Southampton Clean Air Zone Feasibility Study – Air Quality Results Report (AQ3)

Report for Southampton City Council

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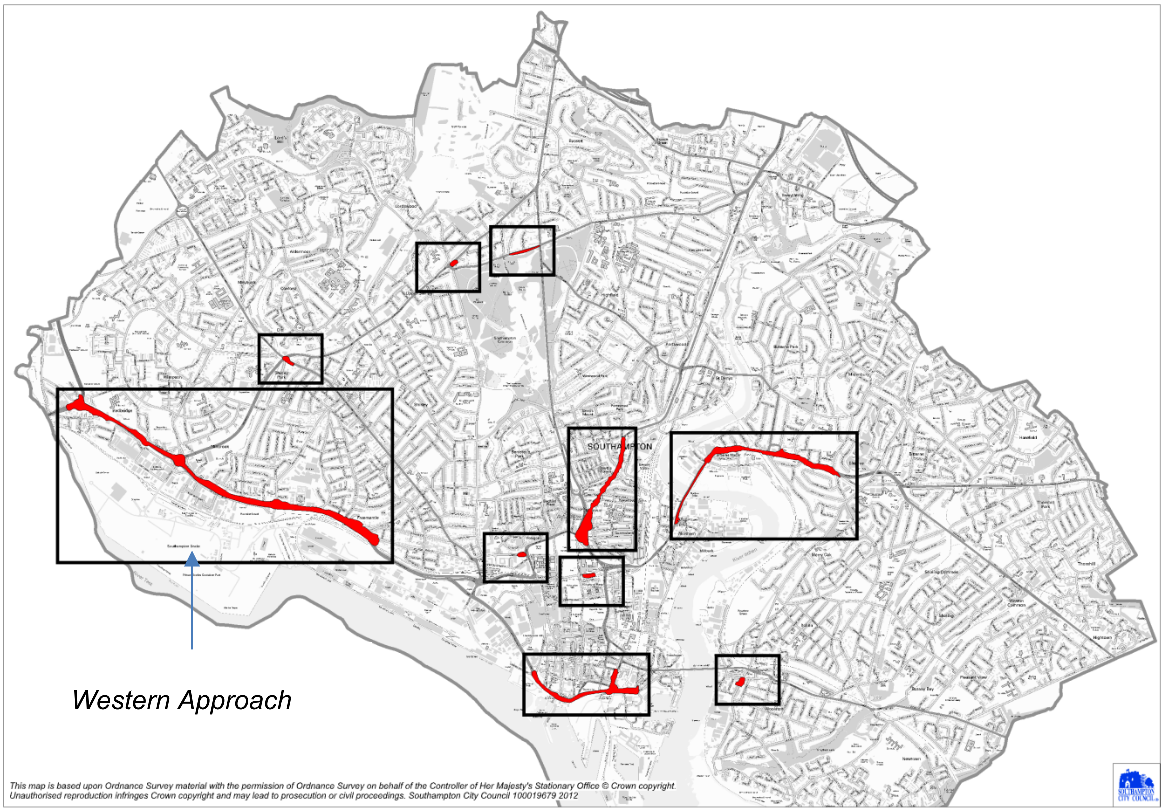
Appendix 1: Southampton updated air quality model verification and adjustment

1 Introduction

Southampton, like many other urban areas, has elevated levels of Nitrogen Dioxide (NO_2) due mainly to road transport emissions. As such Southampton City Council (SCC) has designated 10 Air Quality Management Areas (AQMA) across the City, as shown in Figure 1 below, where concentrations of NO_2 breach Government, health-based air quality objectives and has undertaken reviews of current and predicted levels in the future, including assessments of measures to reduce pollution levels.

Figure 1 Southampton Air Quality Management Areas (AQMA)



In addition, Southampton was identified as one of the initial 5 cities ('first wave') in the UK where the EU Limit Value for NO_2 is not expected to be met by 2020 in DEFRA's 2015 Air Quality Plan. The key area identified by the DEFRA plan that is modelled to exceed in 2020 is the Western Approaches AQMA. The Plan also stated that each of the cities identified are required to develop and implement plans to achieve compliance in the shortest possible time including considering the introduction a formal charging-based Clean Air Zone (CAZ).

This feasibility study has carried out a fully updated assessment of air quality in and around Southampton in relation to the European limit value for NO_2 using the latest data on emission factors and traffic activity. This assessment has been used to establish the extent of any air quality compliance issues in Southampton and to assess the options needed to solve these compliance problems. A first full assessment of the baseline air quality and potentially mitigation measures was reported in March 2018. This was further refined for the outline business case (OBC) submission in July 2018 and used as the basis of a public consultation of the proposed measures.

As part of the consultation work detailed engagement was carried out with key stakeholders, in particular the Port of Southampton, to review the underlying data and assumptions supporting the analysis. Following this review and wider feedback from the consultation the analysis has been updated to provide the most robust evidence available. This has resulted in three scenarios that were taken through for assessment within the full business case (FBC):

- *The 'do minimum' baseline* – this is the updated baseline with revised assumptions plus the inclusion of measures that have already received funding from the Government's 'Early Measures Fund'
- *The non-charging CAZ package* – covering a refined set of freight, bus and taxi measures, plus some additional measures agreed with the port.
- *A City-Wide Class B charging CAZ* – as defined for the OBC.

This report presents the results of this final set of modelling scenarios.

2 Scenario details and modelling assumptions

2.1 The 'do minimum' baseline

There were three key updates that have been made to the modelling of the 'do minimum' baseline:

- Changes to the underlying transport model and forecasts which have developed over the period of the feasibility study;
- Changes to the modelling of the port and port related traffic based on further engagement with the port;
- Inclusion of measures that have now received funding and are currently being implemented.

These are detailed below.

