road to Zero' increase in the % of ULEVs among new car sales (giving 10% ULEVs by 2021);

- no further drop in the %diesel of new car sales beyond 2018; and
- the local switch away from 2nd-hand diesel vehicles among those who regularly drive into Sheffield remains at what the local evidence suggests is its current value (i.e. a 10% anti-diesel switch being applied to 1 in 5 of the older diesel fleet each year, resulting in a **2%** per annum switch away from older diesel in the central Sheffield traffic between 2017 and 2021.

The resulting prediction of the Do Nothing profile of %diesel in central Sheffield car traffic is illustrated in the Figure below.

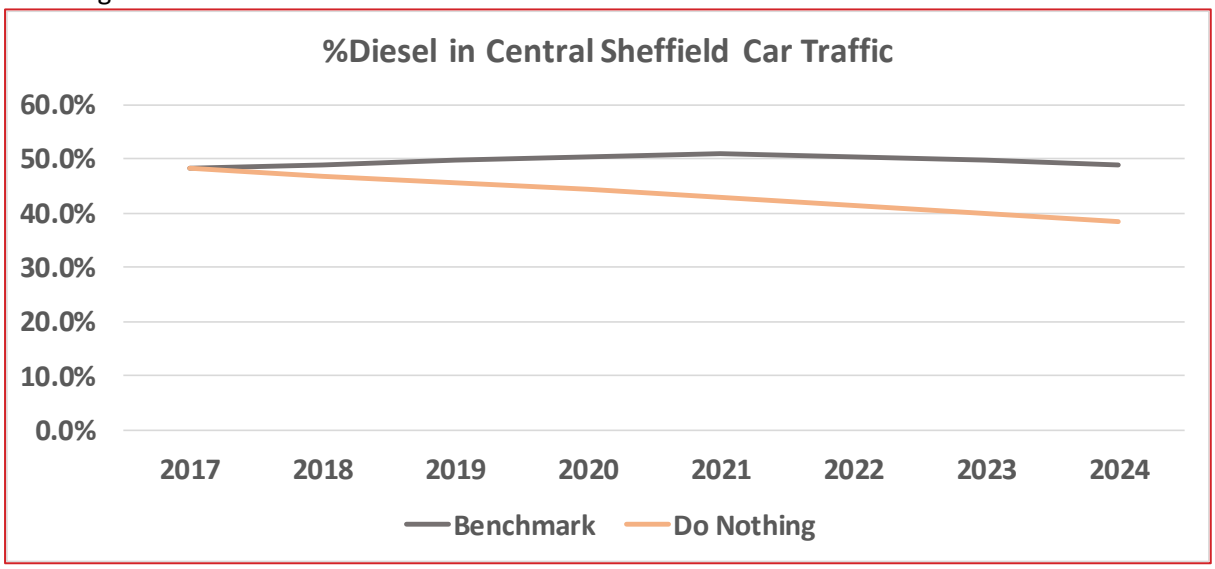

Figure 14 Predicted Do Nothing Profile of %Diesel in Central Sheffield Car Traffic

This profile suggests a **4%** drop in central Sheffield traffic diesel in Sheffield fleet in **2018** and a **16%** drop in diesel car traffic in central Sheffield by 2021.

The 2018 prediction will be checked using local ANPR data prior to the submission of the Full Business Case.

As noted earlier, this is likely to represent a conservative forecast of the reduction in %diesel over time.

Preferred Option Scenario

In our Preferred Option, we have assumed that Sheffield and Rotherham will deliver a 'Hearts and Minds' campaign designed to further discourage the purchase and use of diesel cars by those who regularly drive in areas of poor air quality.

The Do Something scenario set out below sets out our assumptions on how a Hearts and Minds campaign can deliver a further 4% shift away from Diesel cars, which along with the 16% shift away from Diesel, therefore delivers a total 20% shift away from Diesel by 2021. We believe that a further 4% shift from Diesel through a local Hearts and Minds Campaign is a change that is both deliverable and realistic.

