Derby Air Quality Modelling Report (AQ3)

Report for Derby City Council

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Derby Roadside NO_2 Air Quality Feasibility Study

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1 Introduction and outline scope of modelling

Derby City Council (DCC) is one of the initial five cities that were required to carry out a Feasibility Study by the Government for non-compliance with the nitrogen dioxide (NO_2) limit values. This report sets out the Air Quality modelling results from the study.

1.1 Background

Derby, like many other urban areas in the UK, has some locations where NO_2 concentrations are in excess of national and European air quality standards. To date, DCC has declared two Air Quality Management Areas (AQMAs) as a result of exceedances of the UK NO_2 annual mean objective. A map showing the locations of each AQMA is presented in Figure 1. The associated Local Air Quality Management (LAQM) assessment work has concluded that these exceedances are mainly attributable to emissions from road traffic.

Derby City Council was identified in the 2015 National Air Quality Plan as one of five councils required to introduce a Clean Air Zone (CAZ) by the end of 2019. However, under a revision to the national plans released in May 2017, an NO_2 compliance plan is required, which may include a mandatory charging-based CAZ or a range of alternative measures able to deliver the same NO_2 reductions as a charging-based CAZ.

DCC is determining the nature and extent of available measures to address the roadside NO_2 issue. In doing so the council has assessed the feasibility and effectiveness of introducing a charging CAZ, in line with the government's requirements for a benchmark charging CAZ to be considered as one of the options. This has enabled careful consideration of the options to ascertain whether there are other measures, or packages of measures that are just as effective or more effective, at addressing the principle aim of the project, which is to achieve compliance with roadside NO_2 limits in the shortest possible time period. The assessment has been conducted in tandem with the preparation of a draft Low Emissions Strategy (LES) which has helped inform the range of alternative measures able to deliver the same, or more effective, reductions in NO_2 concentrations as a charging-based CAZ.

The key areas identified by the DEFRA plan that were modelled to exceed NO_2 limits in 2020 are at Eastgate and Holms Bridge as shown in Figure 2. DCC has noted in their annual LAQM report[1] that:

> *"The locations highlighted in the national plans as areas of potential exceedance are not areas which have been highlighted as areas of concern under the LAQM regime. The apparent disparity between the national and local results has arisen primarily because of marked differences between the assessment methodologies described under the EU Directive versus the LAQM regime."*
>
> *"The road links highlighted as exceedance points using DEFRA's national modelling results (namely Eastgate and Holms Bridge) are not within influencing distance of receptors considered relevant to the LAQM standards i.e. residential dwellings, schools or care/residential homes. The only public exposure at these locations are footpaths/cycleways, which DEFRA have deemed are relevant to the EU Directive's standards."*

Figure 1: Derby Air Quality Management Areas (AQMAs)

[1] 2016 Updating and Screening Assessment and Progress Report for Derby City Council

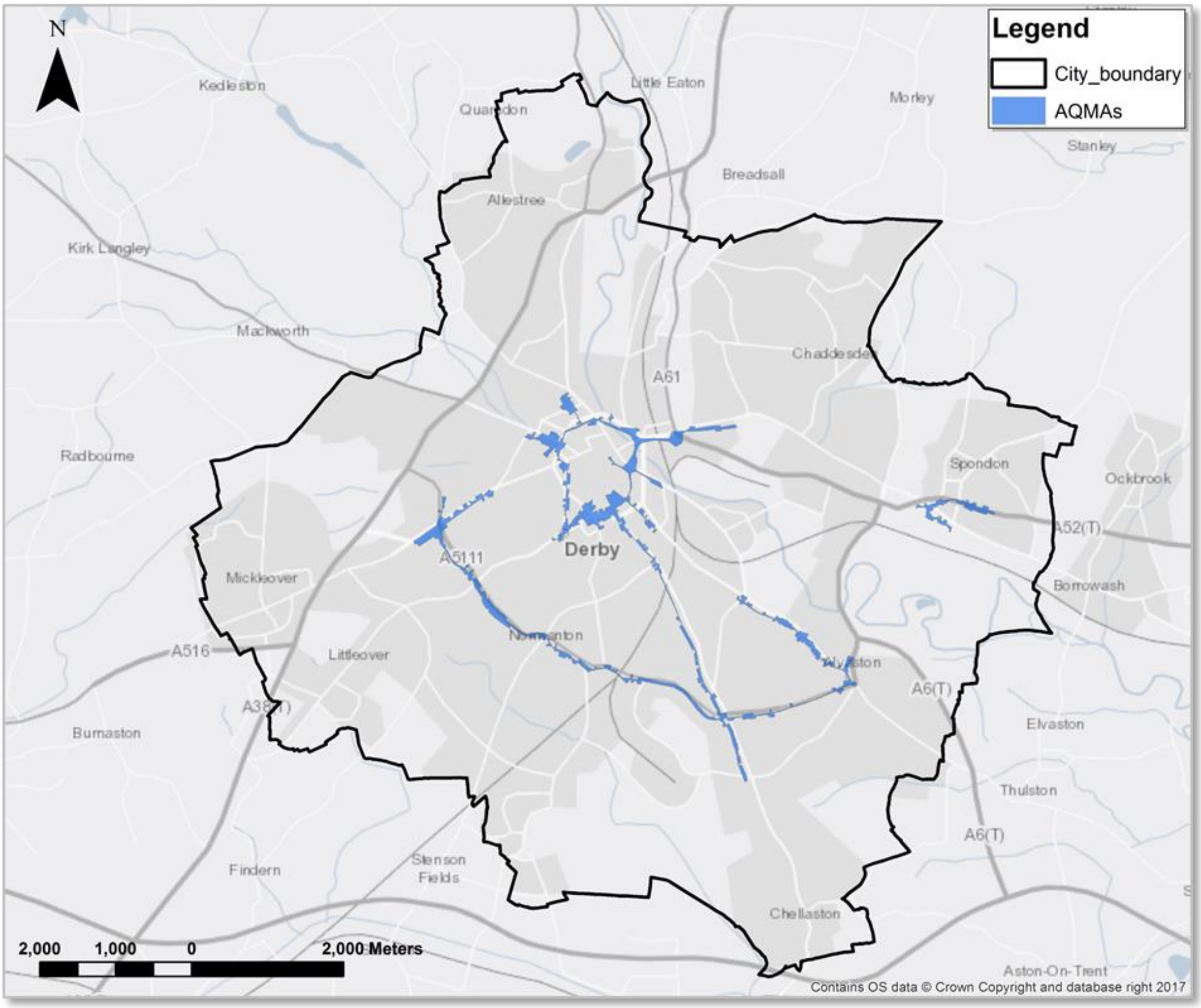
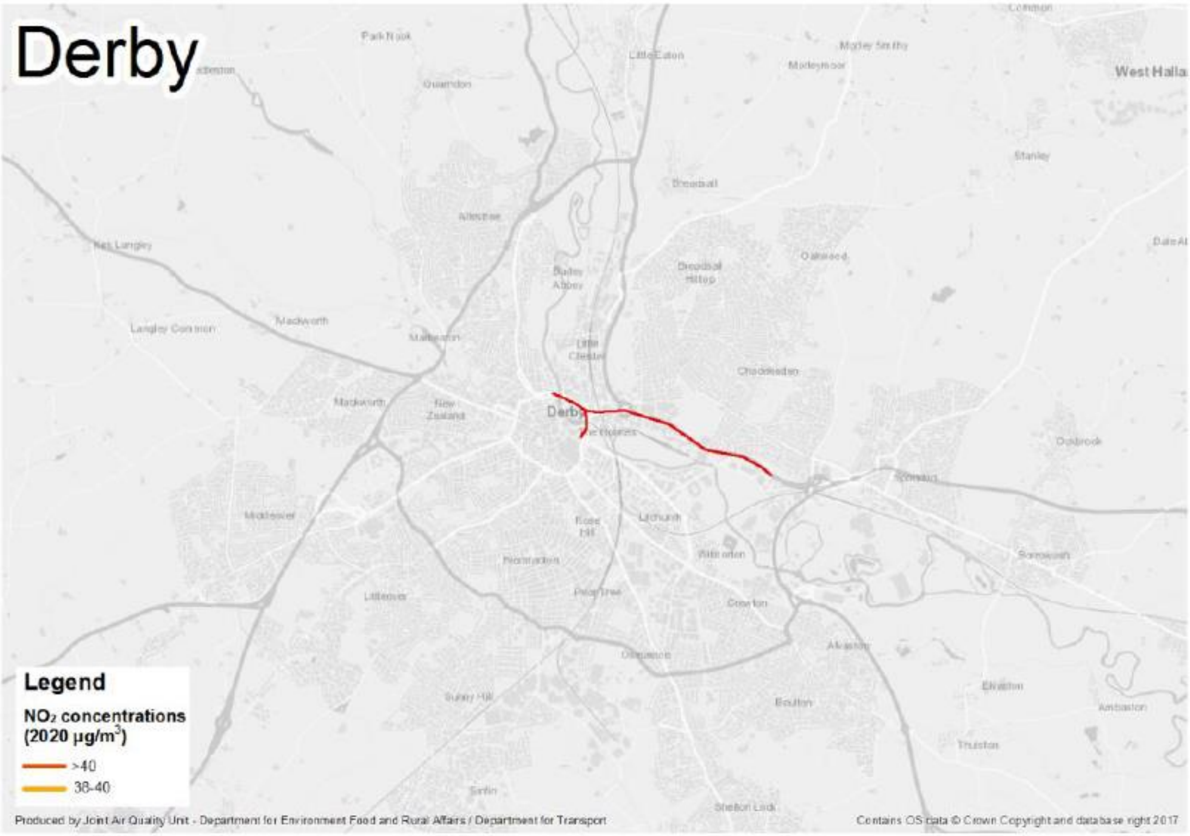

Legend
City_boundary
AQMAs
N
Kedleston
Quarndon
Little Eaton
Morley
Stanley
Breadsall
Allestree
Kirk Langley
Mackworth
Chaddesden
A61
Radbourne
Spondon
Ockbrook
A52(T)
Derby
A5111
Mickleover
Borrowash
Normanton
A516
Littleover
Alvaston
A6(T)
A38(T)
Elvaston
Burnaston
Thulston
A6(T)
Findern
Stenson Fields
Chellaston
2,000 1,000 0 2,000 Meters
Aston-On-Trent
Contains OS data © Crown Copyright and database right 2017

Figure 2: Areas of NO_2 exceedances identified in the National Plan



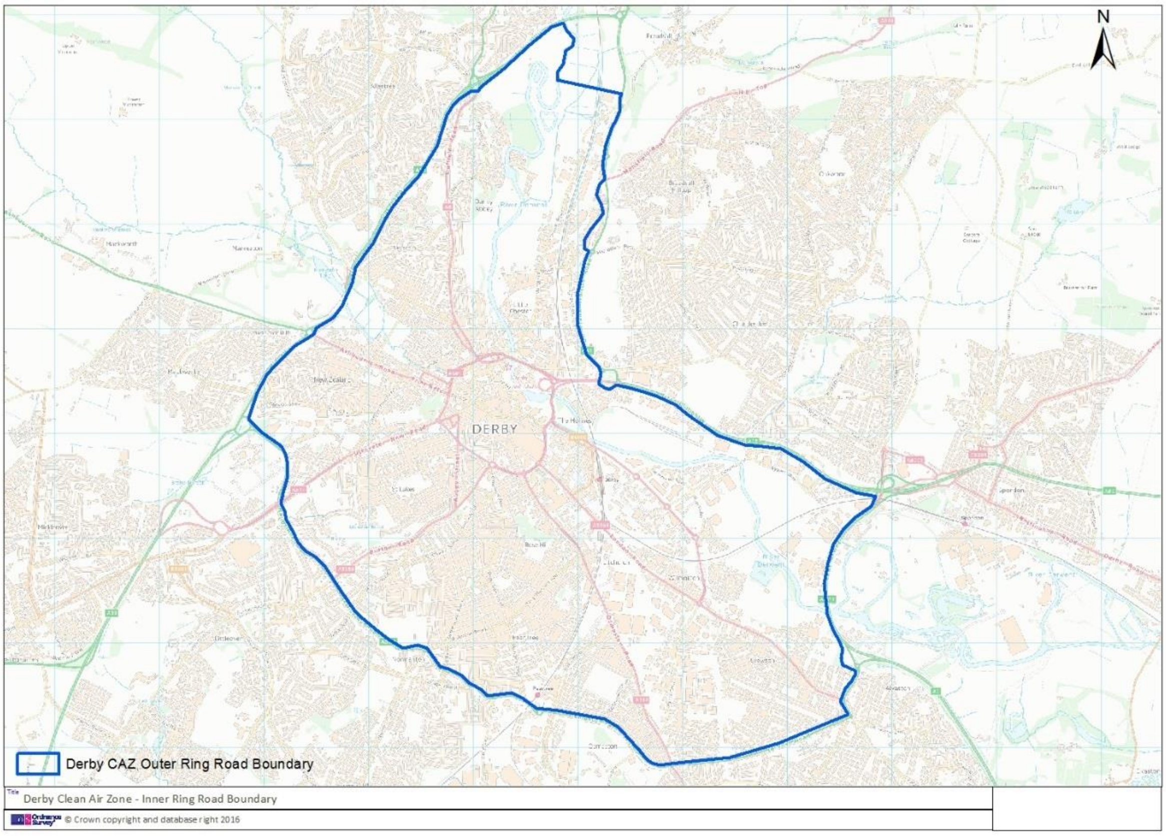
1.2 Outline scheme options

Four future scenarios for 2020 have been modelled for the Full Business Case as part of the feasibility study and covering the following:

- *Test 1 – business as usual (BAU):* this is the standard baseline assessment using the transport model results for 2020 and the projected fleet mix for 2020 based on local ANPR data. This provided the results for the formal 'target determination' process.
- *Test 2 – do minimum:* this scenario accounts for measures that have already received funding approval from government but were not in the original BAU baseline in test 1.
- *Test 3 – Stafford Street traffic management and wider network management scheme:* this is a targeted set of traffic management measures designed to specifically tackle the exceedance problem identified on Stafford Street.
- *Test 4 – A benchmark Class D charging CAZ access restriction*: this scheme would apply to all vehicles entering the area within the outer ring-road. The scheme boundary is illustrated in Figure 3.

In addition, a further test has been carried out for a 2025 reference year which includes the completion of the A38 three junctions upgrade works.

Figure 3: Derby benchmark charging CAZ boundary - area within the outer ring road

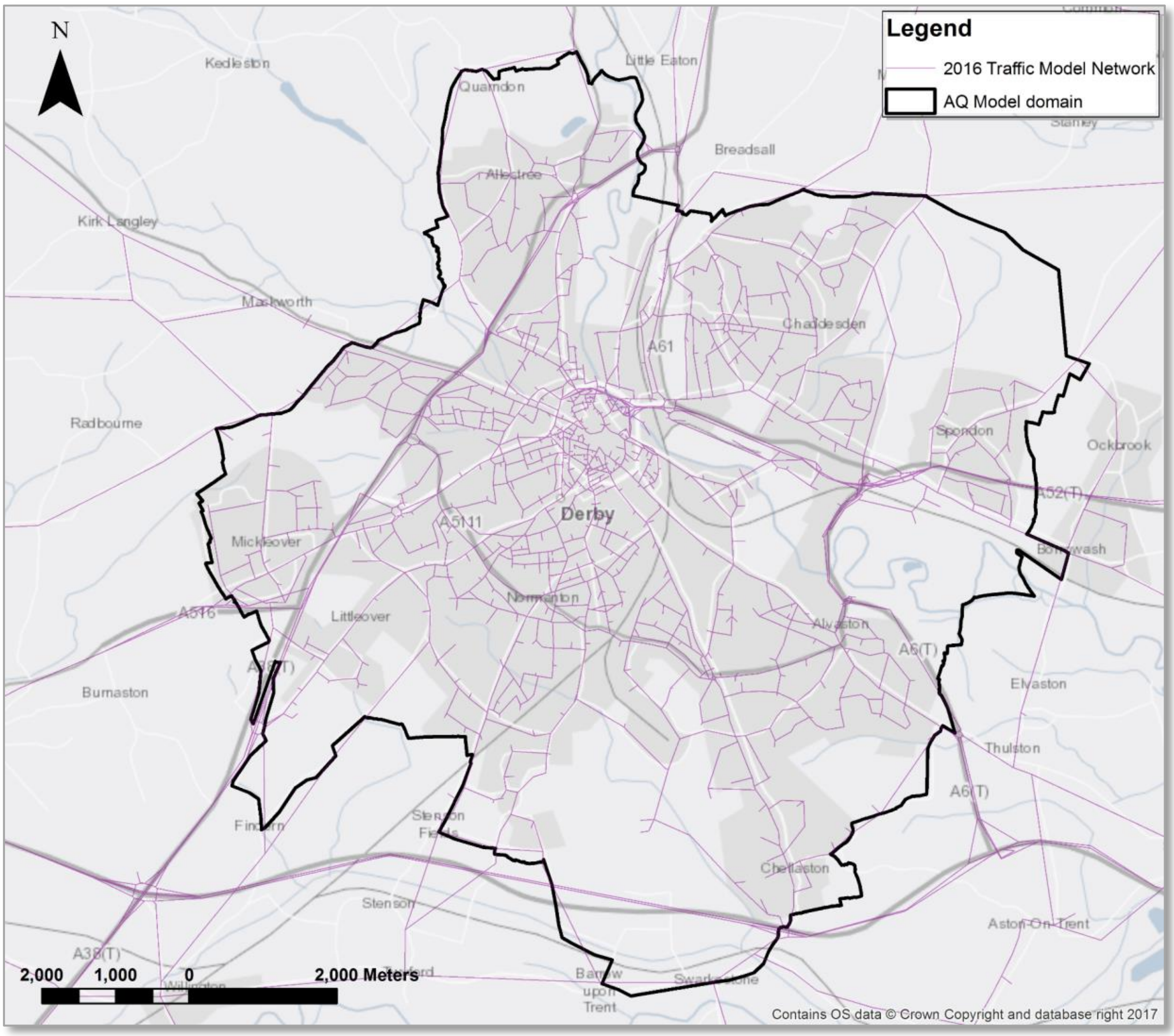


1.3 Model domain

To assess the transport and air quality impacts of these schemes, a model domain is required that covers the potential scheme options, relevant AQMAs and possible diversion routes. The model domain used is shown in Figure 4 and has been chosen to cover the following:

- All of the AQMAs in Derby;
- The main areas of concern identified in the national modelling assessment at Eastgate and Holms Bridge; and
- The wider transport network covered by the Derby Area Transport Model (DATM3), see the Transport Model documentation[2] contained in T1 to T5 of this series of reports to JAQU for further details.

Figure 4: Air quality model domain



[2] 'T2 Local Plan Transport Model Validation Report V5.1', SYSTRA 2017

1.4 Modelling years

There are two key years used in the modelling work, as set out in Table 1 below, plus an additional future reference year. The baseline modelling year is 2016 as this allows use of the latest air quality and transport data. The future baseline is modelled for the assumed implementation year in 2020. Any interim years required will be generated through interpolation rather than direct model tests. For Derby, modelling of a later future reference year in 2025 is also being carried out to allow for the major upgrade to the A38 to be fully implemented and reflected in the results.

Table 1: Model years

Year	Description
2016	**Base year** – using latest available data on air quality and traffic.
2020	**Implementation year** – latest date when the scheme is assumed to be in place, if it is required in Derby.
2025	**Post implementation year** – reference case including the completion of the A38 upgrade works.

1.5 Background modelling

The primary cause of the localised air pollution problems in Derby are related to road traffic emissions. As such the focus of the modelling study is road traffic emissions. However, one background source that was considered as significant and was investigated specifically in the modelling work was a new 200,000 tonnes-per-annum municipal waste incinerator along Sinfin Lane.

The incinerator came into operation between the 2016 baseline and the 2020 target year and so has been added to the 2020 background maps. The details of how this has been modelled and its relation to the wider background is described in 'Air Quality Methodology Report' (AQ2).

2 Options assessed and modelling assumptions

2.1 Description of options

Five scenarios have been modelled for inclusion in the Full Business Case as part of the feasibility study covering the following:

- *Test 1 – business as usual (BAU):* this is the standard baseline assessment using the transport model results for 2020 and the projected fleet mix for 2020 based on local ANPR data. This model run has been used for the purposes of comparing with the National PCM results for the target determination process.

- *Test 2 – do minimum:* this scenario reflects the key measure which could be modelled that has already received funding from Government. This is the Clean Bus Technology Fund (CBTF) bus retrofit programme that will bring the core bus fleet (some 152 vehicles) up to a Euro VI compliant standard.