2.1.1 Changes to the underlying transport model

Three updates have been made in this latest version of the baseline:

- <u>*An updated version of the version of the SRTM has been used*</u> – since the initial work on the modelling started in 2017 the SRTM has been refined and updated. This latest version has been used in the new baseline modelling.
- <u>*Updated coding of the Redbridge roundabout*</u> – to account for the current confirmed scheme design.
- <u>*Use of the latest 2018 National Road Traffic Forecast (NRTF)*</u> – this has been used for HGV and LGV traffic growth and replaces the 2015 NRTF that had been previously used.

2.1.2 Updated assumptions for modelling the port

Following further detailed engagement with the port some updates to the assumptions for modelling the port were made. The key change has been adjustment to the expected level of port growth between 2015 and 2020. In addition to this a number of smaller changes were also made to account for the latest information held by the port. The detail of these changes are provided below.

Vessels travelling to and berthed at port

- <u>*Activity levels*</u>, use assumptions specific for Southampton (up to approximately 5km from the port). The annual average growth rates specific to Southampton have been based on the latest growth forecasts provided by ABP[1] for container vessels, RoRo vessels, cruise ships and bulk carriers. For other vessel types, annual average growth rates for specific vessel categories were taken from the Port of Southampton Master Plan 2016 consultation document section on trade and demand forecasts[2].

- *Fuel types* of vessels. The impacts of the tighter fuel sulphur limit of 0.1% within the SECA from 2015 is accounted for by assuming that vessel operators that used 1.0% S heavy fuel oil in 2014 comply by switching to marine distillate fuel. This is relevant for NO_X due to the slightly lower NO_X emission factor for marine distillates. Based on ABP forecasts[3], LNG is assumed to be used in 20% of cruise ships in 2020 (and those LNG powered vessels are assumed to have 85% lower NOx emission factors compared to vessels combusting distillate fuel. This assumption deviates from the assumptions made in the NAEI for national ship emission projections, in which LNG is used from 2021 as a route to comply with the forthcoming NOx emission control area in the North Sea and English Channel.

- *Vessel fuel efficiency* (with consequent impacts on emissions), of annual improvement in vessel energy efficiency of 1% per year. This accounts for improvements from the Energy Efficiency Design Index, as well as changes over time in vessel capacities. This assumption aligns with the assumptions made in the NAEI for national ship emission projections.

- *Emission factors*. An annual reduction of 1% in the NOx emission factor for ships to 2020 was assumed for vessels serving Southampton. This reduction factor relates to ongoing fleet turnover and thus increasing proportions of newer vessels meeting IMO NO_X Technical Code Tier II levels. This reduction factor specific to Southampton was assumed to be higher than the national average (0.7%) used in the NAEI ship emission projections, because of the port is understood to attract the latest and newest vessels[4].

These changes have given rise to emission levels for shipping similar to that of the 2015 base year and so lower than the original 2020 forecast that had been based on solely on the 2016 Master Plan.

Port machinery changes

- *Activity level*. Similarly, to the vessels projections, the activity level changes have been based on the projected demand changes at the port for the most relevant vessel type as set out in the first bullet point above**Error! Reference source not found.**. For example, the emission sources related to containers – e.g. straddle carriers etc. – have been scaled according to the forecast changes in demand for container vessels. The other emission sources have been similarly scaled with the appropriate commodity type demand forecasts.
- *Emission factor*. We have consulted with DP World and have obtained assumptions their latest plans (as at 2018) for fleet turnover of straddle carriers per emission standard and model type which have been used to project the straddle carrier NO_X emissions to 2020. Aside from straddle carriers (estimated as the largest NOx emission source in the port other than vessels), no other equipment fleet turnover has been accounted for. For the modelling of vehicle emissions on in-port roads that arrive/depart through the dock gates, the same assumptions relating to turnover in the vehicle fleet for in-port roads have been made as for public roads.

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[1] Personal Communication, 15 August 2018.
[2] http://www.southamptonvts.co.uk/admin/content/files/New%20capital%20projects/Master%20Plan%202016/Master%20Plan%202016%20-%202035%20Consultation%20Document%20Oct%202016.pdf
[3] Personal Communication, 15 August 2018.
[4] Personal Communication, ABP, 14 August 2018.

Port related traffic

- *Activity levels*. The adjusted port growth forecasts have also been accounted for in the modelling of port related traffic. The original 2020 forecast was based on the 2016 Master Plan as noted above. The updated forecast primarily affects the container port and port related HGV traffic. The impact of the new forecast was to reduce expect traffic growth to the port between 2015 and 2020 from 29% to 2%.

- *Rail freight share*: A number of changes, based on historic data, were discussed with the port [5] that affect the share of freight to the port by rail, which then affected HGV traffic to the port. These factors comprised the following:

    - Reduced diesel prices – lower than expected road diesel prices have seen the share of rail fright drop from 34% in 2015 to 30% in 2017.

    - Changes to the rail freight subsidy – this is expected to increase somewhat from 2017 through to 2020 and will counteract the current drop in rail share due to lower fuel prices bringing it back to an expected level of 34% in 2020.

    - Rail lengthening project - the Redbridge rail lengthening project, which will increase rail freight capacity by allowing for longer trains, is due to be completed before 2020. This will further reduce the cost of rail freight and is expected to increase rail share to 36% in 2020.

  These changes compare to an original forecast based on the 2016 Master plan of a 39% rail share by 2020.