We have assumed that, as a result of this local (and any corresponding national) campaigns, the downward trend in the %diesel of new car sales (in Sheffield) will continue at a rate similar to the

average rate of decline observed over the past three years (=12% per annum[11]), and the out-migration rate of 2nd-hand diesel will increase by around 2% per annum from 2019 onwards.

The figure below compares the EFT/Benchmark (no change to the 2015 pattern), Do Nothing and Do Something projections of the %diesel in new car sales.

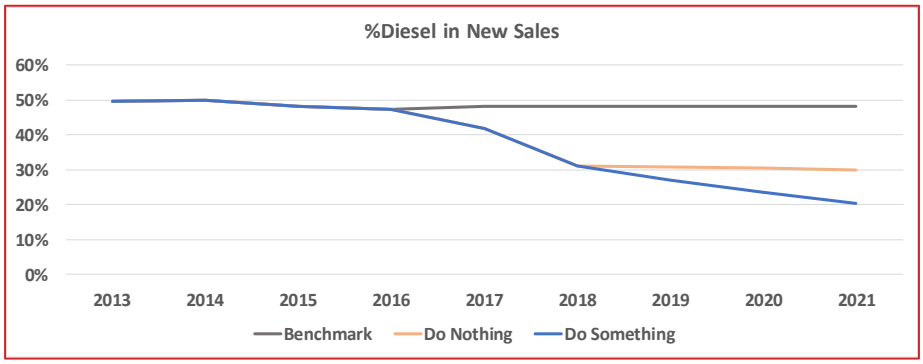

Figure 15 Comparison of Different Profiles of the Change in %Diesel in New Car Sales

Results

The table and figure below compares the impact of the Do Nothing and Do Something fleet scenarios with the EFT-based benchmark scenario described previously.

Table 12 Impacts of Do Nothing and Do Something Fleet Scenarios on the %Diesel in the Central Sheffield Car Fleet

Year	2017	2018	2019	2020	2021	2022	2023	2024
Benchmark	48.1%	48.9%	49.6%	50.3%	50.9%	50.3%	49.7%	48.9%
Do Nothing	48.1%	46.9%	45.6%	44.3%	42.9%	41.4%	39.9%	38.3%
Do Something	48.1%	46.9%	45.3%	43.3%	40.9%	38.1%	35.0%	31.6%