- *Test 3 – Stafford Street traffic management and wider network management scheme:* this is a targeted set of traffic management measures designed to significantly reduce traffic flows along Stafford Street, complemented by wider network management in order to achieve compliance with the NO_2 limit value in this location.
- *Test 4 – A benchmark Class D charging CAZ access restriction:* this scheme would apply to all vehicles entering the area within the outer ring-road and is a benchmark charging access restriction scheme against which to test the traffic management option in terms of compliance with the NO_2 limit values as soon as possible. The bus retrofit measures have not been included to avoid double counting of the compliance assumptions associated with the benchmark charging option. The traffic management option on Stafford Street has also not been included to ensure that the re-routing effects of the benchmark charging option were fully understood and that this test was not undermined by any potentially conflicting management schemes.
- *Test 5 – 2025 reference year:* a test for 2025 has been carried out which includes the completion of the A38 three Derby junctions grade separation work but no other measures as a reference test for 2025. This test has been carried to test compliance against the NO_2 limit value in 2025 under business as usual conditions. This will also be used to support projections used for the 10 year appraisal period for the cost benefit analysis.

2.2 Modelling assumptions

The details of the how the overall air quality model has been set up and the development of the baseline is provided in ‘AQ2 Air Quality Modelling Methodology Report’. The approach taken and assumptions made, in modelling the other scenarios are set out in the sections below.

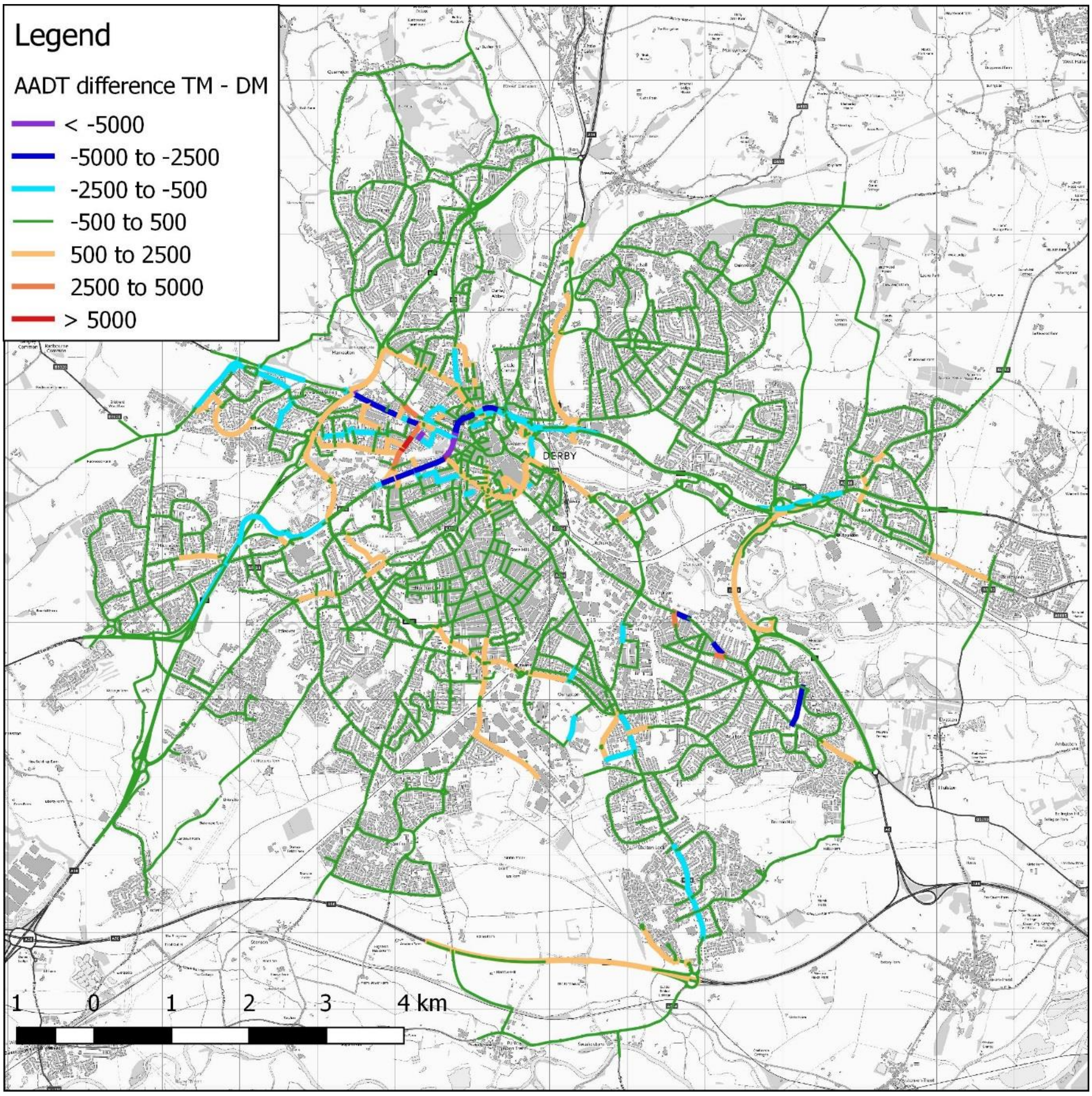
2.2.1 Test 2 – Do Minimum

This test adds the CBTF bus retrofit programme to the BAU baseline. The measure is based on funding that has been provided to retrofit buses in the Derby public service bus fleet that do not meet the Euro VI standard to become Euro VI compliant. In total funding has been provided for 152 buses in the fleet to be upgraded to a Euro VI standard and the modelling therefore assumes all buses in the city are Euro VI. However, it leaves all coaches as per the existing baseline.

2.2.2 Test 3 – Stafford Street traffic management and wider network management

A targeted set of traffic management measures including changes to the traffic control system and junction adjustments have been designed to significantly limit traffic flows on Stafford Street, which was a key compliance concern. The scheme uses network wide urban traffic management control systems (UTMC) to manage the traffic that is displaced from Stafford Street. These traffic and network management measures have been evaluated in the traffic model. The changes in traffic flows (AADT) that are the result of this test and that have been used in the air quality assessment are shown below in Figure 5. These changes in flows show a decrease on the north side of the inner ring road due to the reduction in capacity at Stafford Street and an increase on the south side. You can also see increases in the smaller roads to the north and west of Stafford Street as traffic is finding alternative routes. The most significant increase in traffic as a result of the scheme is along Uttoxeter Old Road.

Figure 5: Changes in AADT against the baseline as a result of the Stafford Street traffic management scheme



This traffic management test builds on the ‘Do Minimum’ baseline and so also includes the CBTF bus retrofit programme from the ‘do minimum’ scenario.

2.2.3 Test 4 – Class D Benchmark CAZ charging access restriction

The Class D charging access restriction is first modelled in the transport model to assess traffic responses to the scheme. In doing this the traffic model assesses the behaviour of both compliant vehicles (those that naturally meet the standard or are upgraded to do so) and non-compliant vehicles. The proportion of vkm that upgrade in response to the scheme is taken from guidance provided by JAQU as shown in Table 2 below. This upgrade response assumption is based on data developed for the London ULEZ with a charge of £100/day for the heavy-duty vehicles and £12.50 for light duty vehicles. This same charge is assumed in the traffic model to assess the response of non-compliant vehicles in terms of paying the charge, avoiding the zone or cancelling the trip.

This traffic data is then used in the air quality model to model the emissions from the vehicle fleet for both compliant and non-compliant vehicles. The detailed fleet split for compliant vehicles is generated using the baseline 2020 vehicle fleet split and applying the JAQU upgrade assumption shown Table 2. An additional upgrade assumption applied is that 75% of diesel vehicles that upgrade will switch to petrol (where possible – i.e. affecting cars, taxis and LGVs). The remaining vehicles then give the fleet split for the non-compliant vehicles. In the case of the Class D these assumptions are applied to all vehicle types.

Table 2: JAQU assumptions on behavioural response to the CAZ (vkm)

Proportions of non-compliant vehicle kilometres which react to the zone								
	Petrol Cars	**Diesel Cars**	**Petrol LGVs**	**Diesel LGVs**	**RHGVs**	**AHGVs**	**Buses**	**Coaches**
Pay charge – Continue into zone	7.1%	7.1%	20.3%	20.3%	8.7%	8.7%	0.0%	15.6%
Avoid Zone – vkms removed, modelled elsewhere	21.4%	21.4%	10.0%	10.0%	0.0%	0.0%	0.0%	0.0%
Cancel journey – vkms removed completely	7.1%	7.1%	6.0%	6.0%	8.7%	8.7%	6.4%	12.5%
Replace Vehicle – vkms replaced with compliant vkms	**64.3%**	**64.3%**	**63.8%**	**63.8%**	**82.6%**	**82.6%**	**93.6%**	**71.9%**

Source: JAQU, CAZ Technical working group minutes – 15/2/17

The Class D CAZ access restriction scheme has been modelled as a benchmark scheme against which to compare the other options in relation to compliance as soon as possible. As such this option has been modelled on its own and not combined with any of the other options.

The way the benchmark is modelled also does not include any sunset periods for residents, other users or further measures or mitigation that may ultimately be required for the delivery of such a scheme.

2.2.4 Test 5 Reference test for 2025

This test uses a reference traffic model run with the inclusion of the A38 Derby junctions grade separation scheme. The vehicle fleet used in the air quality model is a projection to 2025 using national trends but a starting point based on the local ANPR data collected. No other measures are included except for assuming that all buses will be Euro VI as a result of the current CBTF funding and natural fleet evolution.

3 Model results for 2016 base year and 2020 'BAU' baseline

3.1 Comparison with PCM

For comparison with national SL-PCM model results, annual mean NO_2 concentrations at the roadside locations assessed in the national compliance PCM model have been extracted from the RapidAir dispersion model results; the results have been presented in both tabular form and using graduated colours on a map of the study area.

Roadside receptor locations in the PCM model are at a distance of 4m from the kerb and at 2m height. To represent this in our city scale modelling, a subset of the OS Mastermap GIS dataset provided spatially accurate polygons representing the road carriageway; receptor locations were then placed at 50m intervals along relevant road links using a 4m buffer around the carriageway polygons.

Each PCM link has a unique Census ID number and a grid reference assigned which is typically the co-ordinates describing the location of the DfT traffic count points on each link; this location may not however be where the highest roadside concentrations are occurring along the entire link length when using a more detailed local scale modelling method with observed average vehicle speeds on shorter road sections. The PCM links within our model domain range in length from approximately 120m to 3.25km; we have therefore reported the highest of the modelled concentrations from the city scale model receptors, 4m from the carriageway.

A list of PCM road link Census IDs within the Derby reporting zone was provided by JAQU.

A comparison of the local model maximum concentration modelled 4m from each PCM link and the corresponding PCM results (in the list provided by JAQU only) from 2016 to 2020 are presented in Table 3. The results for 2016 and 2020 are full model results, the interim years are interpolated results. Maps showing the predicted annual mean results in 2016 and 2020 are presented in Figure 6 to 9 (maps have not been produced for the interpolated results). These model results should be considered in context with the model uncertainty quantified during model verification (see Section 3.3).

The results show that:

- At locations where the PCM model indicates that NO_2 annual mean concentrations will be less than the 40 $\mu g.m^{-3}$ objective in 2020, the tabulated results of the local model are largely consistent with the PCM results with the exception of the Stafford Street section of Census ID38406 – where the local model indicates a significantly higher annual mean in both 2016 and 2020. At the diffusion tube site at this location model agreement is reasonably good in the 2016 base year. The local model is therefore considered to be more representative of local emissions and pollutant dispersion. High concentrations at this location are attributable to the both the average daily traffic flow and the limiting effect of the street canyon on dispersion. A fairly significant increase in average daily traffic is predicted at this location in the 2020 future base year, which counteracts the projected reduction in vehicle emissions from fleet turnover.

- At all locations where the PCM model indicates that NO_2 annual mean concentrations will be in excess of the 40 $\mu g.m^{-3}$ objective in 2020; the local model predicts compliance. These model results should be considered in context with the model uncertainty quantified during model verification. The relevant census ID points where an exceedance of the NO_2 annual mean objective was predicted by the national model were:
    - ID37967, A52 (Eastgate to Raynesway) – where the local model is slightly lower, but still at risk of exceedance given model error.

- ID46556, A52 Eastgate – where the local model is significantly lower, but local monitoring at this location suggests the model is underpredicting.

- ID7877 and ID81247, both along A601 St Alkmund's Way – the local model is showing much lower results, however, the local monitoring data at this location suggests that the local model may be under predicting at this location.

Although the exact locations of exceedances differ, the overall pattern between the PCM national model and the local model is similar with the highest concentration being on the A52 coming into the inner ring road and around the A601 inner ring road. Canyon effects and the volume of local traffic are giving rise to the highest concentrations at Stafford Street in the local model.

Table 3: NO_2 annual mean concentrations 2016 baseline year, 2018 interim year and 2020 future baseline year - Comparison of PCM vs local model results (µg.m^{-3})

CensusID	Zone code	Road Name	Length (m)	Road management description			PCM baseline results					Run 1 Local model baseline				
					X	Y	2015	2017	2018	2019	2020	2016	2017	2018	2019	2020
16361	32	A38	2,166	Highways England	434682	338879	45.1	40.5	38.1	36.0	33.8	44.1	42.0	40.0	37.9	35.8
16362	32	A38	595	Highways England	431094	333377	40.7	37.7	35.7	34.0	32.1	36.5	36.4	36.2	36.1	36.0
16520	32	A52	912	Derby City Council	434000	336700	33.2	31.9	30.7	29.5	28.1	36.3	34.9	33.4	32.0	30.5
18308	32	A6005	656	Derby City Council	439000	335820	34.3	33.0	32.0	30.9	29.6	37.5	36.5	35.5	34.5	33.4
18373	32	A5111	676	Derby City Council	438560	333380	36.1	34.5	33.2	32.0	30.4	30.3	29.3	28.2	27.1	26.0
18386	32	A6096	760	Derby City Council	440000	335870	24.1	22.9	22.0	21.1	20.1	31.0	29.6	28.3	26.9	25.6
27256	32	A514	1,553	Derby City Council	436840	333000	32.8	31.4	30.2	29.0	27.7	40.2	38.8	37.4	36.0	34.6
27766	32	A5111	656	Derby City Council	433000	335970	30.8	29.5	28.5	27.5	26.2	29.7	28.4	27.2	26.0	24.7
27767	32	A5111	1,278	Derby City Council	437900	333000	29.2	27.8	26.7	25.7	24.5	32.6	31.4	30.3	29.1	28.0
27788	32	A5250	653	Local Authority	435000	335470	36.2	34.7	33.6	32.5	31.1	31.6	30.3	29.0	27.7	26.4
27938	32	A601	168	Derby City Council	435600	335680	35.8	34.5	33.5	32.4	31.1	38.8	37.4	35.9	34.4	32.9
28014	32	A61	1,314	Derby City Council	436112	336742	42.3	39.8	38.0	36.4	34.6	37.5	36.1	34.8	33.4	32.0
28255	32	A5250	1,112	Derby City Council	434200	334910	31.3	29.9	28.8	27.7	26.4	30.5	29.1	27.8	26.4	25.1
28431	32	A6005	399	Derby City Council	438900	335700	31.1	30.0	29.0	28.1	27.0	32.4	31.5	30.6	29.7	28.8
37288	32	A516	1,314	Derby City Council	434400	336000	30.6	29.2	28.1	27.0	25.7	37.8	35.8	33.9	31.9	30.0
37405	32	A608	3,003	Derby City Council	436970	339000	26.2	24.8	23.8	22.8	21.7	31.8	30.6	29.3	28.1	26.9
37810	32	A5111	1,183	Derby City Council	434000	334150	32.6	31.2	30.1	29.1	27.7	31.0	29.8	28.5	27.2	26.0
37967	32	A52	2,268	Derby City Council	437350	336000	49.6	46.9	44.9	43.0	40.9	44.5	43.1	41.7	40.2	38.8
38236	32	A601	634	Derby City Council	434830	336624	39.7	38.4	37.2	36.0	34.4	41.2	40.0	38.9	37.7	36.6
38406	32	A601	113	Derby City Council	434740	336300	27.1	25.9	25.0	24.0	22.9	53.1	52.2	51.2	50.3	49.3
46171	32	A5194	2,048	Derby City Council	436000	335361	36.6	35.1	33.9	32.7	31.3	38.8	37.2	35.5	33.9	32.3
46394	32	A38	1,341	Highways England	432600	335910	41.8	37.8	35.5	33.6	31.6	41.3	39.6	37.9	36.2	34.5
46556	32	A52	557	Derby City Council	436000	336500	51.0	48.4	46.4	44.4	42.2	39.7	38.5	37.3	36.1	34.9

CensusID	Zone code	Road Name	Length (m)	Road management description			PCM baseline results					Run 1 Local model baseline				
					X	Y	2015	2017	2018	2019	2020	2016	2017	2018	2019	2020
47261	32	A514	1,899	Derby City Council	435930	335000	29.1	27.6	26.7	25.7	24.6	38.9	37.5	36.1	34.7	33.3
47768	32	A5111	1,618	Derby City Council	436000	333300	35.7	34.1	32.8	31.6	30.2	38.5	37.1	35.8	34.4	33.0
47796	32	A6005	990	Derby City Council	439950	335330	27.6	26.4	25.5	24.6	23.5	30.2	29.1	28.1	27.0	26.0
47986	32	A601	442	Derby City Council	435700	336000	39.1	37.5	36.3	35.0	33.5	45.2	43.4	41.6	39.8	38.0
56162	32	A6	952	Derby City Council	435200	340000	30.6	28.8	27.5	26.3	24.9	27.5	26.4	25.3	24.2	23.0
56563	32	A52	1,579	Derby City Council	433000	337070	33.3	30.9	29.3	27.9	26.3	31.1	29.6	28.2	26.7	25.3
57677	32	A5111	1,127	Derby City Council	435000	333580	32.8	31.4	30.3	29.3	28.0	39.3	37.9	36.5	35.1	33.7
57767	32	A38	1,870	Highways England	433000	336550	47.8	43.9	41.6	39.6	37.4	44.5	42.7	41.0	39.2	37.4
58080	32	A6005	462	Derby City Council	439860	335400	30.8	29.4	28.3	27.2	25.9	38.2	37.1	36.1	35.1	34.1
6167	32	A6	3,576	Derby City Council	434850	339000	27.6	26.1	25.1	24.1	22.8	42.2	40.7	39.2	37.6	36.1
6540	32	A52	328	Highways England	439650	335620	43.1	41.0	39.3	37.8	36.0	38.3	37.3	36.3	35.3	34.3
70040	32	A601	830	Local Authority	434850	336000	25.3	24.1	23.1	22.2	21.2	28.7	27.4	26.2	24.9	23.7
7228	32	A514	1,801	Derby City Council	437200	332000	29.2	28.1	27.1	26.2	24.9	28.4	27.6	26.7	25.9	25.1
7232	32	A516	1,671	Derby City Council	432746	335093	39.9	38.2	36.9	35.6	33.9	34.7	33.0	31.2	29.5	27.7
73356	32	A52	2,808	Highways England	440500	335540	43.1	40.9	39.2	37.7	35.8	39.0	37.9	36.7	35.6	34.4
73357	32	A6096	4,350	Derby City Council	440760	336420	23.0	21.6	20.7	19.8	18.8	25.4	24.4	23.3	22.2	21.1
73359	32	A61	1,435	Derby City Council	436260	338500	36.3	34.2	32.7	31.4	29.8	31.3	30.1	28.9	27.7	26.5
73362	32	A516	2,631	Highways England	430700	333800	22.0	20.3	19.3	18.3	17.3	31.6	30.5	29.3	28.2	27.1
74456	32	A38	1,088	Highways England	431840	334780	47.1	43.1	40.8	38.8	36.6	46.7	45.0	43.2	41.4	39.6
75406	32	A5250	450	Local Authority	435320	335550	29.6	28.4	27.5	26.6	25.6	33.4	32.2	30.9	29.6	28.3
75407	32	A5250	281	Local Authority	435300	335470	29.6	28.4	27.5	26.6	25.6	32.9	31.4	29.8	28.2	26.7
75408	32	A5250	207	Local Authority	435100	335450	33.8	32.4	31.3	30.2	28.9	27.6	26.3	25.1	23.9	22.6
75410	32	A52	571	Derby City Council	434700	336500	28.4	27.4	26.4	25.5	24.4	36.6	35.6	34.7	33.7	32.8
75411	32	A52	278	Derby City Council	434700	336400	32.6	31.1	29.9	28.7	27.4	36.5	35.4	34.3	33.3	32.2