2.1.3 Funded measures

Three measures that have already received funding and are due to be fully implemented by 2020 are also included in the do minimum baseline and cover:

- *A package of cycling infrastructure improvement measures* – covering investment in Southampton Cycling Network (SCN) routes 1, 5, 8 and 10 being completed by 2020. These have been added to the transport model and impact on private car mode share.
- *The Clean Bus Technology Fund (CBTF)* – funding has been provided to upgrade (retrofit) the remaining 145 non-Euro VI buses in the Southampton bus fleet to Euro VI level. This has been modelled by updating the bus fleet to be fully Euro VI by 2020.
- *The taxi incentive programme* – the Low Emission Taxi Incentive Scheme (LETIS) has funding to upgrade 113 private hire taxis to petrol hybrids from older diesels. Adding these vehicles to the proportion already identified as hybrid from the ANPR data in 2016 would suggest that a minimum of 10% of the taxi fleet would be hybrid by 2020. Adding the expected natural uptake between 2016 and 2020 takes this total to 18% by 2020.

2.2 The non-charging CAZ scheme

The non-charging scheme comprises of two groups of measures: a package of wider city measures to reduce emissions from buses, taxis and HGVs; and a package of measures to reduce emissions from port related activity.

[5] Private communication with DP World and ABP

2.2.1 City-wide emission reduction measures

The city-wide measures build on the existing measures for which funding has been approved and seek to expand on these. The measures modelled are:

- *City centre Euro VI bus traffic condition* – this is being implemented to support the bus retrofit programme providing an extra stick to ensure full uptake of the scheme by 2020. However, since we have assumed all buses are Euro VI in the 'do minimum' baseline no further account has been taken of this measure in the modelling.

- *CAZ compliance set in taxi licencing standards by 2023* – a minimum standard of Euro 6 diesel or Euro 4 petrol will be set in the licencing standards for 2023. However, this was assessed and considered not to have a significant impact on the taxi fleet by 2020 beyond natural turnover and the impact of the LETIS funding already accounted for in the baseline.

- *Delivery service plans and freight consolidation* – a number of key sites are being targeted for these measures, however, the one most likely to see significant impact by 2020 is the hospital. Therefore, only the impact of the scheme on the hospital has been considered and is expected to remove 640 LGVs and 113 HGVs movements from the network weekly due to consolidation. These flows have been removed in the transport model.

2.2.2 Port related emission reduction measures

Two measures have been discussed and agreed for potential implementation with the Port for this non-charging CAZ package:

- *Shore power* – direct connection to shore side electrical power prevents the need for ships to run auxiliary engines whilst in port. By 2020 the port has estimated that 20% of cruise ships will be able to be plugged in to shore power. When 'plugged in' the modelling assumes that the fuel consumption of aux engines "at berth" is reduced by 90% (allowing time for vessels to connect and disconnect from power). This is estimated to reduce cruise ship NOx emissions at berth by 12.1%.

- *Emission related charges using the port booking system* – the container port is proposing a scheme where it would charge non-compliant vehicles a £5 charge to access the port during peak hours. Applying this charge in the transport model indicates that 1% of non-compliant port related HGVs would shift from peak to off peak travel times.

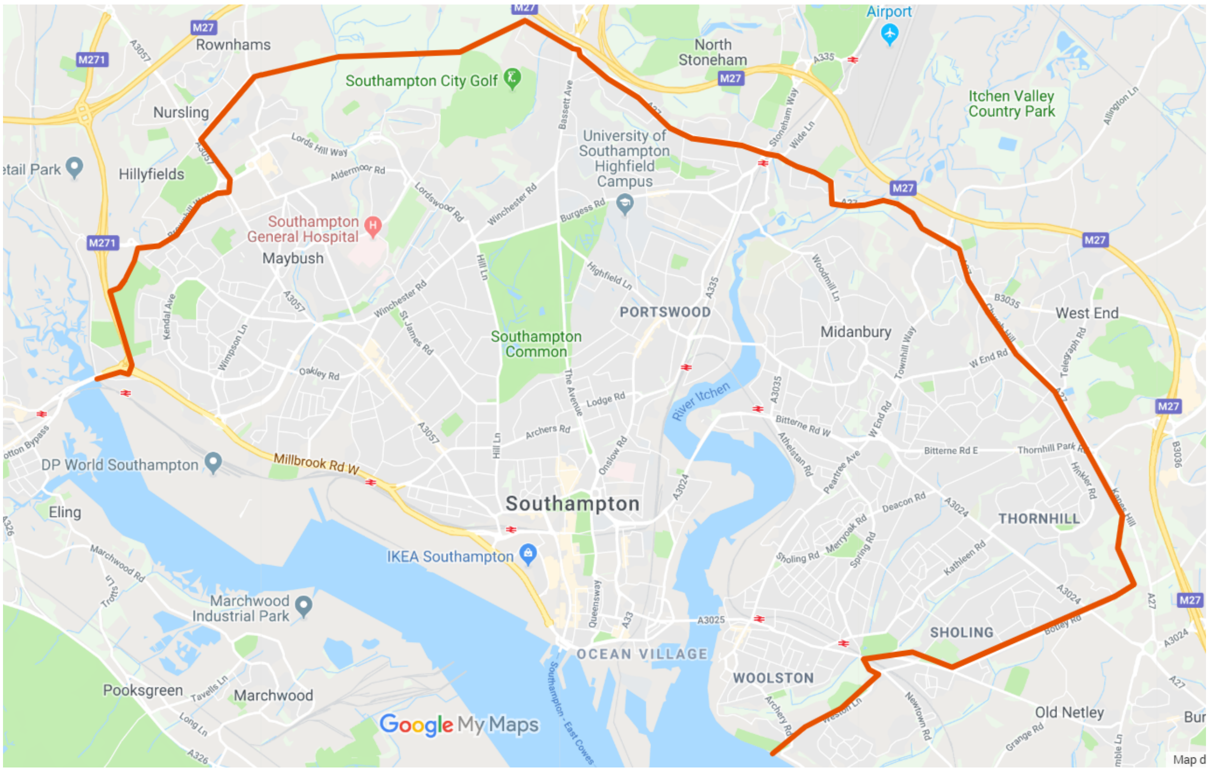
2.3 A city-wide CAZ B charging scheme

The charging scheme assessed was Class B charging CAZ with a boundary set covering the whole Southampton city area as illustrated in Figure 2 below. The Class B CAZ covers buses (including coaches), taxis and HGVs, where vehicles not meeting the Euro 6/VI standard for diesel (or Euro 4 for Petrol) are charged for entering the city. Vehicles that are passing through the city would have the option of diverting around, which in this case is essentially a diversion around the M27.