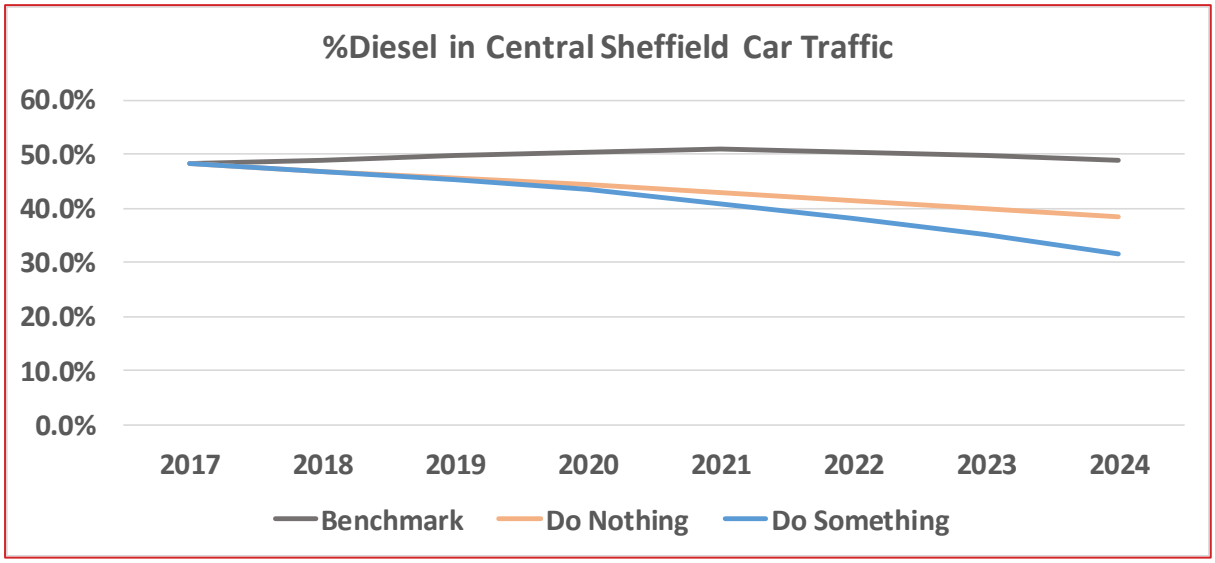

Figure 16 Impacts of Do Nothing and Do Something Fleet Scenarios

[11] Note that this is only half of the 25% per annum reduction observed in 2018

The results show that by 2021, the Do Nothing fleet scenario predicts that the %diesel in central Sheffield car traffic will be around 43%, representing a **16%**[12] drop in the number of diesel cars in the city centre traffic relative to the EFT-based benchmark forecast of 50.9%.

The table also shows that the Do Nothing is predicted to result in the %diesel dropping from 48.1% to 46.9% by 2018. Analysis of ANPR data for November 2017 and November 2018 at some or all of the ANPR camera sites used to inform this analysis could be used to check/confirm that this level of switch has, indeed, taken place. This validating analysis will be carried out prior to the submission of the Full Business Case.

The table and chart also shows that the Do Something fleet scenario is predicted to reduce the %diesel in the 2021 central Sheffield car traffic from around 43% to around 41% by 2021, representing a further **4%** drop relative to the 50.9% benchmark model prediction for 2021. The combined effect of the Do Nothing and Do Something fleet changes is a ≈**20%**[13] reduction in the number of diesel private cars on central Sheffield roads relative to the EFT-based benchmark in 2021, with these vehicles being replaced by a corresponding number of non-diesel vehicles.

Summary and Recommendations

This note clearly explains, using national and local evidence, how the latest trends in diesel car sales (new and second hand) are already influencing the fleets in Sheffield and Rotherham.

It explains the conservative estimates that we have used to show how these changes are forecast to affect the percentage of diesel cars in Sheffield and Rotherham and in particular the central Sheffield area that is subject to the greatest exceedances in NO_2. Together the change in the percentage of new and 2nd-hand diesel car markets is forecast to achieve a 16% shift away from diesel by 2021.
This is important, because the NO_X emissions from a typical diesel car are significantly higher than the NO_X emissions from a similarly-aged petrol or ULEV vehicle, so that any reduction in the percentage of diesel in the car fleet for Sheffield and Rotherham will lead to a corresponding reduction on the overall NO_X emissions.

A key component to achieve compliance by 2021 is to achieve a 20% switch from petrol to diesel by 2021. We believe that a further **4%** shift away from Diesel through a local 'Hearts and Minds' Campaign is a change that is both realistic and deliverable.

Overall, the combination of the underlying Do Nothing trend and our Preferred Option (Clean Air Zone 3C+) will deliver a total shift away from diesel cars of **20%** by mid-2021. Our emissions and air quality modelling suggests that this change in the composition of the local private car fleet will complement the various other more-significant upgrades to the other fleets (black cabs, car-based taxis, buses, LGVs and HGVs) to achieve compliance with the 40µg/m^3 limit of $N0_2$ by 2021 across the Sheffield and Rotherham

The Monitoring and Evaluation Plan outlined in our OBC includes a recommendation that ANPR data from Sheffield and Rotherham's existing network of ANPR cameras is analysed each quarter between now and the implementation of the CAZ in 2021, to ensure that the expected changes in all of the various fleets are being achieved.

This work also suggests that 'peak diesel' has already been passed and the diesel share of the car fleet is therefore now likely to be reducing across the UK. This pattern is not reflected in the current version of the EFT tool. We therefore recommended that JAQU consider updating the EFT fleet forecasts in

[12] (50.9-42.9)/50.9 ≈ 15.7%
[13] = 50.9-40.9)/50.9 ≈ 19.6%

light of the emerging evidence, since we suspect that all/many of the ongoing CAZ studies will be using the out-of-date EFT-based forecasts to predict their future-year NO_2 levels.