CensusID	Zone code	Road Name	Length (m)	Road management description	X	Y	PCM baseline results					Run 1 Local model baseline				
							2015	2017	2018	2019	2020	2016	2017	2018	2019	2020
75412	32	A601	163	Local Authority	434800	336090	21.6	20.4	19.6	18.8	18.0	33.6	31.8	30.1	28.4	26.6
75415	32	A601	132	Local Authority	434800	336220	25.7	24.7	23.8	23.0	21.9	27.8	26.8	25.9	24.9	24.0
75416	32	A516	113	Local Authority	434700	336120	27.0	25.6	24.5	23.4	22.3	35.6	33.7	31.7	29.8	27.9
76083	32	A52	202	Derby City Council	439700	335640	23.4	22.2	21.3	20.5	19.6	36.9	35.8	34.6	33.5	32.4
76084	32	A5111	319	Highways England	439050	335500	26.4	25.1	24.1	23.2	22.2	38.0	37.0	36.0	34.9	33.9
76085	32	A52	1,221	Highways England	439400	335520	42.9	40.8	39.1	37.6	35.8	44.3	42.8	41.4	39.9	38.4
7702	32	A5111	1,221	Derby City Council	433300	335000	33.7	32.2	31.0	29.8	28.4	33.8	32.4	31.1	29.7	28.3
7877	32	A601	510	Derby City Council	435500	336660	48.9	47.3	45.6	44.1	42.0	43.1	41.8	40.4	39.1	37.7
81020	32	A5111	1,189	Highways England	438525	334996	41.2	39.4	37.9	36.5	34.9	42.5	41.5	40.4	39.4	38.3
81077	32	A5111	886	Derby City Council	438640	333640	37.8	36.0	34.6	33.3	31.8	38.4	37.4	36.4	35.4	34.4
81246	32	A6	1,692	Derby City Council	437824	334027	42.0	39.8	38.3	36.8	35.2	45.2	43.8	42.3	40.9	39.4
81247	32	A601	392	Derby City Council	435738	336288	60.8	57.5	54.8	52.3	49.4	43.2	41.7	40.2	38.7	37.2
81248	32	A6	2,506	Derby City Council	436312	335775	37.7	36.1	34.9	33.7	32.2	45.5	43.8	42.0	40.3	38.6
81435	32	A601	267	Derby City Council	434748	336051	24.5	23.5	22.7	22.0	21.0	32.3	31.0	29.7	28.5	27.2
81436	32	A601	400	Derby City Council	435070	335767	34.0	32.7	31.7	30.7	29.4	31.5	30.3	29.1	27.9	26.7
81437	32	A601	320	Derby City Council	435368	335616	33.2	31.8	30.7	29.7	28.5	39.8	38.4	36.9	35.4	33.9
81443	32	A5250	360	Derby City Council	435071	335590	33.4	32.0	30.9	29.9	28.6	37.0	35.3	33.7	32.0	30.3
8227	32	A6096	455	Derby City Council	440040	335640	26.8	25.5	24.6	23.6	22.5	37.9	36.5	35.1	33.7	32.3
83044	32	A601	164	Derby City Council	434700	336190	31.3	30.2	29.2	28.2	27.0	34.4	33.4	32.4	31.4	30.4

Figure 6: Local modelled NO_2 annual mean concentrations 2016 base year – PCM links

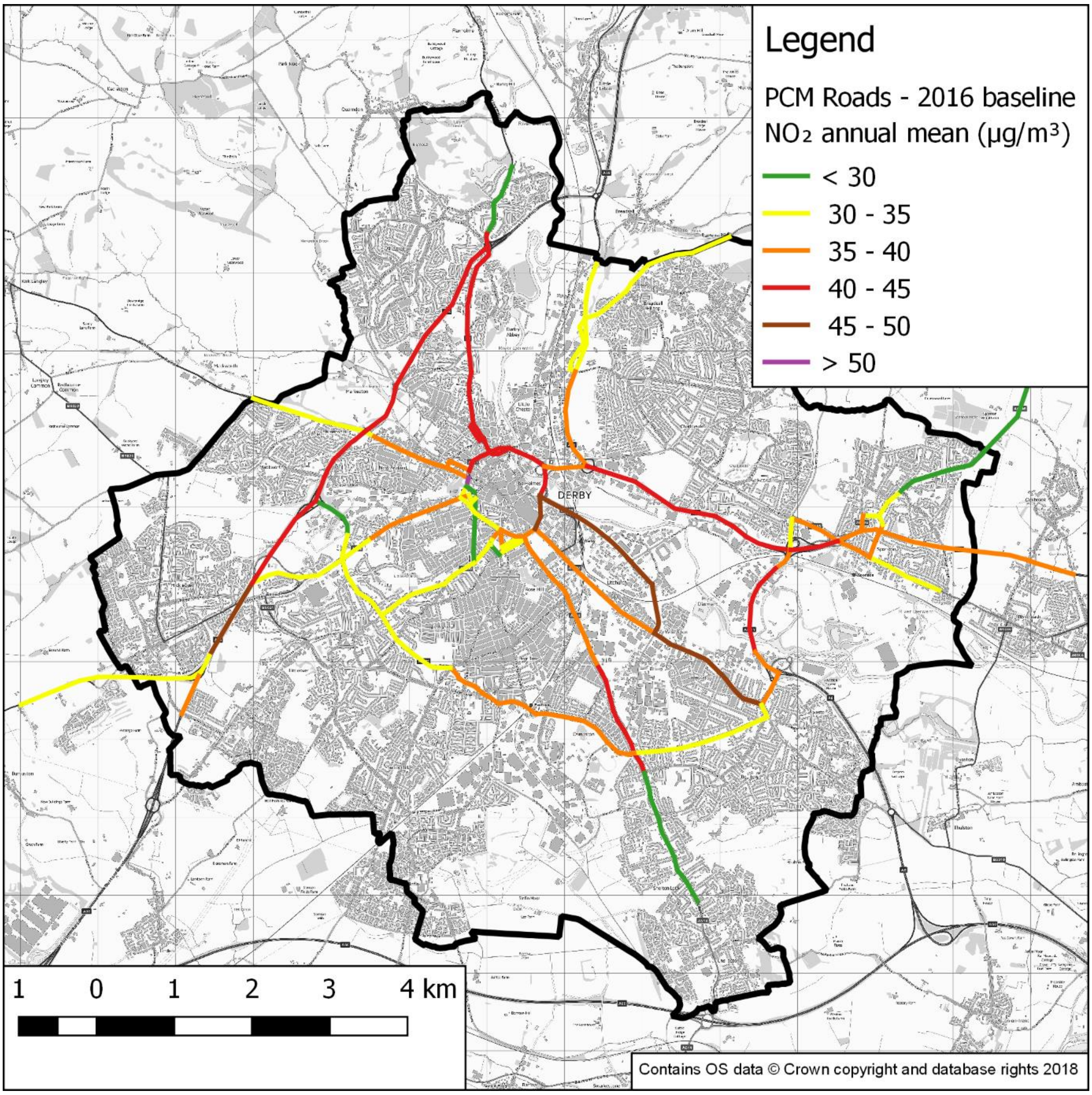
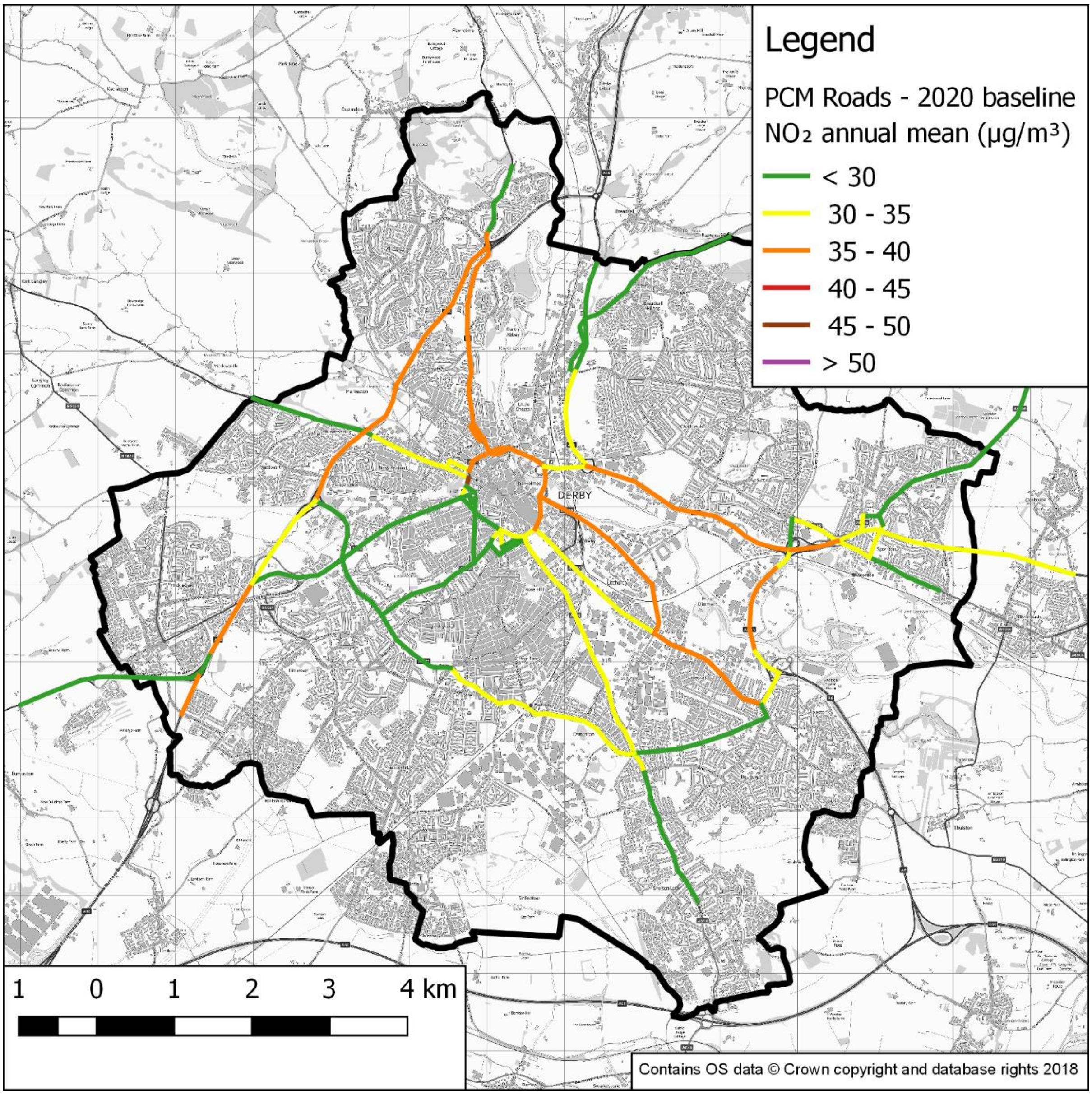


Figure 7: Local modelled NO_2 annual mean concentrations 2020 baseline year – PCM links



3.2 Results for AQMAs and local exceedances

Annual mean NO_2 concentrations measured in 2016 and predicted annual mean NO_2 concentrations at each monitoring site in 2020 are presented in Table 4. We have presented two sets of results in 2020; one using the global/domain wide road NOx adjustment factor, and the other using a site-specific road NOx adjustment factor. The site-specific adjustment factor is simply derived from the ratio of measured and modelled road NOx at that specific site and used to adjust the predicted 2020 results rather than the global adjustment factor derived from model verification. The site-specific results aim to provide an indication of when compliance may be achieved at each monitoring site without any of the bias introduced by using an average road NOx adjustment factor across the entire domain. Further information on model verification and uncertainty is presented in Appendix 1 and Section 3.3 respectively.

The results indicate that in 2020, compliance with the 40 $\mu g.m^{-3}$ NO_2 annual mean objective will be achieved at the majority of current monitoring locations, with the exception of:

- DT10 Nottingham Road – is showing an exceedance with the global adjustment factor, but compliance with the site-specific factor, so not of concern;
- DT11 Eastgate (Pentagon) – shows an exceedance with the site-specific factor, but it is marginal and with no relevant exposure;
- DT34 Kingsway/A38 – shows a significant exceedance with the site-specific factor, but has no relevant exposure;
- DT57 St Alkmunds Way – shows significant exceedance with the site-specific factor and is potentially of concern, it is however a kerbside site (about 1m from the kerb) and so is not considered representative of exposure;
- DT59 Stafford Street Burleigh Mews Flats – shows results consistent with the local modelled PCM receptor results at this location and is the key target for action.

Table 4: Predicted NO_2 annual mean concentrations at monitoring site locations in 2020

Monitoring site name	Site ID	Site type	NO_2 annual mean ($\mu g.m^{-3}$)		
			Measured 2016	Modelled 2020 (using global NOx adjust factor)	Modelled 2020 (site specific NOx adjust factor)
23 Gilbert Close	DT1	Roadside	28.6	28.3	25.0
10 Kirkleys Ave North	DT2	Roadside	29	25.7	25.4
27 Kirkleys Ave South	DT3	Roadside	26	23.4	22.1
24 Nottingham	DT4	Roadside	38	23.5	31.8
1 Station Road	DT5	Roadside	31.1	25.5	26.3
23 Leeway	DT6	Roadside	27.8	28.2	24.0
1 Drury Avenue	DT7	Roadside	27	26.2	23.1
198 Derby Road	DT8	Roadside	29.1	27.1	24.8
109 Highfield Lane	DT9	Roadside	27.8	27.4	24.0
203/201 Nottingham Road	DT10	Roadside	47.4	43.4	39.4
Eastgate (Pentagon)	DT11	Roadside	46.5	31.1	42.0
Bass Recreation Ground/The Holmes	DT12	Urban background	36.3	37.4	30.7
16/18 Harrow Road	DT13	Roadside	29.8	35.9	25.6
713 London Road	DT14	Roadside	26.7	32.0	23.2
938 London Road	DT15	Roadside	43.7	37.2	38.4
1178 London Road	DT16	Roadside	35.4	20.5	30.7
7 Raynesway	DT17	Roadside	30.8	21.3	26.1
772 Osmaston Road	DT18	Roadside	27.1	24.6	22.4
831 Osmaston Road	DT19	Roadside	26.3	24.9	23.3
113 Chellaston Road	DT20	Roadside	27.2	21.3	24.9
376 Osmaston Park Road	DT21	Kerbside	25.2	23.6	21.4
523 Osmaston Park Road	DT22	Roadside	27.3	26.6	23.5
104 Osmaston Park Road	DT23	Roadside	43	31.8	36.8

Monitoring site name	Site ID	Site type	NO_2 annual mean ($\mu g.m^{-3}$)		
			Measured 2016	Modelled 2020 (using global NOx adjust factor)	Modelled 2020 (site specific NOx adjust factor)
32 Newdigate Street	DT24	Roadside	41.2	30.6	35.8
80 Newdigate Street	DT25	Roadside	40.9	29.1	36.0
Warwick Ave monitoring station	DT26	Kerbside	47	23.5	39.4
2a Lime Walk	DT29	Roadside	27.3	21.4	22.3
430 Uttoxeter New Road	DT30	Roadside	26.5	24.3	22.6
431 Uttoxeter New Road	DT31	Roadside	30.8	30.4	25.2
266 Uttoxeter New Road	DT32	Roadside	41	29.7	32.9
150 Radbourne Street	DT33	Roadside	30.9	23.0	25.4
Kingsway / A38	DT34	Roadside	60	32.8	51.1
199 Uttoxeter New Road	DT35	Roadside	32.1	28.0	24.9
59a Stafford Street	DT36	Roadside	36.8	30.8	32.2
4 Dunkirk	DT37	Roadside	26.1	20.2	22.0
Wilson Street West	DT38	Roadside	22.9	22.1	19.1
201 Abbey Street	DT39	Roadside	32.7	22.9	27.7
315 Burton Road	DT40	Roadside	29.4	20.4	24.1
220 Burton Road	DT41	Roadside	31.4	23.5	26.1
114a Burton Road	DT42	Roadside	32.5	26.0	27.2
131 Green Lane	DT43	Roadside	28.1	25.3	23.5
57 Normanton Road	DT44	Roadside	38.1	26.6	30.8
29 Ivy Square off Osmaston Road	DT45	Roadside	32.7	32.5	27.8
114 Osmaston Road	DT46	Roadside	33.6	26.8	28.4
Bradshaw Way	DT47	Roadside	36.1	35.9	30.5
London Road/Westfield	DT48	Roadside	37.2	29.5	29.9
59 Osmaston Road	DT49	Roadside	32.7	30.8	27.7
Royal Telegraph Pub	DT50	Roadside	39.2	40.8	33.0

Monitoring site name	Site ID	Site type	NO_2 annual mean ($\mu g.m^{-3}$)		
			Measured 2016	Modelled 2020 (using global NOx adjust factor)	Modelled 2020 (site specific NOx adjust factor)
176 Siddals Road	DT51	Roadside	30.4	29.0	25.3
123 Nottingham Road	DT52	Roadside	32.4	24.5	27.3
63 Nottingham Road	DT53	Roadside	29.9	36.3	25.5
14 Mansfield Road	DT54	Roadside	30.4	32.6	25.8
171 Mansfield Road	DT55	Roadside	28.8	24.5	24.3
St Marys Court	DT56	Roadside	40.6	30.5	35.8
St Alkmunds Way	DT57	Roadside	54.1	36.3	48.5
171/182 Cavendish Court	DT58	Roadside	27.9	29.3	23.9
Stafford Street Burleigh Mews Flats	DT59	Roadside	50.9	46.0	46.7
189/191 Ashbourne Road	DT60	Roadside	42.3	37.0	34.3
148 Ashbourne road	DT61	Roadside	31.3	25.7	25.9
Millgate, Ashbourne Road	DT62	Roadside	35	28.0	30.3
Friargate / Bridge Street corner	DT63	Roadside	39.2	29.8	32.2
Bridge Street / Agard Street	DT64	Roadside	33.1	29.4	27.7
8 / 10 Agard Street	DT65	Roadside	35	26.0	30.2
69 King Street	DT66	Roadside	26.2	27.1	21.7
Duffield Road (55 West Avenue)	DT68	Roadside	35.3	27.9	29.1
8 Kedleston Road (Chriopodist)	DT69	Roadside	30.9	28.2	24.3
Duffield Road/North Street	DT70	Roadside	32.5	26.5	26.9
5 Duffield Road	DT71	Roadside	35.3	35.8	30.1
14 The Strand	DT72	Roadside	32	19.7	25.0
Victoria Street/Corn Market	DT73	Roadside	25.8	33.0	20.9
Morledge	DT74	Roadside	40.6	28.7	31.1
25 Morledge	DT75	Roadside	38.7	26.4	29.5
Council House	DT76	Urban Centre	26.7	22.5	21.7

3.3 Model uncertainty

Some clear outliers were apparent during the model verification process, whereby we were unable to refine the model inputs sufficiently to achieve good model performance at these locations. There are a number of reasons why this could be the case, including:

- A site located next to a large car park, bus stop, boiler flue, or taxi rank that has not been explicitly modelled due to unknown activity data.
- Sites located underneath trees or vegetation (i.e. unsuitable locations for diffusion tubes to measure NO_2 concentrations effectively).
- Uncertainties in the traffic model outputs (please refer to the traffic model validation report for further information on this).
- Uncertainties in the background maps. At some locations in the model domain the mapped background NOx concentrations look very high compared to the surrounding area; even after discounting all road source sectors from the background maps, the NOx/NO_2 calculator was indicating that a negative road NOx concentration would be required to match the measured NO_2 concentration. This could indicate that the mapped NOx background has been overestimated at these locations. However, it could also indicate uncertainties with the measured NO_2 concentrations.
- Uncertainties introduced by modelling background concentrations at 1km resolution over such a wide area. In this case we have attempted to address this by interpolating the 1km background maps to a finer 1m resolution. This aims to smooth out the sudden changes in background concentrations at the edges of the 1km square background maps. We found that using the interpolated/smoothed background map produced better model performance overall.

To evaluate model performance and uncertainty, the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations was calculated, as detailed in LAQM.TG(16). In this case the RMSE was calculated at 4.9 µg.m^{-3}.

More information on model performance and uncertainty is presented in Appendix 1.

4 Option testing results

Each of the option model runs have been carried out using the assumptions set out in section 2. The results have been extracted in the same way as for the baseline and are shown in the sections below.

4.1 Comparison with PCM

A summary of the modelled annual mean NO_2 results for each of the options is shown in Table 5 with details provided in Table 6 below. The mapped results for the PCM links are shown in Figure 9 to Figure 12, with full contour plot results included in Appendix 2.

Table 5: Summary comparison of the NO_2 for PCM links for the options in 2020

Option	Links > 40 µg/m^3	Links > 35 and < 40 µg/m^3	Average change in NO_2 µg/m^3	Stafford Street, µg/m^3
Test 1 Baseline	1	14	N/A	49.3
Test 2 Do Minimum	1	13	-1.0	48.5
Test 3 Traffic Management Scheme	0	13	-1.3	35.5
Test 4 Class D Charging scheme	0	3	-4.7	38.0
Test 5 Reference test for 2025	0	1	-8.9	36.1

The impact of each option can be summarised as follows:

Test 2 – Do Minimum – This scenario adds the currently funded CBTF measure to the baseline and sets all buses to Euro VI in the model. This has an average impact of reducing emissions on the PCM links of 1µgm^{-3}. Clearly the greatest impact will be on major bus routes on key arterials into the city centre, with the greatest reduction being 5 µg.m^{-3} on a mainly bus only link in the city centre. The impact on Stafford Street is to reduce concentrations from 49.3 to 48.5 µg.m^{-3}.

Test 3 – Traffic Management Scheme (TMS) – This traffic management scheme (with wider network management measures) has been specifically designed to limit traffic levels on Stafford Street to solve the exceedance problem. The results show that it does this extremely well, reducing the concentration here from 48.5 to 35.5µg.m^{-3}. However, this scheme is essentially redistributing traffic across the wider highway network and so across the PCM links the average impact is little better than the 'Do Minimum' scenario with some links showing increases.