The charge for assessment purposes has been set at the same level as the London ULEZ; £100/day for HGVs and buses, and £12.50 per day for taxis. This charge has been used as the modelling uses vehicle upgrade assumptions provided by JAQU and based on the evidence from the London ULEZ as set out in Table 1 below.

This option has been modelled in the transport model to assess potential diversionary or destination shifts as a result of the scheme. Within the transport model buses are fixed and taxis are not directly included (they have been estimated as a proportion of car traffic). As such the traffic response to the CAZ B is largely limited to changes in HGV traffic. However, this may have a knock-on effect to other vehicles classes if journey times change as a results of HGV behaviour and then affect route choices for other vehicle types.

Figure 2 City-wide CAZ Boundary



The traffic model assesses the behaviour of both complaint vehicles (those that naturally meet the standard or are upgraded to do so) and non-complaint vehicles. The proportion of vkm that upgrade in response to the scheme is taken from guidance provided by JAQU as shown in Table 1 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. This same charge is assumed in the traffic model to assess the response of non-compliant vehicles in terms of paying the charging, avoiding the zone or cancelling the trip.

It should be noted that this behavioural response, in terms of the assumed upgrade % for non-compliant vehicles accessing the zone, is the key assumption in the modelling of the city-wide CAZ B scheme. The current assumption, as set out above, is based on data for London provided by JAQU. We recognise that the response locally may differ from this.

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 from using the baseline 2020 vehicle fleet split and applying the JAQU upgrade assumption shown above. 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-complaint vehicles. In the case of the Class B CAZ these assumptions are only applied to buses, HGVs and taxis which are affected by the scheme.

Table 1 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

2.4 Summary modelling assumptions

A summary of the assumptions used in modelling each of the options is provided in Table 2 below, with further details of the assumptions given in the following sections. Additional details on the full air quality modelling and transport modelling methods is given in the air quality and transport modelling methodology reports.

Table 2 Final list of options for assessment

Option	Components	Modelling approach
Do Minimum baseline	Baseline traffic and non-transport activity	This includes: • Updated traffic model with NRTF18 and revised port related traffic assumptions as described above (section 5.1). • Updated port activity with reduced growth, cruise ship LNG usage and adjusted NOx factor forecast.
	Early measure cycling scheme – routes 1, 5, 8 and 10	Additional cycling infrastructure included in the traffic model and this affects private car demand.
	Clean Bus Technology Fund	All non-Euro VI buses retrofitted to Euro VI (total of 145 buses), so have set bus fleet to all Euro VI in the model
	Taxi incentives	Funding to upgrade taxis. Current upgrades are to petrol hybrids. Projected uptake of 113 vehicles. This increase in hybrids is similar to the existing up take rate assumed in the fleet project tool so no further changes made.
Non-charging CAZ	CBTF plus bus traffic condition	Same modelling assumption as Do Minimum above. Inclusion of road traffic condition has no further impact as all buses already Euro VI
	Taxi incentives	Same modelling assumption as Do Minimum above
	Early measure cycling scheme – routes 1, 5, 8 and 10	Additional cycling infrastructure included in the traffic model and this affects private car demand.

	Freight DSP and consolidation	Likely impact focused on hospital deliveries. A reduction in LGV and HGV trips to this zone has been included in the traffic model.
	Shore power for cruise liners	20% of cruise liners assumed to be connected to shore power, rather than running auxiliary engines, while at berth.
	Port emissions-based booking scheme	A £5 charge is applied to all non-compliant (non-Euro VI) HGVs accessing the container terminal during peak hours. This generates a shift from peak to off peak.
City Wide CAZ B	City Wide CAZ B	A City-wide CAZ B, using upgrade assumptions provided by JAQU, is run through the transport model to assess behaviour of non-complaint vehicles. The compliant and non-compliant fleet are then modelled in the AQ model.
	CBTF	Same modelling assumption as Do Minimum above.
	Taxi incentives	Same modelling assumption as Do Minimum above
	Early measure cycling scheme – routes 1, 5, 8 and 10	Additional cycling infrastructure included in the traffic model and this affects private car demand.

3 Updated baseline results

This section provides an update to the baseline results for the Southampton Study area, which includes the changes described above. The model verification work that has been carried out is reported in Appendix 1.

3.1 Comparison with PCM

For comparison with 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 100m 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 spaced at 100m intervals, 4m from the carriageway.

A full list of tabulated results comparing the PCM baseline results with the local modelled results from 2015 to 2020 is shown in Table 3. The results are colour coded with red being above 40 µg/m^3, amber between 36 and 40 µg/m^3 and green under 36 µg/m^3 to reflect the level of uncertainty in the modelling. The table is in three sections:

- Section 1 is the main PCM links for Southampton council area;
- Section 2 is additional PCM links in the wider Southampton model domain;

Mapped results are provided in Figures 3 and 4. They are provided for the 2015 base year and the 2020 target year.

The 2020 results in the Southampton study area show a total of 7 links that are exceeding the limit value, all of which are on the motorway network around the city and into Eastleigh. There are also some points along the Western Approaches, at the end of the M271 and the A33 around Dorset Street, and on the A3024 Northam Road that are between 36 and 40 µg/m^3 so potentially at risk of exceeding within model uncertainty.