APPENDIX B – 2ND HAND CAR SALES SURVEY

Summary of DIVA Creative's Research into Local Car Sales in Rotherham

Care4Air
South Yorkshire Clean Air Campaign

Rotherham Car Dealership Survey

Introduction

Diva Creative conducted a survey across local car dealerships in Rotherham during December 2018. The survey was intended to collect feedback from car salespeople across numerous subjects such as buyer behaviour and marketing topics.

Survey Methodology

The surveys took place on a one-to-one basis and mainly collected qualitative information. Therefore, data collected does not represent actual sales figures, but was provided by the respondents as approximate figures as part of this survey. 9 of the dealers sold new and used cars, and one only sold used cars.

	% petrol sales	% diesel sales	% other
Dealer 1	70	30	0
Dealer 2	60	40	0
Dealer 3	50	50	0
Dealer 4	75	20	5
Dealer 5	50	50	0
Dealer 6	75	25	0
Dealer 7	30	70	0
Dealer 8	55	45	0
Dealer 9	60	35	5
Dealer 10	50	50	0
Average	57.5%	41.5%	1%

Conclusion

Whilst not representing actual quantitative sales figures, this research shows that there is a greater market for petrol cars than for diesel across the 10 dealers surveyed and for both new and second-hand vehicles. This trend was reported to have been on the rise, which fits well with recent data presented by the Society of Motor Manufacturers and Traders https://www.smmt.co.uk/vehicle-data/car-registrations/ which shows that 64.1% of new cars being purchased nationally (2019 to date) are petrol vehicles, and only are 29.1% diesel with 6.8% being alternatively fuelled.

APPENDIX C – THROUGH TRIPS METHODOLOGY

OBC Supplementary Technical Note – Modelling demand response to through trips

Introduction

Our local behavioural research (supplemented by JAQU Guidance) has provided estimates of the likelihood of fleet upgrades by those travelling to/from a proposed charging area, but not any/much evidence regarding the likely fleet upgrade responses of those making trips which pass through the charging area.

Non-compliant vehicles that travel through a proposed CAZ area in a Baseline scenario will be impacted by the introduction of the charging scheme within that CAZ area. The owners of these vehicles have four choices – reroute to avoid the charge, pay the charge and continue to drive through the CAZ, abandon the trip (or change its origin or destination) or upgrade the non-compliant vehicle to a compliant one. This is one more choice that is available to the owners of vehicles making trips which start &/or finish inside the CAZ, who do not have the option to simply reroute to avoid the charge.

In the previous (December 2018) version of our Preferred Option, we made what we-believed at the time to be a conservative 'worst case' assumption, namely that the fleet upgrade responses for non-compliant through trips could/should be ignored and that doing so would generally over-estimate future Do Something emissions, by ignoring these additional Do Something fleet improvements.

However, JAQU have asked us to revisit this assumption, to determine the potential benefits (and disbenefits) from assuming that some or all of the owners of the non-compliant through-trip vehicles might also consider upgrading their vehicles.

The methodology which SCC/RMBC/SYSTRA have discussed and agreed with JAQU for incorporating these additional fleet upgrade effects is described below.

Extraction of through trips

To extract the through trips, a list of links on sections that would be used by traffic inside the CAZ cordon was created.

The 2021 forecast year is created by interpolating between 2017 base year and a 2024 forecast year, thus for each of the 2017 and 2024 unsegmented assignments and the three time periods (morning peak hour, interpeak average hour, and evening peak hour), the routing and demand information was extracted from the model.

This data contains, for each user class, the demand from origin to destination and the exact routing information from origin to destination and all intermediate nodes in the future Baseline (ie prior to the introduction of the CAZ) model.

From this dataset, the routes that passes through any links inside the charging area was extracted for each affected user class. The portion of this demand whose origin and/or destination lies inside the proposed CAZ charging area was then removed, to leave an origin-destination matrix of 'through trips'.