The increases on the PCM links are very small with a maximum increase of 0.2 µg.m^{-3}. This is because much of the traffic re-distribution is taking traffic onto minor/ local distributor roads that are not part of the PCM network. The road with the greatest increase in traffic as a result of the scheme is Uttoxeter Old Road. Since this is not a PCM link additional receptors have been added here in the model to assess the impact on air quality on this road. The results for Uttoxeter Old Road are shown in **Error! Reference source not found.** below. This shows that NO_2 concentrations are low in the baseline on this road and the impact of the traffic management scheme increases concentrations by a maximum of 2 µg.m^{-3} giving the highest result along this link of 29 µg.m^{-3}.

A further screening test was carried out that identified all roads links which had AADT greater than 10,000 (which indicates a potential risk of exceedance). Receptors were then placed along these links using the standard PCM siting criteria (4m from kerb and 25m from major junctions) and NO_2 results extracted. For all identified links none showed a result higher than 40 µg.m^{-3}. Three points were greater than 35 µg.m^{-3} with the maximum being 37 µg.m^{-3}.

Test 4 – Class D Charging CAZ scheme – The scheme was included to provide a benchmark charging access restriction scheme against which the traffic management option could be tested. The results show that the Class D Charging scheme would match the TMS in removing links which exceed the NO_2 limit. It also generates a greater overall reduction in concentrations across city, with an average reduction of 4.7 µg.m^{-3}. However, it does not achieve the same level of reduction at Stafford Street as the TMS, with a concentration of only 38 µg.m^{-3}.

Test 5 – Reference case for 2025 – The 2025 reference case was included to reflect the completion of the three junction upgrade works on the A38, to test compliance against the NO_2 limit value in 2025 under business as usual conditions. The results indicate no exceedances of the objective would occur in 2025, and average NO_2 concentrations were predicted to fall by 8.9 µg.m^{-3}, with concentrations along Stafford Street falling to 36.1 µg.m^{-3}.

Figure 8: Location and NO_2 concentrations for receptors on Uttoxeter Old Road with Test 3 Traffic Management Scheme

Receptor ID	Do Min Sc. (µg.m^{-3})	TMS Sc. (µg.m^{-3})	Difference (µg.m^{-3})
Uttox_0	23.8	25.7	2.0
Uttox_1	23.4	25.4	2.0
Uttox_2	24.7	26.8	2.2
Uttox_3	25.9	27.8	1.9
Uttox_4	25.7	27.5	1.9
Uttox_5	25.9	27.8	1.9
Uttox_6	25.8	27.6	1.8
Uttox_7	27.3	29.0	1.8
Uttox_8	24.4	25.6	1.2
Uttox_9	23.7	25.0	1.2
Uttox_10	23.4	24.6	1.2
Uttox_11	24.3	25.5	1.2
Uttox_12	24.2	25.9	1.7
Uttox_13	22.8	24.5	1.7
Uttox_14	22.4	24.0	1.6
Uttox_15	22.5	24.0	1.5
Uttox_16	23.5	24.8	1.3
Uttox_17	22.9	23.7	0.8
Uttox_18	24.9	26.6	1.6
Uttox_19	26.3	26.4	0.1
Uttox_20	24.5	24.9	0.4
Uttox_21	22.5	22.6	0.2
Uttox_22	25.5	25.6	0.1

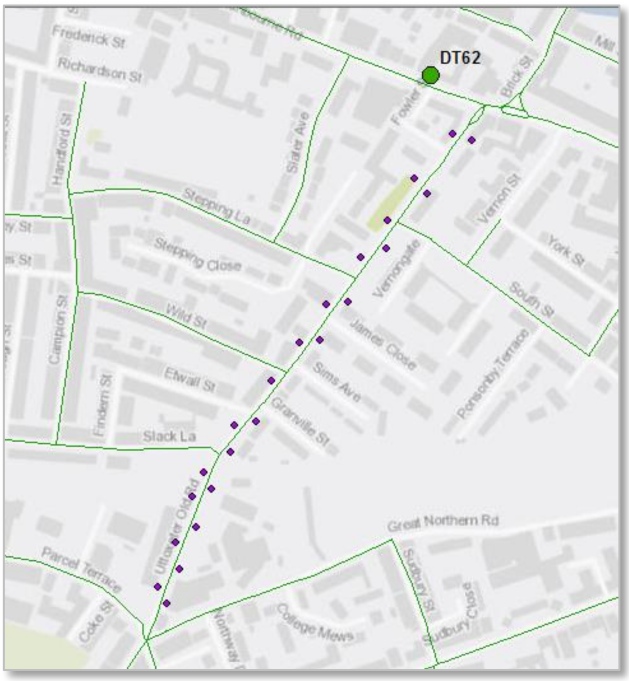


Table 6: NO_2 annual mean concentration results for each option in 2020 ($\mu g.m^{-3}$)

Census ID	Road Name	Length (m)	Road management description	X	Y	Option results in 2020 (Test 5 in 2025)				
						Test 1 Baseline	Test 2 Do Min	Test 3 TM Scheme	Test 4 CAZ D	Test 5 2025 Reference
16361	A38	2,166	Highways England	434682	338879	35.8	35.6	35.8	35.0	24.2
16362	A38	595	Highways England	431094	333377	36.0	35.9	35.9	32.3	25.2
16520	A52	912	Derby City Council	434000	336700	30.5	28.3	28.6	21.9	21.1
18308	A6005	656	Derby City Council	439000	335820	33.4	33.3	33.4	29.1	23.1
18373	A5111	676	Derby City Council	438560	333380	26.0	25.6	25.8	24.0	18.1
18386	A6096	760	Derby City Council	440000	335870	25.6	24.4	24.8	24.7	16.9
27256	A514	1,553	Derby City Council	436840	333000	34.6	33.9	34.3	25.1	26.2
27766	A5111	656	Derby City Council	433000	335970	24.7	24.4	25.1	24.4	18.2
27767	A5111	1,278	Derby City Council	437900	333000	28.0	27.6	27.7	25.6	21.1
27788	A5250	653	Local Authority	435000	335470	26.4	25.9	25.7	22.7	21.2
27938	A601	168	Derby City Council	435600	335680	32.9	32.3	33.5	26.7	23.6
28014	A61	1,314	Derby City Council	436112	336742	32.0	31.7	32.4	27.5	22.5
28255	A5250	1,112	Derby City Council	434200	334910	25.1	24.3	24.8	20.7	19.7
28431	A6005	399	Derby City Council	438900	335700	28.8	28.6	28.7	27.6	19.6
37288	A516	1,314	Derby City Council	434400	336000	30.0	26.3	24.8	22.2	19.6
37405	A608	3,003	Derby City Council	436970	339000	26.9	25.9	26.2	24.5	18.6
37810	A5111	1,183	Derby City Council	434000	334150	26.0	25.9	26.3	24.1	20.6
37967	A52	2,268	Derby City Council	437350	336000	38.8	38.5	38.6	31.8	27.6
38236	A601	634	Derby City Council	434830	336624	36.6	35.9	34.2	27.3	26.5
38406	A601	113	Derby City Council	434740	336300	49.3	48.5	35.5	38.0	36.1
46171	A5194	2,048	Derby City Council	436000	335361	32.3	30.7	30.8	28.3	24.2
46394	A38	1,341	Highways England	432600	335910	34.5	34.4	34.5	31.2	25.0
46556	A52	557	Derby City Council	436000	336500	34.9	34.8	34.9	26.7	25.1

Census ID	Road Name	Length (m)	Road management description	X	Y	Option results in 2020 (Test 5 in 2025)				
						Test 1 Baseline	Test 2 Do Min	Test 3 TM Scheme	Test 4 CAZ D	Test 5 2025 Reference
47261	A514	1,899	Derby City Council	435930	335000	33.3	32.4	32.7	28.0	26.7
47768	A5111	1,618	Derby City Council	436000	333300	33.0	32.6	32.8	31.5	25.4
47796	A6005	990	Derby City Council	439950	335330	26.0	24.7	25.2	24.6	16.9
47986	A601	442	Derby City Council	435700	336000	38.0	36.6	37.2	29.7	30.9
56162	A6	952	Derby City Council	435200	340000	23.0	22.7	22.7	22.0	15.5
56563	A52	1,579	Derby City Council	433000	337070	25.3	25.0	24.9	23.4	18.0
57677	A5111	1,127	Derby City Council	435000	333580	33.7	32.9	33.6	32.3	24.9
57767	A38	1,870	Highways England	433000	336550	37.4	37.1	37.6	35.0	24.7
58080	A6005	462	Derby City Council	439860	335400	34.1	33.9	34.1	29.4	23.6
6167	A6	3,576	Derby City Council	434850	339000	36.1	35.9	36.5	26.4	25.7
6540	A52	328	Highways England	439650	335620	34.3	34.0	34.2	29.6	23.7
70040	A601	830	Local Authority	434850	336000	23.7	23.2	23.1	21.3	19.5
7228	A514	1,801	Derby City Council	437200	332000	25.1	24.6	24.6	22.0	19.5
7232	A516	1,671	Derby City Council	432746	335093	27.7	27.6	27.7	25.3	19.3
73356	A52	2,808	Highways England	440500	335540	34.4	34.1	34.3	30.2	23.9
73357	A6096	4,350	Derby City Council	440760	336420	21.1	20.2	20.5	21.3	14.3
73359	A61	1,435	Derby City Council	436260	338500	26.5	26.3	26.5	26.2	18.7
73362	A516	2,631	Highways England	430700	333800	27.1	26.8	27.1	24.5	19.5
74456	A38	1,088	Highways England	431840	334780	39.6	38.5	38.5	36.1	26.7
75406	A5250	450	Local Authority	435320	335550	28.3	27.8	28.6	24.4	20.7
75407	A5250	281	Local Authority	435300	335470	26.7	25.5	25.7	23.5	19.9
75408	A5250	207	Local Authority	435100	335450	22.6	22.3	22.4	21.6	18.4
75410	A52	571	Derby City Council	434700	336500	32.8	32.0	28.1	25.4	23.9
75411	A52	278	Derby City Council	434700	336400	32.2	31.1	26.9	25.2	23.6

Census ID	Road Name	Length (m)	Road management description	X	Y	Option results in 2020 (Test 5 in 2025)				
						Test 1 Baseline	Test 2 Do Min	Test 3 TM Scheme	Test 4 CAZ D	Test 5 2025 Reference
75412	A601	163	Local Authority	434800	336090	26.6	23.0	23.2	21.2	17.9
75415	A601	132	Local Authority	434800	336220	24.0	23.7	20.7	21.3	18.2
75416	A516	113	Local Authority	434700	336120	27.9	23.9	23.2	21.4	18.5
76083	A52	202	Derby City Council	439700	335640	32.4	32.3	32.3	28.6	22.4
76084	A5111	319	Highways England	439050	335500	33.9	33.9	34.1	31.3	24.0
76085	A52	1,221	Highways England	439400	335520	38.4	38.2	38.3	31.5	26.8
7702	A5111	1,221	Derby City Council	433300	335000	28.3	28.0	28.5	25.1	19.7
7877	A601	510	Derby City Council	435500	336660	37.7	37.6	37.0	27.6	26.7
81020	A5111	1,189	Highways England	438525	334996	38.3	38.2	38.5	34.9	28.2
81077	A5111	886	Derby City Council	438640	333640	34.4	34.0	34.5	31.3	24.9
81246	A6	1,692	Derby City Council	437824	334027	39.4	34.8	32.3	30.3	24.8
81247	A601	392	Derby City Council	435738	336288	37.2	37.0	37.1	28.0	25.7
81248	A6	2,506	Derby City Council	436312	335775	38.6	36.8	37.1	31.3	26.0
81435	A601	267	Derby City Council	434748	336051	27.2	25.8	26.1	21.6	19.4
81436	A601	400	Derby City Council	435070	335767	26.7	26.5	27.2	21.8	20.2
81437	A601	320	Derby City Council	435368	335616	33.9	33.1	34.4	26.8	24.3
81443	A5250	360	Derby City Council	435071	335590	30.3	29.1	29.6	24.2	21.7
8227	A6096	455	Derby City Council	440040	335640	32.3	31.3	31.8	29.6	21.6
83044	A601	164	Derby City Council	434700	336190	30.4	30.0	24.8	25.3	22.7

Figure 9: Annual mean NO_2 concentration for Test 2 Do Minimum in 2020

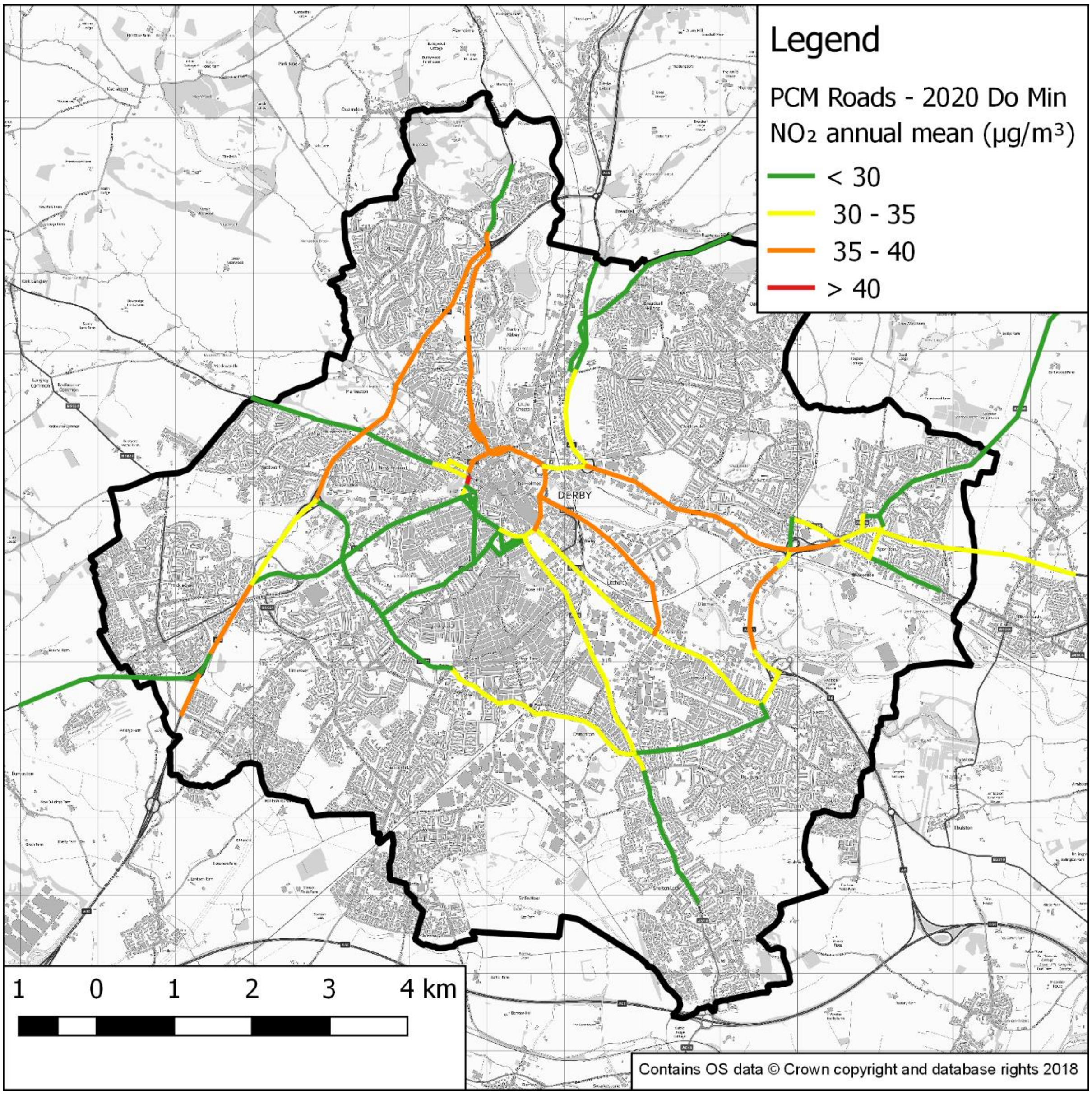


Figure 10: Annual mean NO_2 concentration for Test 3 Traffic management scheme

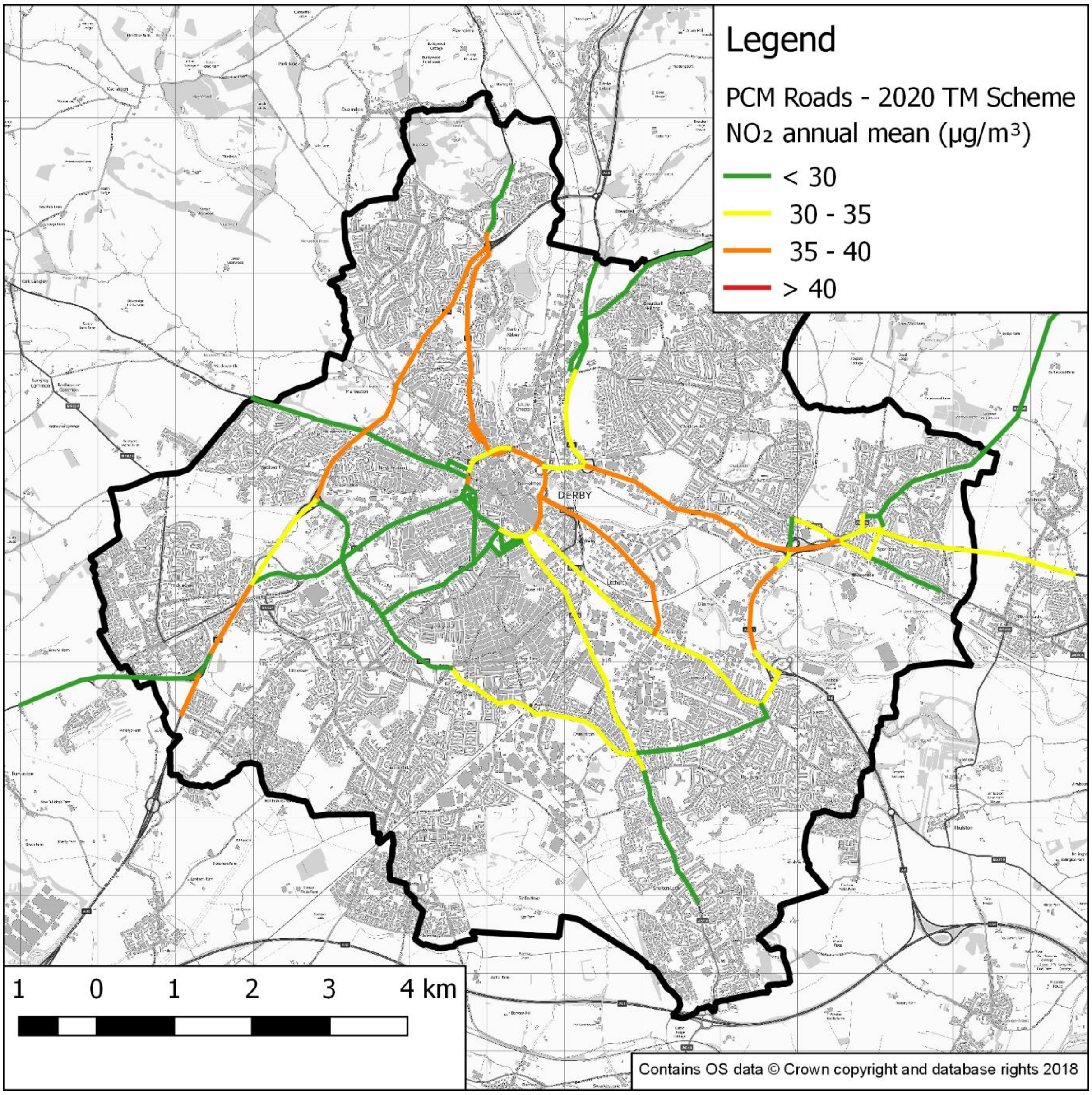


Figure 11: Annual mean NO_2 concentrations for Test 4 Class D CAZ charging scheme