Table 3 Comparison of PCM and local NO2 Annual mean concentrations 2015 to 2020

CensusID	LA Name	Road Name	Length (m)	PCM Baseline					Local Baseline					
				2015	2017	2018	2019	2020	2015	2016	2017	2018	2019	2020
Southampton Links														
16340	Southampton Council	A35	1,082	28	27	26	25	24	32	30	29	28	26	25
16891	Southampton Council	A3024	2,346	33	32	31	30	28	39	37	35	33	32	30
16892	Southampton Council	A335	454	39	37	36	34	33	35	34	33	32	31	29
17531	Southampton Council	A3024	1,701	28	27	26	25	24	29	27	25	23	21	20
17532	Southampton Council	A33	531	33	32	31	30	29	33	32	31	30	29	28
17974	Southampton Council	A33	403	30	29	28	27	25	37	35	34	32	30	29
18113	Southampton Council	A3035	1,374	23	22	22	21	20	24	23	22	21	20	19
26062	Southampton Council	M271	585	39	36	35	33	31	51	47	43	40	36	32
26296	Southampton Council	A27	3,195	31	30	29	28	27	39	37	36	34	32	31
26351	Southampton Council	A33	805	37	36	35	33	32	40	38	36	35	33	31
26371	Southampton Council	A35	1,552	28	27	26	25	24	30	29	27	26	25	24
27635	Southampton Council	A3057	1,340	24	24	23	22	21	25	24	23	22	21	21
36987	Southampton Council	A334	1,657	30	29	28	27	26	25	24	23	22	21	20
37658	Southampton Council	A3025	2,303	27	26	25	24	23	33	32	31	29	28	26
38212	Southampton Council	A33	734	40	39	38	37	35	36	35	34	33	32	31
46375	Southampton Council	A35	1,394	30	29	28	27	26	35	33	32	31	29	28
46963	Southampton Council	A3024	1,663	37	36	35	33	32	50	47	45	43	40	38
46964	Southampton Council	A335	1,151	36	35	33	32	31	35	34	33	32	31	29
48317	Southampton Council	A33	498	31	30	30	29	28	24	23	23	22	21	21
48456	Southampton Council	A33	195	30	29	29	28	27	25	25	24	23	23	22
48513	Southampton Council	A33	285	29	28	28	27	27	27	27	26	25	24	23
56347	Southampton Council	A33	3,252	55	52	50	48	46	43	42	40	39	37	36
56374	Southampton Council	A35	711	33	32	31	30	29	30	29	27	26	25	24
57434	Southampton Council	A33	153	33	32	31	30	29	35	33	32	30	29	27
57672	Southampton Council	A33	162	36	35	35	35	34	32	31	29	28	26	25
6292	Southampton Council	A27	1,062	32	31	30	29	28	26	25	24	23	22	21

6349	Southampton Council	A33	1,506	34	32	31	30	29		33	32	30	29	27	26
6367	Southampton Council	A35	1,743	29	28	27	26	25		31	30	29	27	26	25
6368	Southampton Council	A35	1,678	58	52	49	46	44		43	41	40	38	37	36
6933	Southampton Council	A33	2,249	35	33	32	31	30		44	42	41	39	38	37
70064	Southampton Council	A33	239	34	33	32	31	30		24	23	22	22	21	20
70066	Southampton Council	A33	219	30	29	28	28	27		32	31	30	29	28	27
70108	Southampton Council	A27	421	25	25	24	23	22		18	17	17	16	15	15
70109	Southampton Council	A35	772	24	23	22	21	21		25	23	22	21	20	19
73605	Southampton Council	A3025	750	24	23	22	22	21		26	25	24	23	22	21
73613	Southampton Council	A3057	166	23	22	21	20	19		22	21	20	20	19	18
73615	Southampton Council	A35	289	63	58	55	52	49		46	44	42	40	38	36
75250	Southampton Council	A33	293	32	31	30	30	29		37	36	34	33	31	29
75251	Southampton Council	A33	275	42	40	39	38	37		39	37	36	35	33	32
75252	Southampton Council	A33	987	43	41	40	39	38		37	36	34	33	32	30
75253	Southampton Council	A35	1,010	39	38	36	35	33		30	29	28	27	26	25
75258	Southampton Council	M27	569	44	43	41	39	37		54	53	52	51	50	50
7569	Southampton Council	A3035	2,011	30	29	28	27	26		33	32	30	29	27	26
7580	Southampton Council	A3057	3,057	30	29	28	27	26		41	38	35	32	29	26
86003	Southampton Council	A33	276	37	36	35	34	33		34	34	33	32	31	30
99871	Southampton Council	A3024	1,401	37	36	35	34	32		42	40	38	36	34	32
99872	Southampton Council	A335	2,089	34	32	31	30	29		37	36	36	35	35	34
37658	Southampton Council	A3025	447	27	26	25	24	23		33	32	31	29	28	26
46964	Southampton Council	A335	246	36	35	33	32	31		35	34	33	32	31	29
6292	Southampton Council	A27	892	32	31	30	29	28		26	25	24	23	22	21
73613	Southampton Council	A3057	678	23	22	21	20	19		22	21	20	20	19	18
7569	Southampton Council	A3035	119	30	29	28	27	26		33	32	30	29	27	26
Other links in Southampton study area															
7988	Eastleigh Borough Council	A27	264	27	27	26	25	24		27	26	25	23	22	20
7992	Eastleigh Borough Council	A334	121	37	36	34	33	31		27	26	25	24	23	22
8129	Eastleigh Borough Council	A3025	58	24	23	22	22	21		21	20	20	19	18	17