Note that this through-trip matrix will only include the proportion of the original demand which chooses to travel through the proposed CAZ area in the future-year Baseline. For example, if an OD pair has two equally good routes, one through the proposed CAZ and the other around it, then we would expect the through trip matrix to only include around 50% of the original OD demand of non-compliant vehicles (ie just the subset which chooses to route through the CAZ-area in the Baseline traffic assignment).

Note also that we use the travel pattern before the introduction of the charge, not after, so that the matrix of through trips is the full set of those who would be affected by the introduction of the CAZ charging, not just those who opt to pay the charge to continue to drive through the CAZ area in the Do Something scenario.

Applying demand response to through trips

When creating the compliant/non-compliant segmented OD-matrix to highway input, it is initially done using the same methodology as without through trips, splitting the demand by its origin and destination. From the through trips OD-matrix, two matrices are created, one multiplied by absolute difference in compliance between trips to/from the CAZ cordon and other trips which is added to the compliant part of the highway matrix, and one multiplied by absolute difference in non-compliance between trips to/from the CAZ cordon and other trips which is removed from the non-compliant part of the highway matrix. For 50% through trips, the factors above are reduced by 50%. The new matrix is then assigned to the highway network.

APPENDIX D – SHEFFIELD AIR QUALITY TRENDS

The change in NO_2 emissions at the emissions hotspots, sites with a NO_2 concentration above 40µg/m^3, have been analysed. The hotspots are listed in Table 13 together with the NO_2 concentrations from 2013 to 2018. This list does not contain Arundel Gate and two M1 sites as they are not representative of the general Sheffield city centre traffic pattern. The average NO_2 concentration reduces over time as presented in Table 14 with an average reduction of 4.9% or 2.5 µg/m^3, which corresponds to a 0.6 µg/m^3 reduction per quarter.

Table 13 NO_2 Concentration at Emission Hotspots 2013 – 2018

	NO_2 (µg/m^3)					
Site	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
463 Queens Road	65	62	60	55	53	50
Brightside Lane (Jenkin Road)	67	64	65	57	50	49
Winster Road			57	55	52	47
Shoreham Street	58	53	55	52	48	46
London Road -Ponsfords	57	56	55	49	46	46
Queens Road - G Casino	53	52	49	45	43	45
Pond Street Interchange	63	59	60	49	49	45
Chesterfield Road - Meersbrook Park	63	56	54	50	48	45
London Road -Sark Road	56	54	54	50	44	45
Fitzalan Square	67	60	61	50	48	45
Brightside Lane (Forgemaster)	55	55	54	48	45	44
Western Bank/Clarkson Street	50	48	51	47	46	44
Shop Front Parkway R/A	43	39	41	37	39	43
Ecclesall Fisheries, 97 Ecclesall Rd South	61	57	53	51	44	43
Penistone Road	56	54	52	46	46	42
Barkers Pool Taxi Rank				47	42	42
Duke Street	53	47	52	47	45	42
Whitham Road/Crookes	54	56	58	47	46	42
Attercliffe Road (Bodmin Street)	64	63	53	50	44	42
Brightside Lane (Stevenson Road)	51	52	48	44	38	41
Attercliffe Road (Staniforth Road)	58	56	50	44	39	41
98 Bawtry Road	56	51	52	49	43	41
47 Bawtry Road	58	56	55	47	44	41
Attercliffe Common (Terry Street)	47	46	48	47	41	41
Chesterfield Road - Olivet Road	53	50	50	43	43	40
Wicker	45	45	43	43	46	40
Waingate	70	60	54	49	46	40
73 Burngreave Road	51	50	51	49	42	40
Queens Road - Asda	47	46	45	44	40	40
West Street/Leopold Street	48	47	47	41	42	40

Table 14 - Average NO2 Reduction at Monitored locations in Sheffield to 2018

Time	NO_2 ($\mu g/m^3$) Difference	NO_2 Percentage Difference
Last year	-1.7	-3.5%
Last 2 years	-2.4	-4.9%
Last 3 years	-3.2	-6.3%
Last 4 years	-2.6	-5.0%
Last 5 years	-2.6	-4.9%
Overall average per year	-2.5	-4.9%
Median	-2.6	-4.9%