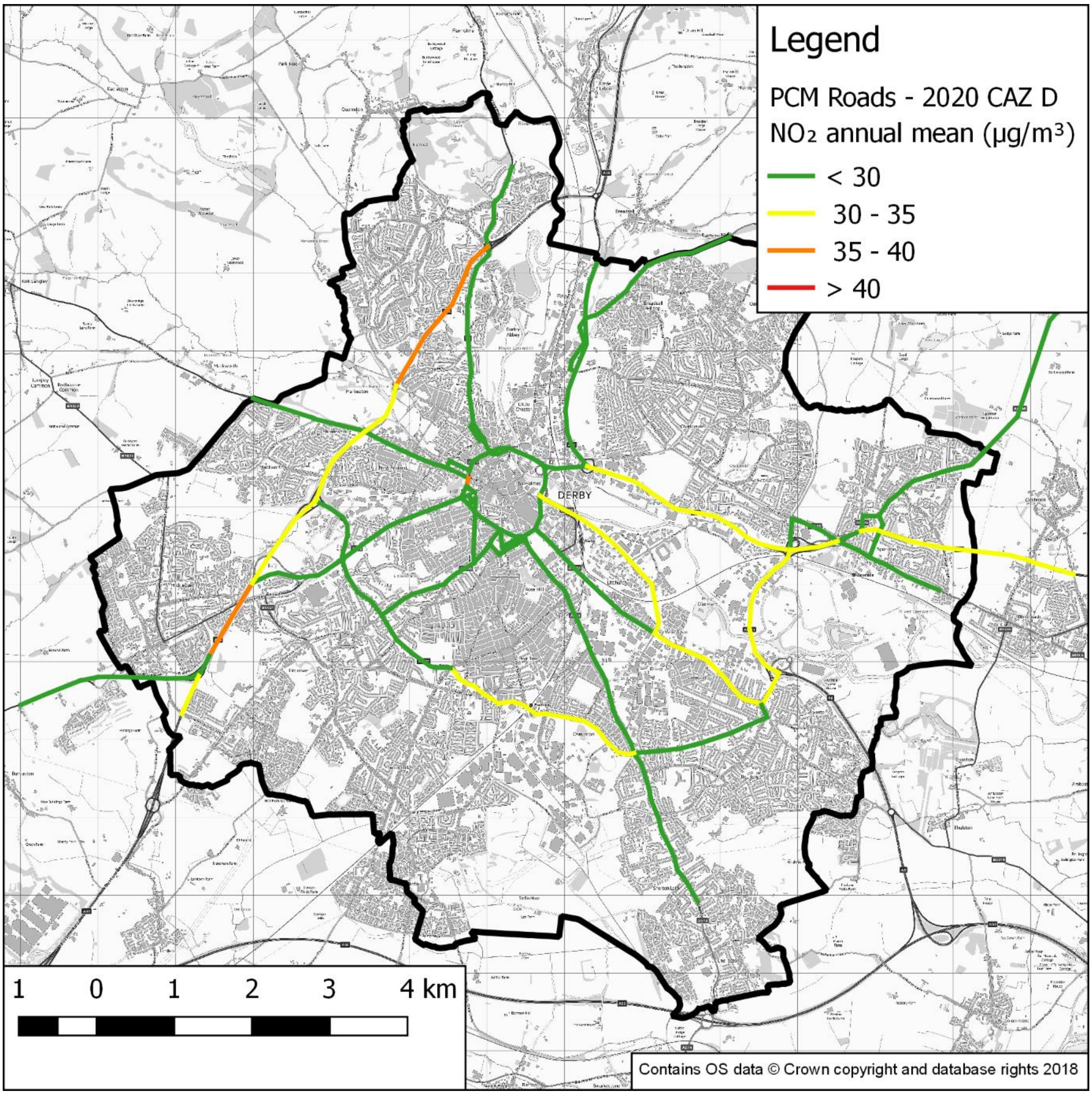
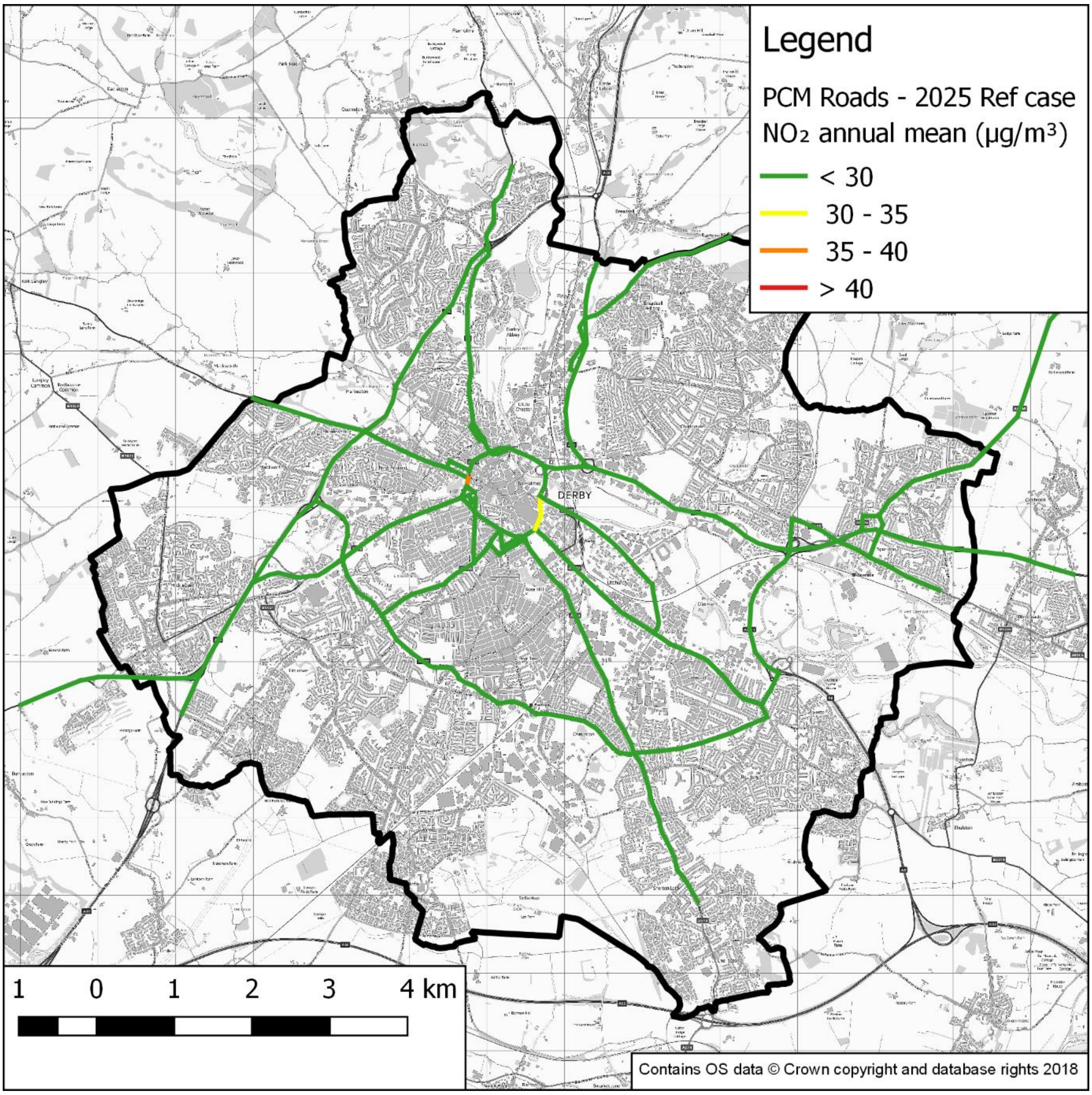


Figure 12: Annual mean NO_2 concentration for the Test 5 Reference 2025 results



4.2 Results at key monitoring locations

Modelled NO_2 annual mean concentrations have also been extracted from the model for each of the monitoring locations in Derby. As with the baseline scenarios we have presented the results calculated using both the global Road NOx adjustment factor in Table 7, and the site-specific adjustment factor in

Table 8. These results provide an indication of the impact of the options in relation to localised areas of concern relevant to local air quality management.

It should be noted that the use of global Road NOx adjustment figures are the approved methodology for the assessment. However, to ensure the approach is as thorough as possible, it is good practice to also consider the results with site specific adjustment factors. Where these sets of results show any deviations, these have been explored further and any risks considered. However, there will be inherent differences in the two sets of data.

The results using the global road NOx adjustment indicate that NO_2 annual mean concentrations will be below the 40 µg.m^{-3} limit value at monitoring sites for all of the options modelled with the exception of DT50 under the TMS, and DT10 under charging CAZ D:

- DT50 is located on the roundabout linking the London Road and the Inner Ring Road and shows a value of 40.5 µg.m^{-3} which is on the border line of exceedance. However, this location has no significance for compliance with the EU Limit Value as the result is removed when applying the requirements of the EU Directive, which specifically excludes locations within 25m of a major junction.

- DT10 is on Nottingham Road and shows a value of 41.8 µg.m^{-3}, which is likely to be generated by traffic diversion around the charging CAZ D scheme, but this is not present in the 'Do Min', TMS and 2025 future reference case scenarios. This exceedance is also not seen when site specific adjustment is considered below.

However, these results should be considered in context with the model uncertainty and differences between measured and modelled concentrations in the 2016 baseline scenario as described in Appendix 1. This is apparent in the results calculated using a site-specific road NOx adjustment which indicates some remaining exceedance issues in relation to the 'Do Minimum', TMS option and CAZ D scenarios:

- DT11 A52 Eastgate - on the Pentagon roundabout which remains at 41.5 µg.m^{-3} in the 'do min' and TMS scenarios, but has no relevant receptors when considering LAQM standards as it is located within an industrial/commercial zone. This location is solved by the CAZ D.

- DT34 A38 Kingsway – showing levels between 49 and 51 µg.m^{-3} for all scenarios except the 2025 reference case. Again, this is of little concern with respect to direct health implications as there is no relevant exposure under LAQM standards. This is part of Highways England's strategic road network, rather than Derby City Council's local road network and will be strongly influenced by the proposed A38 improvements with compliance shown in 2025 when this scheme is completed. As such Derby City Council are committed to sharing the outcome of this study and working with Highways England to consider this as appropriate in association with the planned A38 work.

- DT57 St Alkmunds Way – showing levels at 48.4 µg.m^{-3} under the 'Do Minimum scenario dropping to 46.5 µg.m^{-3} with the traffic management scheme in place, and is solved with the CAZ D. This is, in effect, a kerbside location which creates significant modelling uncertainty due to being so close to the carriageway. It is also not representative of exposure being so close to the carriageway and so has no relevant receptors under LAQM standards.

DT11 and DT34, as noted previously, have no relevant exposure so have not been considered a concern under the LAQM regime. That leaves DT57 on St Alkmunds Way that could indicate a location of concern that still remains under both the ‘Do Minimum and TMS scenarios.

The location along St Alkmunds way has been explored further in terms of potential concern. At this location there is another monitoring site (DT56) which is not kerbside, being about 5m from the road, and can be considered to be more representative of exposure and the EU Directive compliance standards. The local site results at DT56 also indicate that the model with the global adjustment factor is under-predicting, but to a lesser degree. However, the results at this location do show compliance with the 40 $\mu g.m^{-3}$ limit in the baseline, do minimum and traffic management scenarios using both global and site-specific adjustment.

A further check was carried out using the site-specific adjustment factors derived from DT56 and DT57 and applying these to nearby PCM receptors along St Alkmunds Way. Adjustment using the factor from DT56, which could be considered the more representative of this location, indicated compliance with the limit value in both the ‘Do min’ and TMS scenarios. Adjustment using the factor from DT57 indicated non-compliance with the limit value in the ‘Do min’ scenario but compliance with the traffic management scenario. These further checks suggest that any potential compliance issue here can be solved by the traffic management scheme.

Table 7: NO_2 annual mean concentration results at monitoring sites for each option in 2020 using global Road NOx adjustment factor ($\mu g.m^{-3}$)

Monitoring site name	Site ID	Site type	NO_2 annual mean ($\mu g.m^{-3}$)			
			Test 2 Do min	Test 3 TM scheme	Test 4 CAZ D	Test 5 2025 Reference
23 Gilbert Close	DT1	Roadside	28.2	28.2	25.3	19.5
10 Kirkleys Ave North	DT2	Roadside	25.6	25.6	23.2	17.9
27 Kirkleys Ave South	DT3	Roadside	23.3	23.4	21.6	16.3
24 Nottingham	DT4	Roadside	22.4	22.6	22.7	15.5
1 Station Road	DT5	Roadside	24.7	24.9	24.3	16.8
23 Leeway	DT6	Roadside	28.0	28.1	26.1	19.1
1 Drury Avenue	DT7	Roadside	26.1	26.2	24.0	18.3
198 Derby Road	DT8	Roadside	26.9	26.9	27.0	18.1
109 Highfield Lane	DT9	Roadside	27.4	27.3	23.9	19.7
203/201 Nottingham Road	DT10	Roadside	38.0	37.6	41.8	26.5
Eastgate (Pentagon)	DT11	Roadside	30.8	30.9	24.4	22.6
Bass Recreation Ground/The Holmes	DT12	UB	36.8	36.9	28.0	25.9
16/18 Harrow Road	DT13	Roadside	35.3	35.1	30.8	26.2
713 London Road	DT14	Roadside	30.7	30.8	28.3	24.2
938 London Road	DT15	Roadside	32.7	29.3	28.3	22.8
1178 London Road	DT16	Roadside	19.4	18.8	18.4	14.4
7 Raynesway	DT17	Roadside	20.7	20.8	19.6	15.4
772 Osmaston Road	DT18	Roadside	24.5	24.5	20.5	19.0
831 Osmaston Road	DT19	Roadside	24.5	24.2	21.8	19.3
113 Chellaston Road	DT20	Roadside	21.0	21.1	19.2	16.3
376 Osmaston Park Road	DT21	Kerbside	23.5	23.7	21.2	18.4
523 Osmaston Park Road	DT22	Roadside	26.3	26.6	25.2	20.8
104 Osmaston Park Road	DT23	Roadside	31.3	31.7	30.4	24.6
32 Newdigate Street	DT24	Roadside	30.2	30.9	30.0	23.3

Monitoring site name	Site ID	Site type	NO_2 annual mean (µg.m^{-3})			
			Test 2 Do min	Test 3 TM scheme	Test 4 CAZ D	Test 5 2025 Reference
80 Newdigate Street	DT25	Roadside	28.9	29.6	29.2	22.9
Warwick Ave monitoring station	DT26	Kerbside	23.5	23.6	22.0	16.7
2a Lime Walk	DT29	Roadside	21.4	21.5	20.3	15.5
430 Uttoxeter New Road	DT30	Roadside	24.0	23.7	21.2	16.7
431 Uttoxeter New Road	DT31	Roadside	27.8	27.8	24.1	19.5
266 Uttoxeter New Road	DT32	Roadside	25.3	25.0	21.4	18.7
150 Radbourne Street	DT33	Roadside	23.0	23.2	22.6	16.1
Kingsway / A38	DT34	Roadside	32.7	33.2	31.9	23.2
199 Uttoxeter New Road	DT35	Roadside	23.5	22.9	20.3	17.2
59a Stafford Street	DT36	Roadside	30.0	25.2	24.9	22.9
4 Dunkirk	DT37	Roadside	20.2	20.2	18.7	15.8
Wilson Street West	DT38	Roadside	22.0	22.2	19.7	17.4
201 Abbey Street	DT39	Roadside	22.8	22.9	20.9	18.8
315 Burton Road	DT40	Roadside	20.1	20.0	18.7	16.8
220 Burton Road	DT41	Roadside	23.1	23.0	21.1	20.1
114a Burton Road	DT42	Roadside	25.6	25.6	22.7	20.6
131 Green Lane	DT43	Roadside	25.2	25.9	22.4	19.3
57 Normanton Road	DT44	Roadside	25.5	25.7	23.0	19.7
29 Ivy Square off Osmaston Road	DT45	Roadside	31.4	31.6	27.4	23.9
114 Osmaston Road	DT46	Roadside	26.3	26.3	24.6	19.4
Bradshaw Way	DT47	Roadside	34.9	36.4	28.0	25.4
London Road/Westfield	DT48	Roadside	24.9	26.8	32.5	19.5
59 Osmaston Road	DT49	Roadside	28.9	29.2	25.9	21.3
Royal Telegraph Pub	DT50	Roadside	39.9	40.5	29.9	27.6
176 Siddals Road	DT51	Roadside	27.4	27.4	23.5	19.9
123 Nottingham Road	DT52	Roadside	24.5	24.4	21.4	17.4
63 Nottingham Road	DT53	Roadside	36.1	35.6	26.9	25.5
14 Mansfield Road	DT54	Roadside	30.7	31.1	24.6	21.7
171 Mansfield Road	DT55	Roadside	23.5	23.6	20.3	16.2
St Marys Court	DT56	Roadside	30.4	29.6	24.1	22.0
St Alkmunds Way	DT57	Roadside	36.1	35.0	27.0	26.0
171/182 Cavendish Court	DT58	Roadside	28.9	27.2	23.5	21.6
Stafford Street Burleigh Mews Flats	DT59	Roadside	45.2	33.9	35.8	33.7
189/191 Ashbourne Road	DT60	Roadside	33.7	32.1	24.0	27.4
148 Ashbourne road	DT61	Roadside	23.8	23.2	19.0	17.1
Millgate, Ashbourne Road	DT62	Roadside	27.5	27.5	21.5	20.8
Friargate / Bridge Street corner	DT63	Roadside	27.9	26.9	21.7	20.6
Bridge Street / Agard Street	DT64	Roadside	28.8	28.9	22.3	21.3
8 / 10 Agard Street	DT65	Roadside	25.6	25.3	21.1	19.2
69 King Street	DT66	Roadside	25.6	25.3	21.3	19.1
Duffield Road (55 West Avenue)	DT68	Roadside	26.0	26.9	21.0	19.8

Monitoring site name	Site ID	Site type	NO_2 annual mean (µg.m^{-3})			
			Test 2 Do min	Test 3 TM scheme	Test 4 CAZ D	Test 5 2025 Reference
8 Kedleston Road (Chiropodist)	DT69	Roadside	23.6	24.6	20.1	18.2
Duffield Road/North Street	DT70	Roadside	25.5	26.6	20.7	19.6
5 Duffield Road	DT71	Roadside	35.7	36.2	26.3	25.5
14 The Strand	DT72	Roadside	19.0	19.2	18.7	14.7
Victoria Street/Corn Market	DT73	Roadside	21.4	21.5	21.5	16.9
Morledge	DT74	Roadside	22.6	22.6	21.8	16.5
25 Morledge	DT75	Roadside	21.6	21.6	21.2	15.8
Council House	DT76	Urb Centre	20.4	20.4	20.1	14.8

Table 8: NO_2 annual mean concentration results at monitoring sites for each option in 2020 using site specific Road NOx adjustment factor (µg.m^{-3})

Monitoring site name	Site ID	Site type	NO_2 annual mean (µg.m^{-3})			
			Test 2 Do min	Test 3 TM scheme	Test 4 CAZ D	Test 5 2025 Reference
23 Gilbert Close	DT1	Roadside	25.0	25.0	22.9	17.3
10 Kirkleys Ave North	DT2	Roadside	25.4	25.4	23.1	17.7
27 Kirkleys Ave South	DT3	Roadside	22.1	22.1	20.7	15.4
24 Nottingham	DT4	Roadside	29.7	30.0	30.0	20.1
1 Station Road	DT5	Roadside	25.5	25.7	25.0	17.3
23 Leeway	DT6	Roadside	23.8	23.9	22.7	16.3
1 Drury Avenue	DT7	Roadside	23.0	23.1	21.6	16.1
198 Derby Road	DT8	Roadside	24.6	24.6	24.7	16.6
109 Highfield Lane	DT9	Roadside	24.0	23.9	21.8	17.3
203/201 Nottingham Road	DT10	Roadside	34.7	34.3	38.2	24.2
Eastgate (Pentagon)	DT11	Roadside	41.5	41.6	29.4	30.6
Bass Recreation Ground/The Holmes	DT12	UB	30.3	30.4	24.8	21.5
16/18 Harrow Road	DT13	Roadside	25.6	25.6	25.6	20.3
713 London Road	DT14	Roadside	23.7	23.6	24.5	19.7
938 London Road	DT15	Roadside	33.6	29.9	28.8	23.2
1178 London Road	DT16	Roadside	26.7	23.9	22.1	17.9
7 Raynesway	DT17	Roadside	25.0	25.3	22.9	18.2
772 Osmaston Road	DT18	Roadside	22.3	22.3	19.5	17.8
831 Osmaston Road	DT19	Roadside	22.9	22.7	20.8	18.3
113 Chellaston Road	DT20	Roadside	24.4	24.5	21.7	18.6
376 Osmaston Park Road	DT21	Kerbside	21.4	21.5	19.8	17.1
523 Osmaston Park Road	DT22	Roadside	23.3	23.5	22.5	18.8
104 Osmaston Park Road	DT23	Roadside	36.2	36.7	34.9	27.8
32 Newdigate Street	DT24	Roadside	35.3	36.2	35.1	26.4