8559	Eastleigh Borough Council	A3025	642	35	34	33	32	31	40	39	37	36	34	33
16269	Eastleigh Borough Council	A27	126	23	23	22	21	20	23	23	22	21	21	20
16321	Eastleigh Borough Council	M3	1211	36	34	32	31	30	52	51	50	49	48	47
17793	Test Valley Borough Council	M27	876	45	43	41	40	38	80	77	73	70	67	63
28018	Test Valley Borough Council	M27	387	53	50	48	46	43	49	46	44	41	38	36
29041	Test Valley Borough Council	M3	579	31	31	30	29	27	45	43	42	41	39	38
36039	Eastleigh Borough Council	A3024	552	37	35	34	33	31	39	37	36	34	32	30
36293	Eastleigh Borough Council	A27	647	26	25	25	24	23	24	23	22	21	20	20
38107	Test Valley Borough Council	M27	140	55	54	51	49	46	57	56	55	55	54	54
47635	Test Valley Borough Council	A3057	62	25	24	23	23	22	22	21	21	20	19	19
48064	Eastleigh Borough Council	M27	1212	41	40	38	37	35	83	82	80	79	77	76
56058	Test Valley Borough Council	M271	327	47	44	42	40	38	41	40	38	36	35	33
56931	Eastleigh Borough Council	A334	470	41	39	37	36	34	35	33	32	30	29	27
73606	Eastleigh Borough Council	A3024	285	28	26	25	24	23	29	28	27	26	24	23
73607	Eastleigh Borough Council	A27	12	27	27	26	25	24	22	21	21	20	19	18
73609	Eastleigh Borough Council	M27	343	40	39	37	36	34	66	64	63	62	60	59
73614	Test Valley Borough Council	M271	476	44	42	40	38	36	28	26	25	24	23	22
75259	Test Valley Borough Council	M27	704	52	50	48	46	44	79	76	73	71	68	66
36375	New Forest District Council	A35	30.625	57	53	50	48	45	45	43	41	39	37	35

Figure 3 Local modelled annual NO_2 concentrations in Southampton in 2015

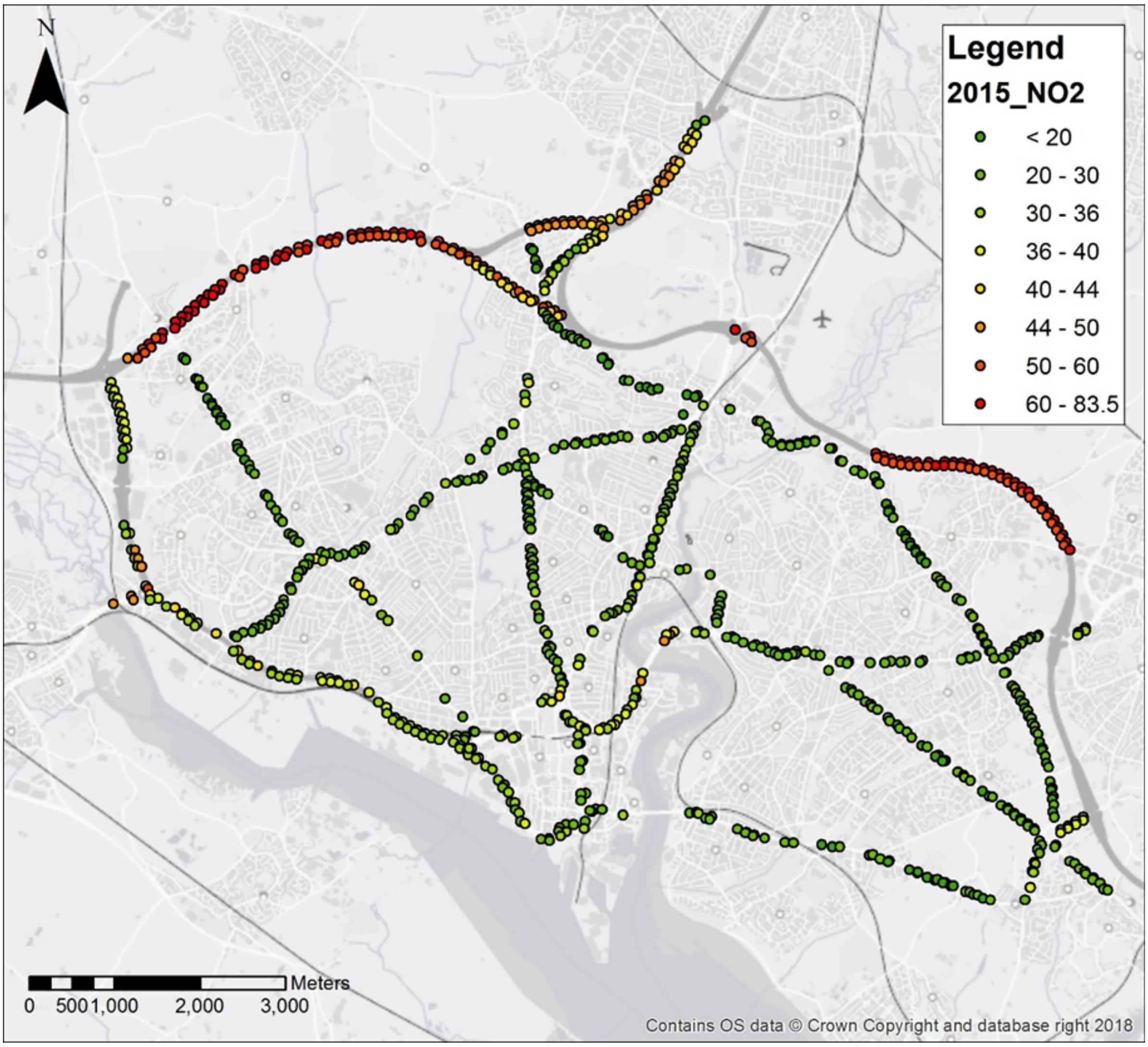
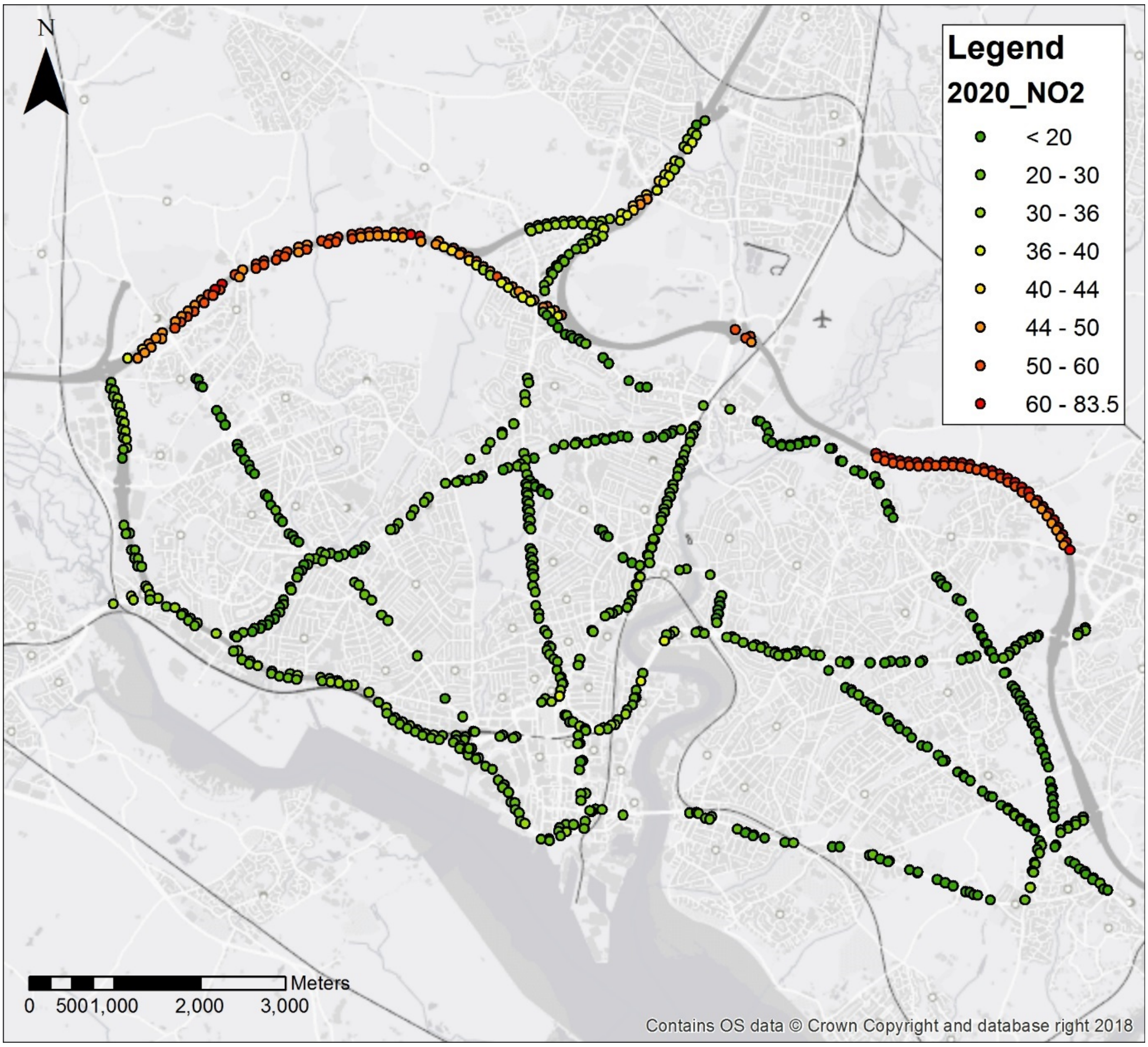