Monitoring site name	Site ID	Site type	NO_2 annual mean ($\mu g.m^{-3}$)			
			Test 2 Do min	Test 3 TM scheme	Test 4 CAZ D	Test 5 2025 Reference
80 Newdigate Street	DT25	Roadside	35.8	36.8	36.3	27.2
Warwick Ave monitoring station	DT26	Kerbside	39.2	39.6	35.2	26.4
2a Lime Walk	DT29	Roadside	22.3	22.4	21.1	16.1
430 Uttoxeter New Road	DT30	Roadside	22.4	22.1	20.1	15.7
431 Uttoxeter New Road	DT31	Roadside	23.4	23.4	20.9	16.7
266 Uttoxeter New Road	DT32	Roadside	27.7	27.3	22.9	20.3
150 Radbourne Street	DT33	Roadside	25.4	25.6	24.8	17.8
Kingsway / A38	DT34	Roadside	51.0	51.8	49.9	37.5
199 Uttoxeter New Road	DT35	Roadside	21.5	21.0	19.1	15.9
59a Stafford Street	DT36	Roadside	31.4	26.1	25.8	23.8
4 Dunkirk	DT37	Roadside	22.0	22.1	19.4	17.0
Wilson Street West	DT38	Roadside	19.0	19.1	18.6	15.5
201 Abbey Street	DT39	Roadside	27.5	27.7	23.7	22.3
315 Burton Road	DT40	Roadside	23.4	23.3	20.8	19.1
220 Burton Road	DT41	Roadside	25.5	25.5	22.6	21.8
114a Burton Road	DT42	Roadside	26.6	26.7	23.3	21.3
131 Green Lane	DT43	Roadside	23.5	23.9	21.6	18.1
57 Normanton Road	DT44	Roadside	29.0	29.4	24.7	21.9
29 Ivy Square off Osmaston Road	DT45	Roadside	27.2	27.3	25.0	21.2
114 Osmaston Road	DT46	Roadside	27.7	27.8	25.5	20.4
Bradshaw Way	DT47	Roadside	29.8	30.8	25.5	21.8
London Road/Westfield	DT48	Roadside	25.1	27.1	33.0	19.8
59 Osmaston Road	DT49	Roadside	26.4	26.6	24.4	19.5
Royal Telegraph Pub	DT50	Roadside	32.5	32.9	26.4	22.8
176 Siddals Road	DT51	Roadside	24.3	24.3	22.1	17.8
123 Nottingham Road	DT52	Roadside	27.3	27.2	22.8	19.3
63 Nottingham Road	DT53	Roadside	25.4	25.2	21.8	18.1
14 Mansfield Road	DT54	Roadside	24.7	24.9	21.5	17.5
171 Mansfield Road	DT55	Roadside	23.3	23.4	20.2	16.1
St Marys Court	DT56	Roadside	35.6	34.5	26.7	25.7
St Alkmunds Way	DT57	Roadside	48.4	46.5	33.3	34.6
171/182 Cavendish Court	DT58	Roadside	23.6	22.7	20.6	17.9
Stafford Street Burleigh Mews Flats	DT59	Roadside	45.9	34.3	36.2	34.2
189/191 Ashbourne Road	DT60	Roadside	31.4	30.0	22.8	25.4
148 Ashbourne road	DT61	Roadside	24.0	23.3	19.1	17.2
Millgate, Ashbourne Road	DT62	Roadside	29.7	29.7	22.5	22.4
Friargate / Bridge Street corner	DT63	Roadside	30.0	28.8	22.7	22.1
Bridge Street / Agard Street	DT64	Roadside	27.2	27.2	21.5	20.1
8 / 10 Agard Street	DT65	Roadside	29.7	29.2	23.1	22.0
69 King Street	DT66	Roadside	21.0	20.9	19.1	15.9
Duffield Road (55 West Avenue)	DT68	Roadside	27.0	28.0	21.5	20.5

Monitoring site name	Site ID	Site type	NO_2 annual mean (µg.m^{-3})			
			Test 2 Do min	Test 3 TM scheme	Test 4 CAZ D	Test 5 2025 Reference
8 Kedleston Road (Chriopodist)	DT69	Roadside	21.1	21.8	18.8	16.2
Duffield Road/North Street	DT70	Roadside	26.0	27.0	20.9	19.9
5 Duffield Road	DT71	Roadside	30.0	30.4	23.4	21.7
14 The Strand	DT72	Roadside	21.6	22.2	19.9	16.5
Victoria Street/Corn Market	DT73	Roadside	19.4	19.4	19.4	14.7
Morledge	DT74	Roadside	23.4	23.4	22.4	17.1
25 Morledge	DT75	Roadside	22.5	22.5	21.8	16.5
Council House	DT76	Urb Centre	20.1	20.1	20.0	14.7

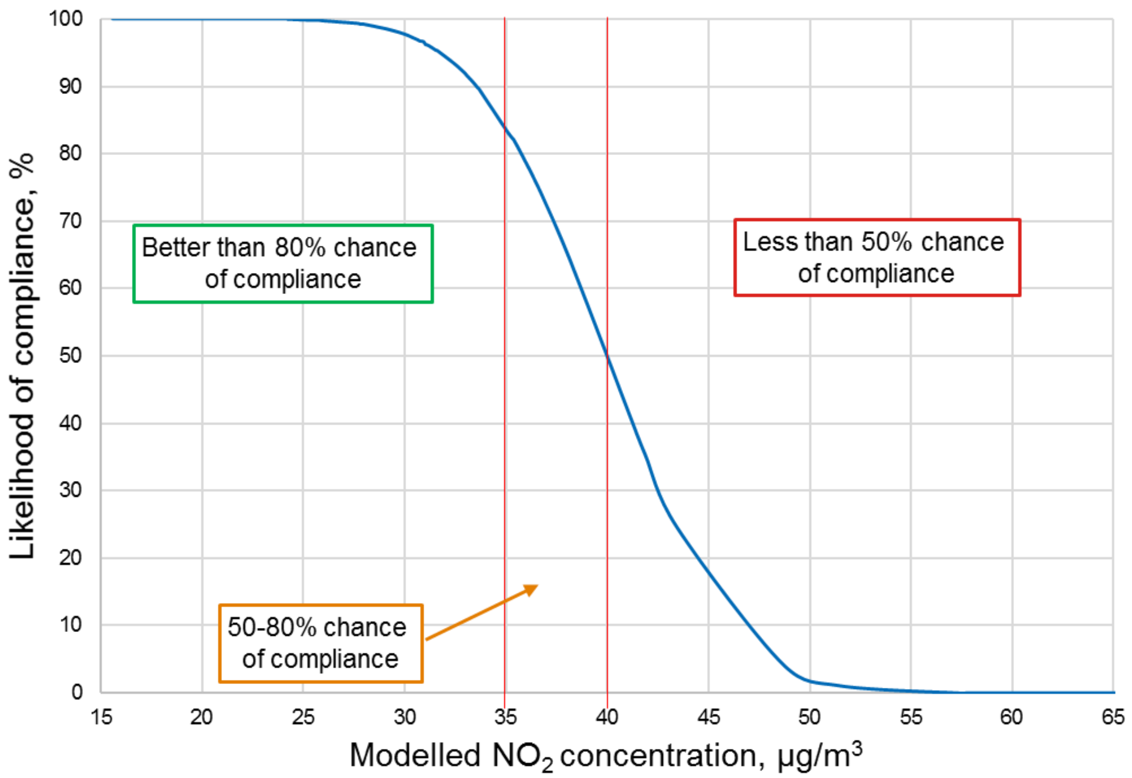
5 Sensitivity analysis

5.1 Model performance

Overall model performance is assessed both in the transport model and air quality model for the base year comparing modelled and measured data. Ultimately the combined level of model performance is assessed through verification of the air quality model against measured concentration data. In this process model performance and uncertainty is assessed using the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations, as detailed in Technical Guidance LAQM.TG(16). In this case the RMSE was calculated at 4.9 $\mu g.m^{-3}$ as described in section 3.3. This can then be used as a measure of uncertainty on forecast results for future years.

The RMSE can also be used to indicate likelihood of achieving a given results based on this level of model uncertainty as illustrated in Figure 13. This shows that for a model with an RMSE of 5 $\mu g.m^{-3}$ a modelled result of 35 $\mu g.m^{-3}$ or less is required to have an 80% or better likelihood of compliance. This uncertainty metric has therefore been used when considering the results by identifying locations over 35 $\mu g.m^{-3}$ as being at risk of exceedance.

Figure 13 Probability distribution of compliance with an RMSE of 5 µg.m^{-3}



Full details and results of the air quality model verification process is included in appendix 1.

5.2 Option assumption sensitivity tests

The sensitivity tests that have been carried out for the Derby modelling to test the robustness of the outcomes were defined in section 6 of the AQ2 methodology report. These comprise two tests on the options being compared and a set of wider tests on model parameters. The results of the option sensitivity tests are provided in this section with the results of the wider sensitivity tests provided in section 5.3.

The two option sensitivity tests carried out were:

- *The traffic management scheme without the clean bus technology fund* improvements to the bus fleet. This test was to assess whether compliance would still be achieved if no bus operators took up the funding and upgraded their non-Euro VI vehicles to Euro VI. This is the worst-case scenario and currently commitments have been made by the bus operators to upgrade 66% of the non-compliant fleet.

- *The CAZ D charging with no upgrade response*. This is again the worst-case scenario in which no one upgrades their vehicles and all drivers opt to either pay the charge, divert or not make the trip. These responses are determined by the traffic model.

The results from these two tests are shown in Table 9 and Table 10 below.

The test on the preferred traffic management option clearly shows that without the CBTF concentrations would increase for many of the PCM links, with some significant increases where bus flows are large. However, even with these increases no PCM link is pushed into non-compliance with the NO_2 limit value. This then indicates that even with a poor uptake of the CBTF by bus operators the preferred traffic management scheme would still achieve compliance.

With the CAZ D 0% upgrade test there are significant increases in NO_2 concentration against the benchmark scheme as might be expected. Therefore, the impact of the scheme would be significantly reduced in this extreme case. In fact with no upgrade response the CAZ D would be little better that the 'do min' situation with a significant NO_2 exceedance still existing on Stafford Street. This indicates that the scheme is sensitive to the upgrade assumption as it is this upgrade effect that generates most of the benefit of the scheme.

Table 9: 2020 Preferred Traffic Management Option – comparison of modelled NO_2 annual mean concentrations with and without the effect of the Clean Bus Technology Fund (CBTF)

CensusID	Road Name	2020 NO_2 annual mean concentration ($\mu g.m^{-3}$)		
		Pref TM scheme (with CBTF)	Pref TM scheme (no CBTF)	% change in concentration
16361	A38	36	36	0%
16362	A38	36	36	0%
16520	A52	29	29	2%
18308	A6005	33	33	0%
18373	A5111	26	26	1%
18386	A6096	25	26	4%
27256	A514	34	35	1%
27766	A5111	25	25	0%
27767	A5111	28	28	1%
27788	A5250	26	26	2%
27938	A601	33	34	2%

CensusID	Road Name	2020 NO_2 annual mean concentration (µg.m^{-3})		
		Pref TM scheme (with CBTF)	Pref TM scheme (no CBTF)	% change in concentration
28014	A61	32	32	0%
28255	A5250	25	26	3%
28431	A6005	29	29	0%
37288	A516	25	29	18%
37405	A608	26	27	3%
37810	A5111	26	26	0%
37967	A52	39	39	0%
38236	A601	34	34	0%
38406	A601	36	36	2%
46171	A5194	31	32	5%
46394	A38	34	34	0%
46556	A52	35	35	0%
47261	A514	33	33	2%
47768	A5111	33	33	1%
47796	A6005	25	26	4%
47986	A601	37	38	4%
56162	A6	23	23	1%
56563	A52	25	25	1%
57677	A5111	34	34	2%
57767	A38	38	38	0%
58080	A6005	34	34	0%
6167	A6	37	37	0%
6540	A52	34	34	0%
70040	A601	23	23	2%
7228	A514	25	25	1%
7232	A516	28	28	0%
73356	A52	34	34	0%
73357	A6096	20	21	4%
73359	A61	26	27	0%
73362	A516	27	27	0%
74456	A38	39	40	3%
75406	A5250	29	29	1%
75407	A5250	26	27	4%
75408	A5250	22	23	2%
75410	A52	28	29	3%
75411	A52	27	28	4%
75412	A601	23	27	15%
75415	A601	21	23	9%
75416	A516	23	28	20%
76083	A52	32	32	0%
76084	A5111	34	34	0%

CensusID	Road Name	2020 NO_2 annual mean concentration (µg.m^{-3})		
		Pref TM scheme (with CBTF)	Pref TM scheme (no CBTF)	% change in concentration
76085	A52	38	38	0%
7702	A5111	29	29	0%
7877	A601	37	37	0%
81020	A5111	38	38	0%
81077	A5111	35	35	0%
81246	A6	32	37	13%
81247	A601	37	37	0%
81248	A6	37	39	4%
81435	A601	26	27	3%
81436	A601	27	27	0%
81437	A601	34	35	2%
81443	A5250	30	31	4%
8227	A6096	32	33	3%
83044	A601	25	26	3%

Table 10: 2020 CAZ D – comparison of modelled NO_2 annual mean concentrations when zero percent vehicle upgrade sensitivity is tested

CensusID	Road Name	2020 NO_2 annual mean concentration (µg.m^{-3})		
		CAZ D using JAQU upgrade assumptions	CAZ D 0% upgrade sensitivity test	% change
16361	A38	35	36	2%
16362	A38	32	34	6%
16520	A52	22	25	15%
18308	A6005	29	32	10%
18373	A5111	24	26	9%
18386	A6096	25	25	3%
27256	A514	25	31	24%
27766	A5111	24	26	5%
27767	A5111	26	28	11%
27788	A5250	23	25	8%
27938	A601	27	30	10%
28014	A61	27	30	9%
28255	A5250	21	23	10%
28431	A6005	28	29	5%
37288	A516	22	25	11%
37405	A608	25	27	9%
37810	A5111	24	26	8%
37967	A52	32	36	12%

CensusID	Road Name	2020 NO_2 annual mean concentration ($\mu g.m^{-3}$)		
		CAZ D using JAQU upgrade assumptions	CAZ D 0% upgrade sensitivity test	% change
38236	A601	27	31	14%
38406	A601	38	45	19%
46171	A5194	28	30	7%
46394	A38	31	33	5%
46556	A52	27	30	13%
47261	A514	28	32	13%
47768	A5111	31	34	9%
47796	A6005	25	25	3%
47986	A601	30	35	16%
56162	A6	22	23	5%
56563	A52	23	25	6%
57677	A5111	32	35	8%
57767	A38	35	36	3%
58080	A6005	29	32	9%
6167	A6	26	31	18%
6540	A52	30	33	10%
70040	A601	21	23	10%
7228	A514	22	25	12%
7232	A516	25	27	6%
73356	A52	30	33	9%
73357	A6096	21	22	1%
73359	A61	26	28	6%
73362	A516	24	26	7%
74456	A38	36	39	8%
75406	A5250	24	26	6%
75407	A5250	24	26	10%
75408	A5250	22	22	3%
75410	A52	25	28	11%
75411	A52	25	28	10%
75412	A601	21	23	8%
75415	A601	21	23	6%
75416	A516	21	23	8%
76083	A52	29	31	8%
76084	A5111	31	33	6%
76085	A52	31	35	12%
7702	A5111	25	28	12%
7877	A601	28	32	16%
81020	A5111	35	37	7%
81077	A5111	31	34	8%
81246	A6	30	34	11%

CensusID	Road Name	2020 NO_2 annual mean concentration ($\mu g.m^{-3}$)		
		CAZ D using JAQU upgrade assumptions	CAZ D 0% upgrade sensitivity test	% change
81247	A601	28	33	18%
81248	A6	31	35	13%
81435	A601	22	25	14%
81436	A601	22	24	8%
81437	A601	27	30	10%
81443	A5250	24	27	13%
8227	A6096	30	31	6%
83044	A601	25	28	10%

5.3 Wider sensitivity tests

Both priority and recommended sensitivity tests regarding potential areas of uncertainty in the air quality modelling, as suggested by JAQU have been considered. A review of the various tests is included in Section 6 of the AQ2 methodology report. The review concluded that two of the priority sensitivity tests would be modelled to quantify the potential change in predicted NO_2 annual mean concentrations; and for a number of the remaining recommended tests, discussion would be provided to justify the modelling approach and the potential for variation in the results.

5.3.1 Modelled priority test results

The priority sensitivity tests that have been modelled are:

- *Future emissions standards* - Adjust light vehicle Euro 6 fleet mix to all Euro 6a to represent a worst-case 'high emissions' scenario and re-run emission calculations and dispersion model. This test has been conducted for the 2020 baseline and the 2020 Preferred Traffic Management Option scenarios.

- *Lower f-NO_2 values in projected year by 40%*. This test has been conducted for the 2020 baseline, the 2020 Preferred Traffic Management Option, and the benchmark CAZ D scenario.

Predicted maximum concentrations on PCM links for each of these tests are presented in Table 11 to Table 13. These results can be summarised as follows:

- *Future emission standards test*:
  - When testing this sensitivity on the 2020 baseline results concentrations increase by on average 2% (or 1-2 $\mu g.m^{-3}$). This leads to one new location in excess of the 40 $\mu g.m^{-3}$ limit value - CensusID 74456 on the A38 trunk road. There are two further links that increase up to the limit at CensusID's 37967and 81246. This indicates that there is a risk of further exceedance in the baseline if Euro 6 does not perform as expected.
  - For the 2020 Preferred Traffic Management Option (including the clean bus technology fund), concentrations increase on average by 3% (1 – 2 $\mu g.m^{-3}$). The results indicate there is a risk of NO_2 annual mean concentrations equalling the 40 $\mu g.m^{-3}$ limit value at two locations - Census ID 37967 on the A52 and Census ID 74456 on the A38. Given model uncertainty discussed in section 5.1 this increases the risk of exceedance for the preferred

option, it is however a marginal exceedance and at a locations where public access is unlikely adjacent to Brian Clough Way (A52) and the A38. It is also anticipated that, due to the nature of the network wide traffic management enabled by the preferred option, if monitoring reflects this risk after scheme implementation, further modifications to the management of traffic flow could be effective in addressing the issue.

- *Lower f-NO_2 emission values* – For all three scenarios tested, lowering the proportion of primary NO_2 in the NOx to NO_2 conversion significantly reduces concentrations by an average of 5%, varying from 0% to 12% depending on traffic composition. For the Preferred Traffic Management Option, this reduction would effectively reduce all concentrations below 35 $\mu g.m^{-3}$, with the exception of one location adjacent to Brian Clough Way (A52) where the predicted concentration is 36 $\mu g.m^{-3}$, so removing most remaining risk of exceedance. When tested on the CAZ D scenario, all concentrations are reduced to below 35 $\mu g.m^{-3}$.

Table 11: 2020 baseline sensitivity test results – Maximum predicted NO_2 annual mean on PCM links (Euro 6 emission standards test, and reduced fNO_2 ratios)

CensusID	Road Name	2020 NO_2 annual mean concentration ($\mu g.m^{-3}$)				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
16361	A38	36	37	2%	33	-9%
16362	A38	37	37	2%	33	-10%
16520	A52	31	31	1%	29	-8%
18308	A6005	34	35	3%	31	-7%
18373	A5111	26	27	1%	25	-6%
18386	A6096	26	26	1%	25	-5%
27256	A514	35	36	1%	32	-8%
27766	A5111	25	25	3%	24	-5%
27767	A5111	28	29	1%	27	-6%
27788	A5250	27	27	1%	26	-4%
27938	A601	33	34	1%	32	-5%
28014	A61	33	33	1%	30	-7%
28255	A5250	25	26	2%	24	-5%
28431	A6005	29	30	2%	28	-5%
37288	A516	30	31	2%	28	-5%
37405	A608	27	28	2%	26	-5%
37810	A5111	26	27	2%	25	-5%
37967	A52	39	40	4%	36	-8%
38236	A601	37	38	3%	34	-9%
38406	A601	49	52	5%	44	-12%
46171	A5194	33	33	1%	31	-4%
46394	A38	35	36	2%	32	-9%
46556	A52	35	36	3%	33	-8%
47261	A514	33	34	2%	32	-5%
47768	A5111	33	34	1%	31	-6%
47796	A6005	26	26	1%	25	-4%

CensusID	Road Name	2020 NO_2 annual mean concentration (µg.m^{-3})				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
47986	A601	38	39	2%	36	-7%
56162	A6	23	24	2%	22	-5%
56563	A52	25	26	2%	24	-5%
57677	A5111	34	35	2%	32	-6%
57767	A38	38	38	2%	34	-9%
58080	A6005	34	35	3%	32	-7%
6167	A6	36	38	3%	33	-9%
6540	A52	34	36	3%	32	-7%
70040	A601	24	24	1%	23	-3%
7228	A514	25	26	1%	24	-5%
7232	A516	28	29	2%	26	-6%
73356	A52	35	36	3%	32	-8%
73357	A6096	21	21	1%	21	-3%
73359	A61	27	27	2%	25	-5%
73362	A516	27	28	2%	25	-7%
74456	A38	40	41	4%	36	-10%
75406	A5250	28	29	1%	28	-3%
75407	A5250	27	27	1%	26	-3%
75408	A5250	23	23	0%	22	-1%
75410	A52	33	34	3%	31	-7%
75411	A52	32	33	3%	30	-6%
75412	A601	27	27	1%	26	-4%
75415	A601	24	25	2%	23	-3%
75416	A516	28	28	1%	27	-4%
76083	A52	33	34	3%	30	-7%
76084	A5111	34	35	3%	32	-7%
76085	A52	39	40	3%	36	-8%
7702	A5111	28	29	2%	27	-6%
7877	A601	38	39	3%	35	-8%
81020	A5111	39	40	3%	35	-8%
81077	A5111	35	36	3%	32	-8%
81246	A6	40	40	1%	37	-6%
81247	A601	38	38	2%	35	-8%
81248	A6	39	40	1%	36	-8%
81435	A601	27	28	2%	26	-5%
81436	A601	27	27	1%	26	-4%
81437	A601	34	35	2%	32	-6%
81443	A5250	31	31	1%	29	-5%
8227	A6096	33	33	2%	30	-7%

CensusID	Road Name	2020 NO_2 annual mean concentration (µg.m^{-3})				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
83044	A601	30	31	3%	29	-5%

Table 12: 2020 Preferred traffic management option (including CBTF) sensitivity test results – Maximum predicted NO_2 annual mean on PCM links (Euro 6 emission standards test, and reduced fNO_2 ratios

CensusID	Road Name	2020 NO_2 annual mean concentration (µg.m^{-3})				
		Preferred TM option	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
16361	A38	36	37	3%	33	-8%
16362	A38	36	37	4%	33	-9%
16520	A52	29	30	3%	27	-5%
18308	A6005	33	35	4%	31	-7%
18373	A5111	26	27	3%	25	-4%
18386	A6096	25	25	2%	24	-3%
27256	A514	34	35	3%	32	-6%
27766	A5111	25	26	3%	24	-5%
27767	A5111	28	28	3%	26	-5%
27788	A5250	26	26	2%	25	-3%
27938	A601	33	34	3%	32	-5%
28014	A61	32	33	3%	31	-6%
28255	A5250	25	26	3%	24	-4%
28431	A6005	29	30	3%	28	-4%
37288	A516	25	25	3%	24	-3%
37405	A608	26	27	3%	25	-5%
37810	A5111	26	27	3%	25	-4%
37967	A52	39	40	4%	36	-8%
38236	A601	34	35	4%	32	-7%
38406	A601	36	37	4%	33	-7%
46171	A5194	31	31	1%	30	-2%
46394	A38	34	36	3%	32	-8%
46556	A52	35	36	4%	33	-7%
47261	A514	33	33	2%	31	-4%
47768	A5111	33	34	3%	31	-5%
47796	A6005	25	26	2%	24	-3%
47986	A601	37	38	3%	35	-6%
56162	A6	23	23	3%	22	-4%
56563	A52	25	26	3%	24	-4%
57677	A5111	34	35	3%	32	-6%
57767	A38	38	39	3%	35	-8%

CensusID	Road Name	2020 NO_2 annual mean concentration ($\mu g.m^{-3}$)				
		Preferred TM option	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
58080	A6005	34	35	4%	32	-7%
6167	A6	37	38	4%	34	-8%
6540	A52	34	35	4%	32	-7%
70040	A601	23	23	2%	23	-2%
7228	A514	25	25	3%	24	-4%
7232	A516	28	29	3%	26	-6%
73356	A52	34	36	4%	32	-8%
73357	A6096	20	21	2%	20	-2%
73359	A61	26	27	3%	25	-5%
73362	A516	27	28	3%	25	-6%
74456	A38	39	40	5%	35	-10%
75406	A5250	29	29	2%	28	-3%
75407	A5250	26	26	1%	25	-2%
75408	A5250	22	23	1%	22	-1%
75410	A52	28	29	3%	27	-5%
75411	A52	27	28	3%	26	-4%
75412	A601	23	24	2%	23	-2%
75415	A601	21	21	1%	20	-1%
75416	A516	23	24	2%	23	-2%
76083	A52	32	34	4%	30	-6%
76084	A5111	34	35	3%	32	-6%
76085	A52	38	40	4%	35	-8%
7702	A5111	29	29	3%	27	-5%
7877	A601	37	38	4%	34	-7%
81020	A5111	38	40	4%	35	-8%
81077	A5111	35	36	4%	32	-7%
81246	A6	32	33	2%	31	-3%
81247	A601	37	38	3%	35	-7%
81248	A6	37	38	3%	35	-6%
81435	A601	26	27	3%	25	-4%
81436	A601	27	28	2%	26	-3%
81437	A601	34	35	3%	33	-5%
81443	A5250	30	30	2%	28	-4%
8227	A6096	32	33	3%	30	-6%
83044	A601	25	25	2%	24	-3%

Table 13: 2020 Preferred traffic management option (including CBTF) sensitivity test results – Maximum predicted NO_2 annual mean on PCM links (Euro 6 emission standards test, and reduced fNO_2 ratios

CensusID	Road Name	2020 NO_2 annual mean concentration ($\mu g.m^{-3}$)		
		CAZ D	fNO_2 40% reduction test	% change fNO_2 test
16361	A38	35	32	-8%
16362	A38	32	30	-8%
16520	A52	22	21	-3%
18308	A6005	29	28	-5%
18373	A5111	24	23	-4%
18386	A6096	25	24	-3%
27256	A514	25	24	-3%
27766	A5111	24	23	-4%
27767	A5111	26	25	-4%
27788	A5250	23	22	-1%
27938	A601	27	26	-2%
28014	A61	27	26	-4%
28255	A5250	21	20	-2%
28431	A6005	28	27	-4%
37288	A516	22	22	-2%
37405	A608	25	24	-3%
37810	A5111	24	23	-3%
37967	A52	32	30	-5%
38236	A601	27	26	-4%
38406	A601	38	35	-8%
46171	A5194	28	28	-1%
46394	A38	31	29	-7%
46556	A52	27	26	-3%
47261	A514	28	27	-2%
47768	A5111	31	30	-5%
47796	A6005	25	24	-3%
47986	A601	30	29	-3%
56162	A6	22	21	-4%
56563	A52	23	22	-4%
57677	A5111	32	31	-5%
57767	A38	35	32	-7%
58080	A6005	29	28	-5%
6167	A6	26	25	-4%
6540	A52	30	28	-5%
70040	A601	21	21	-1%
7228	A514	22	21	-3%
7232	A516	25	24	-5%
73356	A52	30	28	-6%
73357	A6096	21	21	-2%

CensusID	Road Name	2020 NO_2 annual mean concentration ($\mu g.m^{-3}$)		
		CAZ D	fNO_2 40% reduction test	% change fNO_2 test
73359	A61	26	25	-5%
73362	A516	24	23	-5%
74456	A38	36	33	-9%
75406	A5250	24	24	-1%
75407	A5250	24	23	-1%
75408	A5250	22	21	0%
75410	A52	25	25	-3%
75411	A52	25	24	-3%
75412	A601	21	21	-1%
75415	A601	21	21	-1%
75416	A516	21	21	-1%
76083	A52	29	27	-5%
76084	A5111	31	30	-5%
76085	A52	31	30	-5%
7702	A5111	25	24	-4%
7877	A601	28	27	-4%
81020	A5111	35	33	-7%
81077	A5111	31	29	-6%
81246	A6	30	29	-3%
81247	A601	28	27	-3%
81248	A6	31	31	-2%
81435	A601	22	21	-2%
81436	A601	22	22	-1%
81437	A601	27	26	-2%
81443	A5250	24	24	-1%
8227	A6096	30	28	-5%
83044	A601	25	24	-3%

5.3.2 Recommended sensitivity tests (not modelled)

5.3.2.1 Emissions at low speeds

JAQU suggests a method for assessing both a ‘high emissions’ and ‘low emissions’ sensitivity test for HGVs and buses modelled at speeds of less than 12kph. We have carried out this test only for the preferred traffic management scheme to test the robustness of this option in relation to uncertainty around emissions a low speed, which may be significant in this case.

In line with the guidance we have filtered all road links in the Derby 2020 traffic management scheme model with speeds less than 12kph. This identified 26 model road links meeting this criterion and these had speeds between 6kph and 11kph. All PCM receptors within 300 m of these 26 links were then used in the following analysis.

Low emissions sensitivity

No concentrations in excess of the 40 µg.m^{-3} limit value have been modelled at any of the receptors where speeds of < 12kph were identified. It was therefore not considered necessary to quantify the impact of reducing HGV and bus emissions at these locations as it would only reduce concentrations further.

High emissions sensitivity

We have used JAQU's second order polynomial, provided in the guidance, to calculate the impact on NOx emissions for Rigid HGV, Artic HGV and Buses at the slowest speed on the identified links of 6 kph which would give rise the highest emissions. However, rather than adjusting individual heavy vehicle type emissions we have used a simpler and quicker alternative screening approach where we have extracted modelled NOx and fNO_2 concentrations at 4 m from the roadside, multiplied total road NOx for all vehicles by the maximum scaling factor derived, which at 6 kph is 114% for buses. We have then applied our model calibration road NOx adjustment factor, converted NOx to NO_2 and compared annual mean concentrations with the 40 µg.m^{-3} limit value. At all receptor locations the re-adjusted NO_2 annual mean concentrations ranged from 18 to 39 µg.m^{-3}, so were less than the limit value.

The outcome of this screening approach confirms that sensitivities when modelling low speeds will not affect the conclusions of the assessment.

5.3.2.2 Zonal vs full model domain calibration

A single road NOx adjustment factor was derived from model verification and used to calculate:

- Citywide modelling results at receptor points adjacent to relevant PCM road links
- Citywide 1m resolution NO_2 annual mean concentration rasters providing a continuous representation of the spatial variation in modelled concentrations.

The use of a zonal model verification approach was also considered during our analysis of modelled vs measured road NOx; we concluded:

- There was no clear pattern in the value of road NOx adjustment factors across different zones of the city; allocating zones would therefore have been a subjective process.
- There could be various factors contributing to variable model agreement at individual measurement sites across the domain, these include uncertainties or omissions in the modelled traffic activity data, uncertainties in estimates of background concentrations, and omission of other nearby sources that have not been explicitly modelled e.g. bus stops, car parks etc. When modelling at the local scale, we typically model with a consistent background concentration across the model domain; and the impact of other sources such as car parks and bus stops can be modelled. Including this amount of detail is not however practical when modelling at city scale.
- Using a zonal approach could be considered relevant when the intention of the modelling is to focus on evidence relevant to specific areas or hotspots within the wider model domain e.g. small AQMAs. For these, applying a zone specific road NOx adjustment factor may reduce the overall average error between measured and modelled concentrations at that location and hence increase confidence in the model results and associated conclusions. However, when generating evidence relevant to citywide impacts, applying different road NOx adjustment factors across the domain may create sudden step changes in modelled concentrations at the edge of each zone. It may also have led to inconsistencies in the modelled concentrations at receptor points adjacent to relevant PCM road links where these were at the edge of a (subjectively allocated) verification zone.
- We have however presented results using road NOx adjustment factors specific to each monitoring site, as described in sections 3.2 and 4.2, which could be considered as a site specific zonal verification approach. This aims to provide an indication of when it is likely that compliance

will be achieved at each measurement site even if the required road NOx adjustment factor is higher than the slope of the best fit line across all sites.

5.3.2.3 Background NO_2 calibration

JAQU's supplementary note on sensitivity testing suggests that some local authorities may have calibrated background concentrations by comparing Defra background maps with measured background concentrations in the local area. LAs then run a sensitivity test by removing the effects of calibration if background concentrations were calibrated in the 'central' modelling and applying a calibration if background concentrations were not calibrated in the 'central' modelling (but this may not be possible if no data is available for calibration).

In this case, this was not considered as an appropriate approach as:

- A combination of various modelled background NOx sources were combined with modelled road NOx concentrations to calculate NO_2 annual mean concentrations. This included emissions from nearby large point sources. Where appropriate, the relevant sector contributions in the NOx background maps were discounted to avoid double counting of the sources modelled explicitly.
- No background NOx measurements were available to calibrate the modelled background.

5.3.2.4 f-NO_2 and calibration

The supplementary note suggests – '*If LAs have a number of roadside chemiluminescence monitors within their model domain they may wish to run a sensitivity test to examine the possible impact of this effect by calibrating for NOx using data from chemiluminescence monitors only (then calibrating for NO_2 using all monitoring sites)'*.

There were no chemiluminescence monitors in Derby in 2016 that could have been used for such a calibration. We also consider that the use of a much more comprehensive set of diffusion results, although with greater uncertainty in the measured concentrations when compared with automatic analysers, gives a much more robust set of model agreement statistics.

5.3.2.5 Surface roughness length

The supplementary guidance states that *JAQU suggest that LAs model both high and low surface roughness sensitivity tests, scaling surface roughness by appropriate amounts (which will vary on a case by case basis)*.

And: '*As with other sensitivity tests the focus should be on the baseline and with measures projected year modelling, although in this case LAs should strongly consider also running the sensitivity in the base year. This is because the surface roughness length will impact on concentrations in the base year, therefore could impact on the calibration factors derived in the base year (and applied in the projected year)*.

As described in the AQ2 modelling method report, we have modelled a uniform surface roughness across the entire domain representing a typical roughness for a large urban area.

We would argue that changing the surface roughness modelled would require re-running and re-verification of the 2016 baseline model to derive a Road NOx adjustment (model calibration) factor that is specific to modelling with that roughness input parameter. To model like for like with the updated baseline, all future year scenarios would also need to be re-modelled and the results processed and re-presented. We anticipate that this would not significantly change the future year modelled concentrations and hence conclusions of the assessment. The level of effort required to do this repeat modelling, combined with the current timescale pressures for delivery of the modelling evidence base, mean that exploring this sensitivity by re-modelling is not currently considered proportionate.

5.3.2.6 Meteorology

The sensitivity guidance contains some useful information regarding the potential for inter-annual variability in meteorological conditions to impact on modelled concentrations.

'*JAQU has attempted to quantify the potential for meteorologically driven inter-annual variability in NO_2 concentrations by investigating the impact of applying 3 different years of meteorological data from the same site (with all other inputs remaining constant) on NO_2 concentrations for a 'mock' LA.*

The study suggests (though results are not statistically meaningful given that only one 'mock' area has been considered with 3 years of meteorological data) that inter-annual changes in meteorology may not have a large impact on the overall distribution of roadside NO_2 concentrations in a local area but can have a significant impact for particular road links (as reflected in the considerably higher maximum concentration in 2015).'

This statement suggests that alternative met years would not significantly affect the overall outcome of the analysis. We also note that to conduct a statistically robust sensitivity test of inter-annual variation in meteorological conditions would require modelling using multiple annual datasets. As it is critical to achieve compliance as quickly as possible in Derby, and timescales for submission of evidence have been agreed, we do not currently have sufficient time or resources to conduct this repeat modelling, therefore exploring this sensitivity in detail by re-modelling multiple times is not currently considered proportionate.

5.4 'Real World' emissions

To complete the feasibility study in Derby some real-world emission measurements were taken at two location in the city to further test the robustness of the fleet data and the emission factors used. These tests were done using a remote sensing emission test system the Opus Accuscan RSD 500 instrument. This instrument accurately measures real-world driving emissions of passing vehicles and is configured to measure emissions of nitric oxide and nitrogen dioxide (and therefore NOx), particulate matter, hydrocarbons, carbon monoxide and ammonia.

A summary report of the measurements is provided in Appendix 3. They key findings from this were as follows:

- The fleet composition recorded matched the data used in the study from previous ANPR results so provided an additional check on the robustness this data used in modelling.

- The emissions data collected for light duty vehicles was compared to the COPERT emission factors used in the model. This suggested that real world emissions were significantly higher than the COPERT factors at these locations by a factor of up to 2 or more.

The comparison of the measured emissions with the COPERT factors is particularly important and provides some evidence to explain why model adjustment factors applied to road traffic NOx are often as high as 2 or more.

6 Conclusions

The air quality assessment has modelled 4 scenarios in 2020:

- ‘Do minimum’ – providing an assessment of concentration with no further interventions;
- The Stafford Street traffic management scheme – using traffic management measures to tackle the exceedance identified on Stafford Street;
- The CAZ D benchmark charging scheme – providing an alternative solution against which to compare the traffic management scheme;
- A 2025 future scenario – which tests compliance with the limit values by 2025 after the A38 highways works are completed.

The local ‘Do minimum’ results for 2020 indicate that all PCM links will be in compliance with the 40µmg^{-3} limit value for NO_2 with the exception of Stafford Street. This street is modelled to have significant traffic growth and sits within a canyon. These combine to give an NO_2 exceedance in 2020.

The traffic management scheme was designed to target the problem in Stafford Street by significantly reducing traffic flows along this route. This option brings the Stafford Street location comfortably into compliance. The scheme does generate a certain amount of traffic diversion on to alternative routes, however, these routes have low NO_2 concentrations and even with the additional traffic no exceedances of the limit value are predicted.

In comparison to the traffic management scheme a CAZ D benchmark charging scheme will also remove the exceedance on Stafford Street, though the impact is less in this location than the targeted traffic management scheme. However, the CAZ D scheme does result in more wide spread reductions in NO_2 concentrations across the city.

In the longer term the modelling for 2025, when the A38 highways scheme has been completed, shows significant reductions in NO_2 concentrations across the city with compliance at all locations including Stafford Street. This indicates that by 2025 neither the traffic management scheme nor a charging scheme would be needed to achieve compliance. Therefore, any compliance scheme would only need to be operated for a maximum of 4 to 5 years.

Sensitivity testing has been carried out to assess the robustness of these outcomes. The key results from this testing are as follows:

- The traffic management will generate compliance whether or not the existing Clean Bus Technology Fund is taken up by local bus operators.
- If there is no upgrade response in relation to the charging scheme, then this scheme will not achieve compliance.
- With Euro 6 light duty vehicles only performing to stage 6a one new exceedance would be generated in the ‘do minimum’ scenario on the A38 and two locations under the traffic management scheme would come up to, but not over, the limit value. However, both locations do not have significant relevant exposure.
- Analysis of heavy-duty emissions at low speed also indicates that emissions could increase but not sufficiently to cause non-compliance with the traffic management scheme.

The assessment indicates that the preferred targeted traffic management scheme will solve the exceedance problem on Stafford Street and not cause knock on problems elsewhere within the city.

However, this solution does only solve this one location and does not generate measurable wider air quality benefits. This option is also robust under the sensitivity tests carried out, although poor real-world performance of vehicle emissions would increase the risk of the scheme not producing full compliance. In comparison the benchmark CAZ D charging scheme will also generate compliance and in addition wider air quality benefits. However, it is a much more significant scheme impacting a large number of vehicles. It is also at risk of non-compliance with the limit value if drivers do not upgrade their vehicles to the level assumed or as quickly as assumed.

Overall this would suggest that the traffic management scheme is the most robust scheme for achieving compliance with the NO_2 limit values across the PCM defined road network as soon as possible.

Appendix 1 – Air quality model verification and adjustment

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations; this helps to identify how the model is performing and if any adjustments should be applied. The verification process involves checking and refining the model input data to try and reduce uncertainties and produce model outputs that are in better agreement with the monitoring results. This can be followed by adjustment of the modelled results if required. The LAQM.TG(16) guidance recommends making the adjustment to the road contribution of the pollutant only and not the background concentration these are combined with.

The approach outlined in LAQM.TG(16) section 7.508 – 7.534 (also in Box 7.14 and 7.15) has been used in this case.

All roadside automatic and diffusion tube NO_2 measurement sites in Derby have been used for model verification.

It is appropriate to verify the performance of the Rapid Air model in terms of primary pollutant emissions of nitrogen oxides (NOx = NO + NO_2). To verify the model, the predicted annual mean Road NOx concentrations were compared with concentrations measured at the various monitoring sites during 2016.

The model output of Road NOx (the total NOx originating from road traffic) was compared with measured Road NOx, where the measured Road NOx contribution is calculated as the difference between the total NOx and the background NOx value. Total measured NOx for each diffusion tube was calculated from the measured NO_2 concentration using the latest version of the Defra NOx/NO_2 calculator issued for use in the CAZ cities (v5.3).

The initial comparison of the modelled vs measured Road NOx identified that the model was under-predicting the Road NOx contribution at most locations. Refinements were subsequently made to the model inputs to improve model performance where possible.

The gradient of the best fit line for the modelled Road NOx contribution vs. measured Road NOx contribution was then determined using linear regression and used as a global/domain wide Road NOx adjustment factor. This factor was then applied to the modelled Road NOx concentration at each discretely modelled receptor point to provide adjusted modelled Road NOx concentrations. A linear regression plot comparing modelled and monitored Road NOx concentrations before and after adjustment is presented in Figure A3.1.

The total annual mean NO_2 concentrations were then determined using the NOx/NO_2 calculator to combine background and adjusted road contribution concentrations.

Some clear outliers were apparent during the model verification process, whereby we were unable to refine the model inputs sufficiently to achieve acceptable model performance at these locations. There are a number of reasons why this could be the case e.g.

- A site located next to a large car park, bus stop, boiler flue, or taxi rank that has not been explicitly modelled due to unknown activity data.
- Sites located underneath trees or vegetation i.e. unsuitable locations for diffusion tubes to measure NO_2 concentrations effectively.
- No traffic model road link included where the NO_2 sampler is located, or not all road links included e.g. at a junction.

- Uncertainties in the traffic model outputs (please refer to the traffic model validation report for further information on this).
- Uncertainties in the background maps. At some locations in the model domain the mapped background NOx concentrations look very high compared to the surrounding area; even after discounting all road source sectors from the background maps, the NOx/NO_2 calculator was indicating that a negative road NOx concentration would be required to match the measured NO_2 concentration. This could indicate that the mapped NOx background has been overestimated at these locations; it could also however indicate uncertainties with the measured NO_2 concentrations.
- Uncertainties introduced by modelling background concentrations at 1km resolution over such a wide area. In this case we have attempted to address this by interpolating the 1km background maps to a finer 1m resolution this aims to smooth out the sudden changes in background concentrations at the edges of the 1km square background maps. We found that using the interpolated/smoothed background map produced better model performance overall.

17 out of 76 diffusion tube sites were considered as outliers and were therefore excluded from the verification process. A primary NOx adjustment factor (PAdj) of **1.5882** based on model verification using the remaining 2016 NO_2 measurements was derived and applied to all modelled Road NOx data prior to calculating an NO_2 annual mean.

A plot comparing modelled and monitored NO_2 concentrations before and after adjustment during 2016 is presented in Figure A3.2.

Figure A3.1 Comparison of modelled Road NO_x Vs Measured Road NO_x before and after adjustment 2016

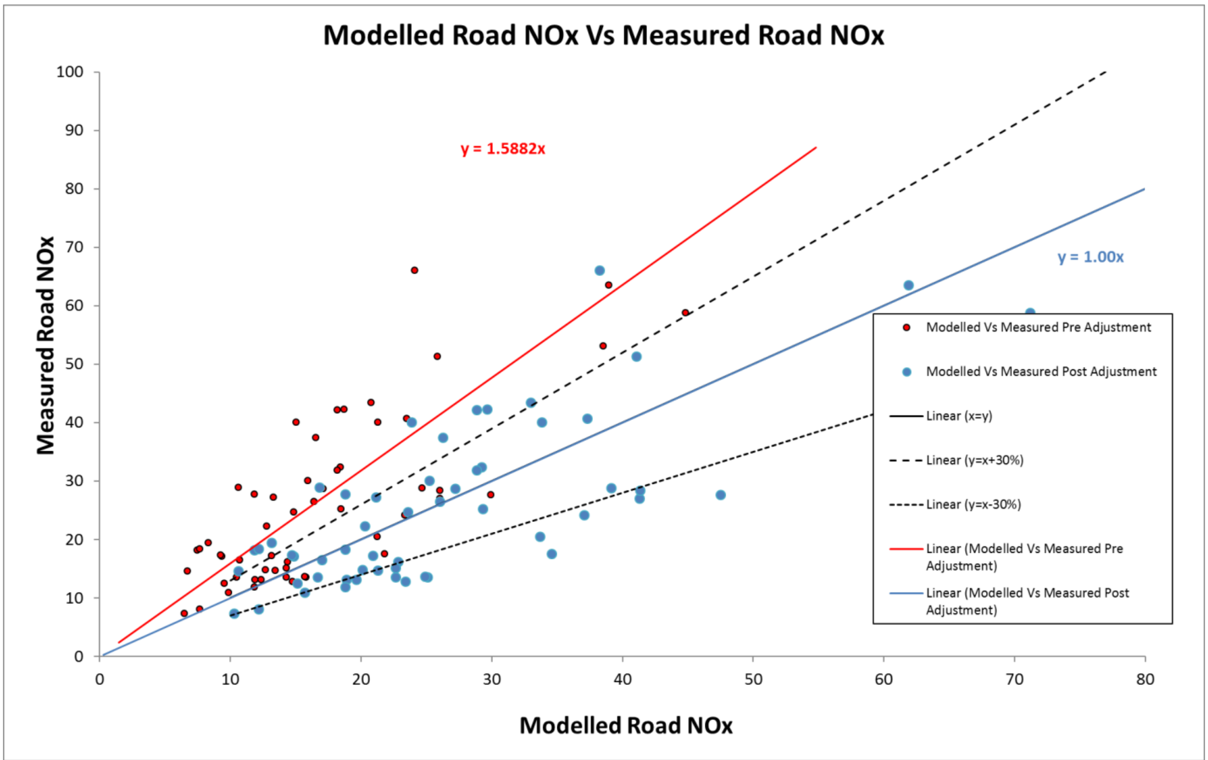
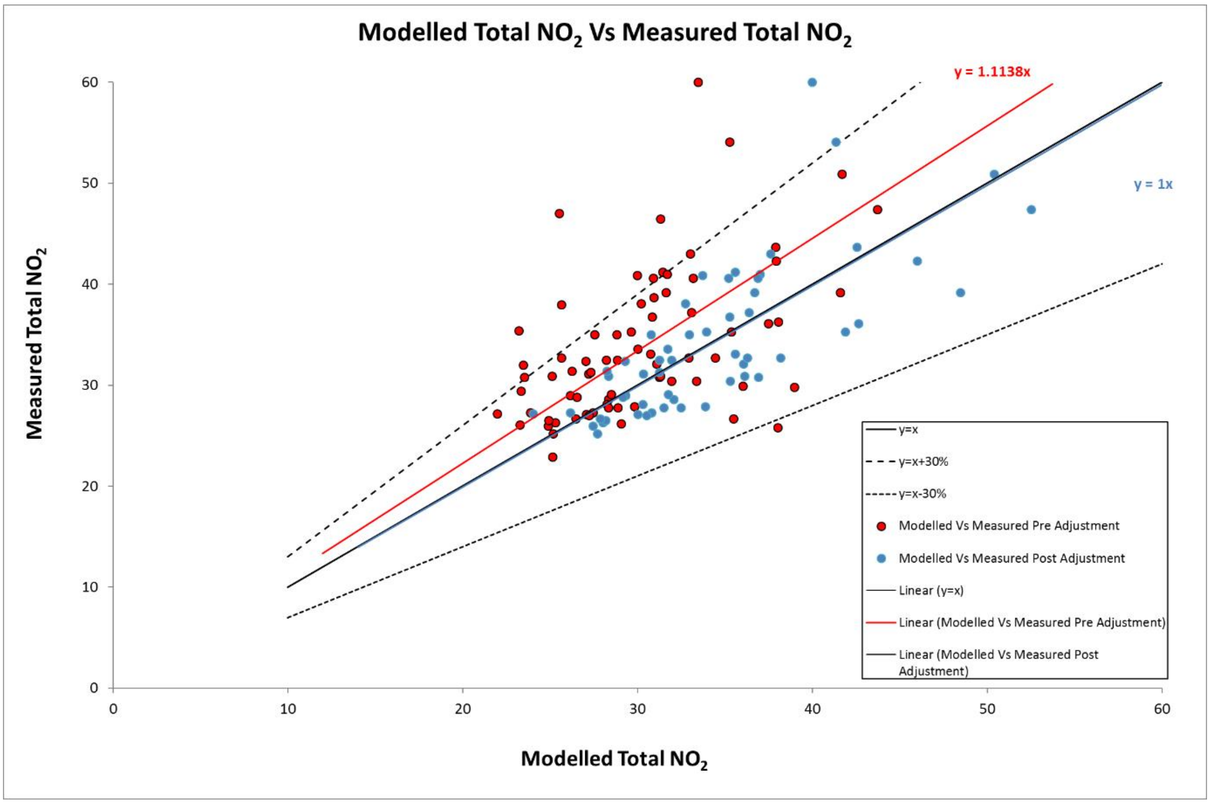


Figure A3.2: Modelled vs. measured NO_2 annual mean 2016



To evaluate the model performance and uncertainty, the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations was calculated, as detailed in Technical Guidance LAQM.TG(16). The calculated RMSE is presented in Table A3.1.

In this case the RMSE when outliers were excluded was calculated at 4.9 µg.m^{-3}.

Table A3.1: Root mean square error

NO_2 monitoring site	Measured NO_2 annual mean concentration 2016 (µg.m^{-3})	Modelled NO_2 annual mean concentration 2016 (µg.m^{-3})	Difference measured – modelled (µg.m^{-3})
DT1	28.6	32.0	-3.36
DT10	47.4	52.0	-4.62
DT15	43.7	42.4	1.3
DT18	27.1	29.8	-2.73
DT19	26.3	27.8	-1.54
DT2	29.0	29.2	-0.22
DT20	27.2	23.9	3.34
DT21	25.2	27.5	-2.33
DT22	27.3	30.5	-3.21
DT23	43.0	37.3	5.74
DT24	41.2	35.5	5.71
DT25	40.9	33.5	7.42
DT29	27.3	26.2	1.13
DT3	26.0	27.4	-1.37
DT30	26.5	28.3	-1.77

DT31	30.8	37.0	-6.17
DT32	41.0	37.1	3.94
DT33	30.9	28.1	2.81
DT34	60.0	39.4	20.62
DT35	32.1	36.2	-4.12
DT36	36.8	35.3	1.5
DT41	31.4	28.2	3.17
DT42	32.5	31.1	1.37
DT43	28.1	30.2	-2.1
DT44	38.1	32.6	5.46
DT45	32.7	38.1	-5.44
DT46	33.6	31.7	1.94
DT47	36.1	42.3	-6.24
DT48	37.2	36.6	0.65
DT49	32.7	36.2	-3.51
DT5	31.1	30.1	0.96
DT50	39.2	48.2	-8.99
DT51	30.4	35.1	-4.72
DT52	32.4	29.1	3.3
DT55	28.8	29.0	-0.23
DT56	40.6	35.0	5.61
DT57	54.1	41.1	13.05
DT58	27.9	33.6	-5.69
DT59	50.9	50.2	0.73
DT6	27.8	32.3	-4.54
DT60	42.3	45.5	-3.19
DT61	31.3	31.1	0.23
DT62	35.0	32.6	2.43
DT63	39.2	36.4	2.81
DT64	33.1	35.1	-2.01
DT65	35.0	30.4	4.59
DT68	35.3	33.9	1.39
DT69	30.9	36.2	-5.25
DT7	27.0	30.4	-3.39
DT70	32.5	31.9	0.56
DT71	35.3	41.7	-6.36
DT74	40.6	37.0	3.62
DT76	26.7	27.9	-1.21
DT8	29.1	31.8	-2.65
DT9	27.8	31.4	-3.58
		RMSE (excluding clear outliers)	**4.96**

Appendix 2 NO_2 concentration contour plots

Figure A2.1 NO_2 modelled concentrations for baseline

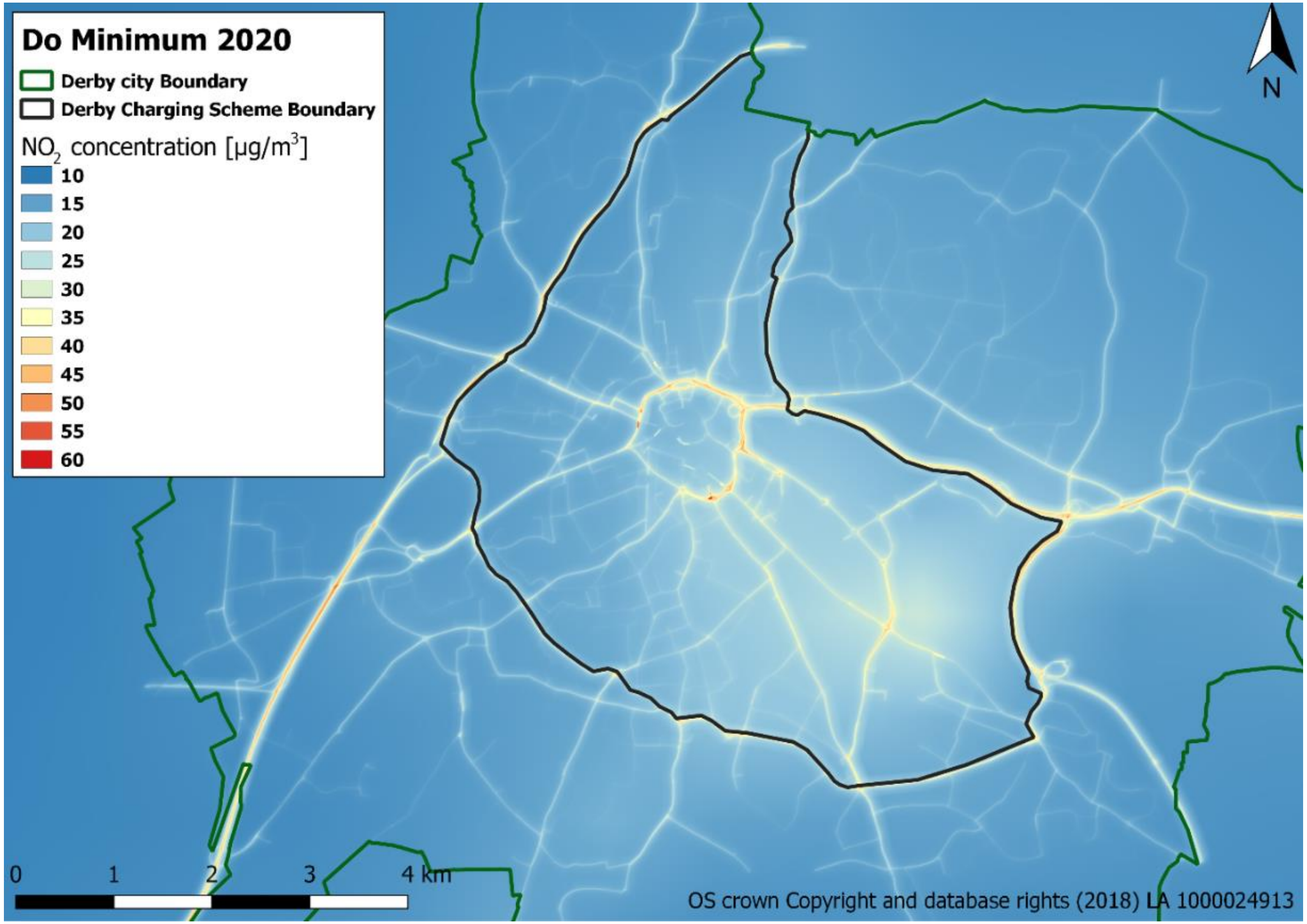


Figure A2.2 NO_2 modelled concentrations for Stafford Street traffic management scheme

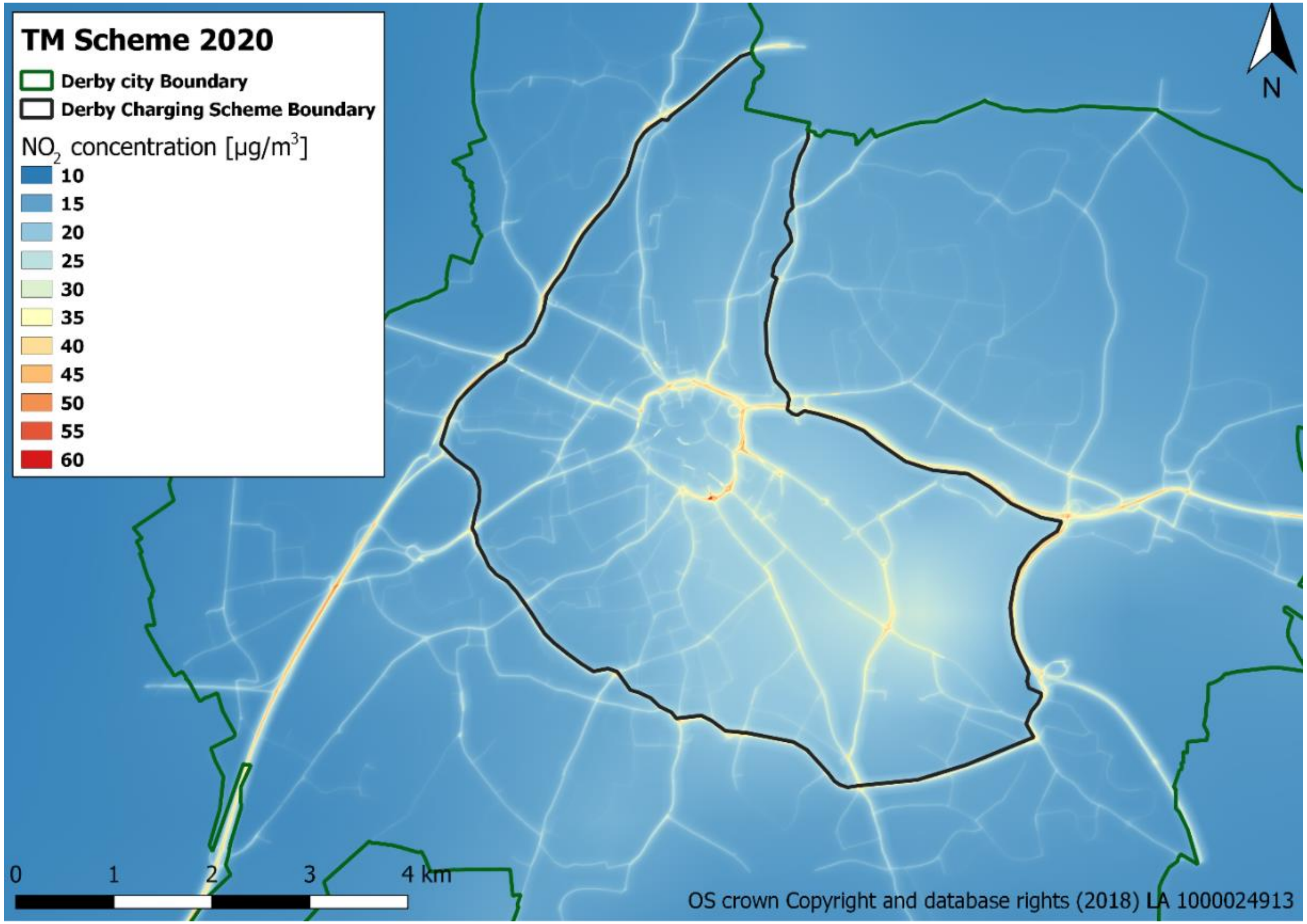
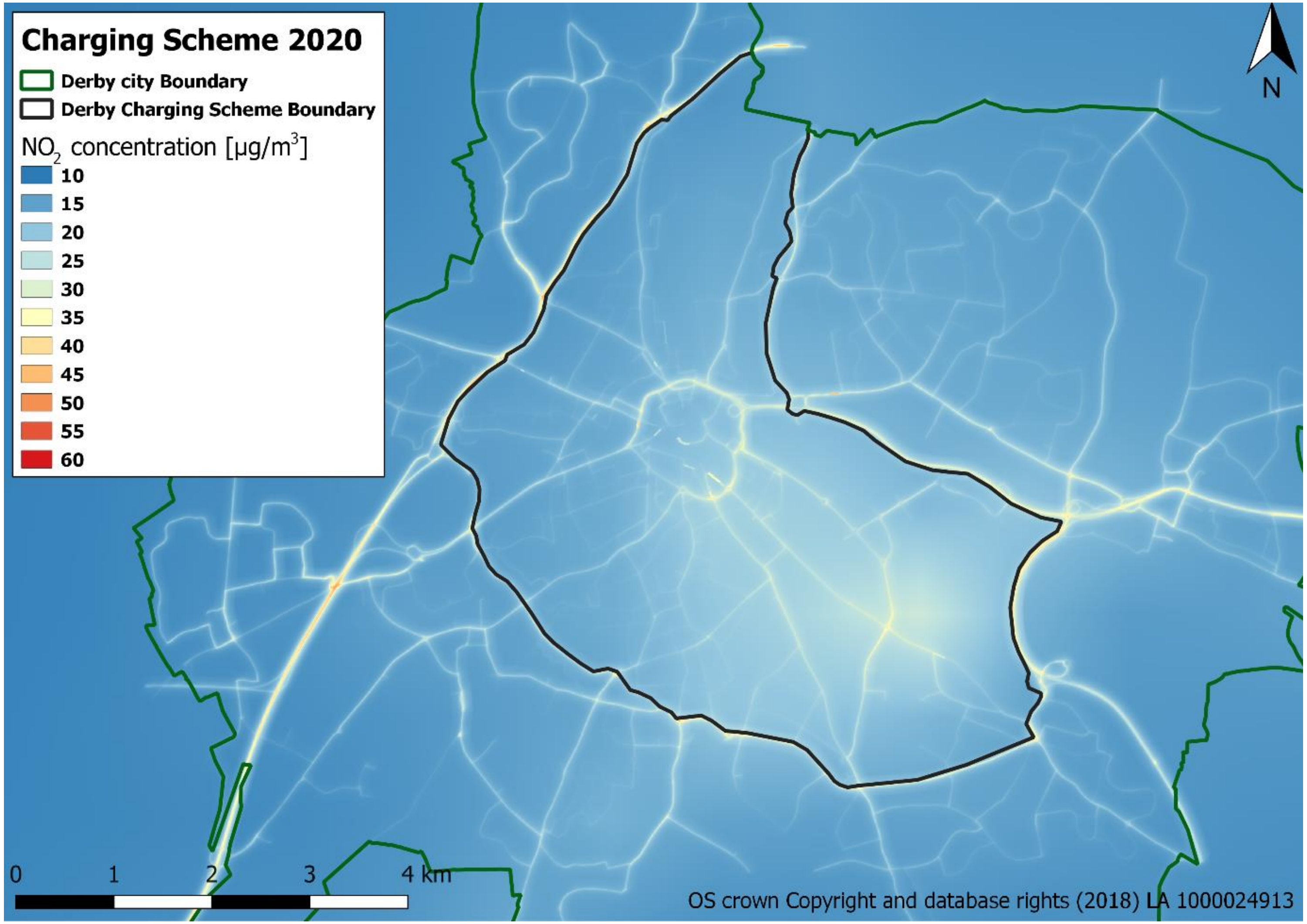


Figure A2.3 NO_2 modelled concentrations for charging scheme



Appendix 3 – Real-world emission measurements with the OPUS remote sensing system

The report has been written using the online analysis functionality of the ‘R’ programming system. Clicking on the imbedded HTML link below will open the report in your web-browser.

site_report_Derby.html

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