Figure 4 Local modelled annual NO_2 concentrations in 2020



3.2 Results at local monitoring points

The annual mean NO_2 concentrations measured in 2015 and modelled in 2020 are shown in Table 4 below. The 2020 results are shown both for the main global adjustment factor that has been used for all other model results and for a local site specific adjustment using just the data at the monitoring location. The local adjusted results give an indication of the concentration if specific context at this location is consider accounting for factors that may not be directly assessed in the model.

The results for Southampton indicate that in 2020, compliance with the 40 μg.m^{-3} NO_2 annual mean objective will be achieved at all locations with the global adjustment factor. The local adjusted results show two sites that may be exceeding the limit value in 2020:

- Cranbury Place – this is significantly underpredicted by the model as this is a road that is not in the traffic model and so we have no traffic data. As such the local adjustment significantly increases concentration here but this is not a reliable results as 2015 adjustment will not account for fleet improvement to 2020.

- 5 Commercial Road (N140) – this is somewhat underpredicted by the globally adjusted model, with local adjustment suggesting there may be little reduction in concentration from 2015 to 2020.

Table 4: Predicted NO_2 annual mean concentrations at monitoring site locations in 2015 and 2020

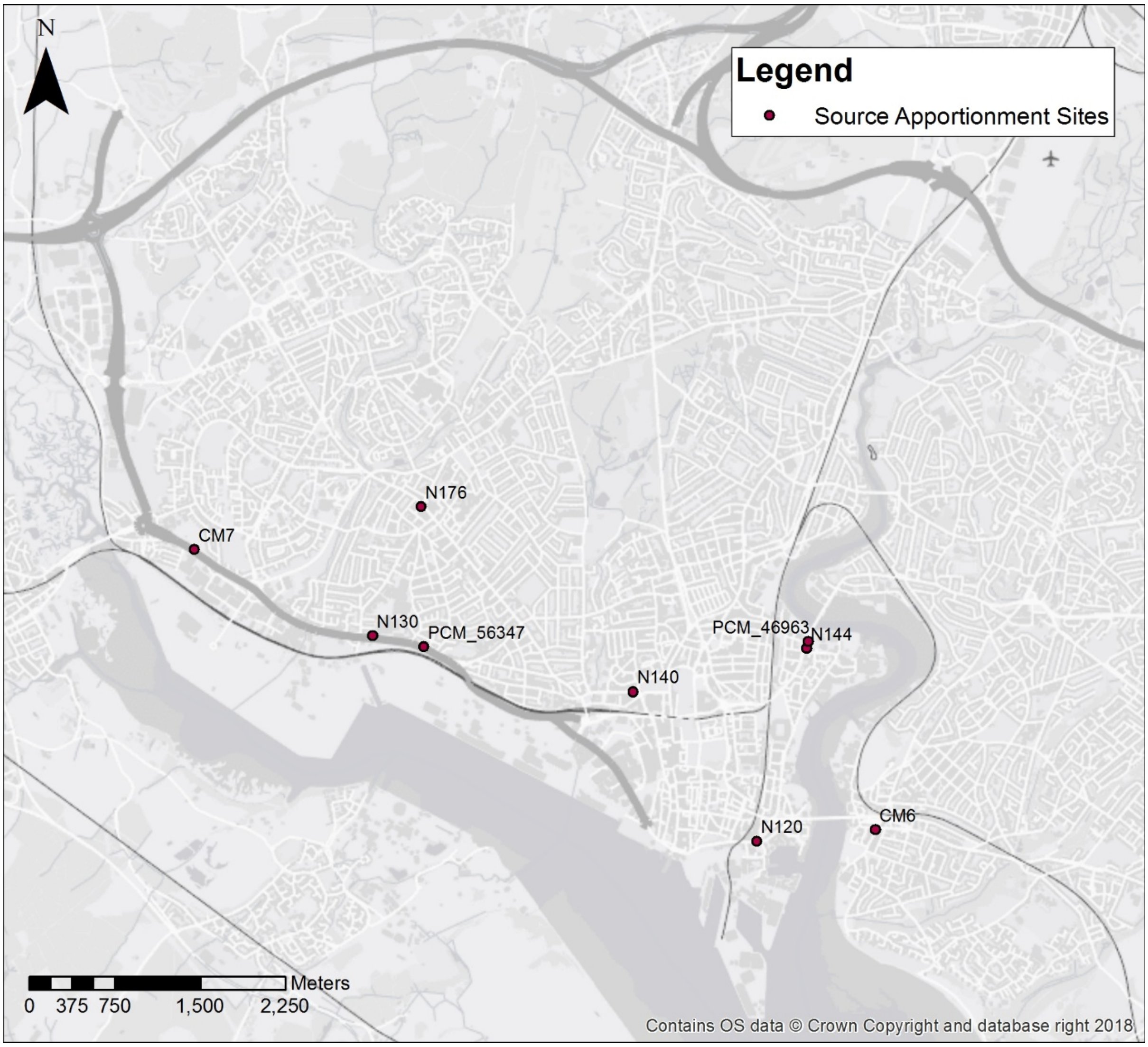
Monitoring site name	Site ID	Site type	NO_2 annual mean (μg.m^{-3})		
			Measured 2015	Modelled 2020 (Global)	Modelled 2020 (Local)
CM1 AURN Brintons Road	CM1	Urban Centre	32.0	27.4	25.8
CM4 Onslow Road	CM4	Roadside	42.0	32.8	33.8
CM6 Victoria Road	CM6	Roadside	42.0	17.6	30.1
Redbridge School Fence	N101	Roadside	44.7	31.2	36.1
64 Burgess Road	N102	Roadside	29.8	18.8	24.5
485 Millbrook Road	N103	Roadside	31.7	28.2	25.1
Regents Park Junction	N104	Roadside	38.4	28.5	31.3
2 Romsey Road	N106	Roadside	37.9	20.4	25.0
Cranbury Place	N107	Roadside	51.9	31.3	57.0
72 Bevois Valley Road	N109	Roadside	37.2	25.6	29.0
206 Bitterne Road	N113	Roadside	34.9	22.9	26.5
Bitterne Library, Bitterne Road	N114	Roadside	32.8	24.3	25.2
54 Redbridge Road	N115	Roadside	36.4	30.4	30.1
57 Redbridge Road	N116	Roadside	38.1	25.2	31.5
3 Rockstone Place	N118	Roadside	32.3	21.4	32.7
6-9 Canute Road	N120	Roadside	38.0	30.7	32.3
151 Paynes Road	N122	Roadside	31.5	29.3	25.9
102 St Andrews Road	N123	Roadside	32.8	26.5	28.3
305 Millbrook Road	N124	Roadside	37.3	31.3	30.9
Princes Court	N125	Roadside	35.3	28.8	27.0
107 St. Andrews Road	N126	Roadside	32.8	27.5	28.1
Canute Road	N129	Roadside	28.8	32.3	27.0

367A Millbrook Road	N130	Roadside	44.8	30.8	36.9
142 Romsey Road 1	N131	Roadside	37.9	24.3	24.4
539 Millbrook Road	N133	Roadside	30.7	23.6	24.3
433-435 Millbrook Road	N134	Roadside	37.6	27.8	30.2
24 Victoria Road	N135	Roadside	31.4	19.2	22.6
23 Victoria Road	N136	Roadside	31.1	20.8	22.5
66 Burgess Road 1	N138	Roadside	43.8	31.5	35.9
5 Commercial Road	N140	Roadside	44.8	38.8	44.1
Town Quay	N141	Kerbside	30.5	31.7	27.6
102 Romsey Road	N143	Roadside	34.4	22.2	22.7
208 Northam Road	N144	Roadside	31.8	35.7	25.0
222 Northam Road	N146	Roadside	28.7	32.4	22.7
44B Burgess Road	N149	Roadside	32.5	20.5	26.8
134 Romsey Road	N151	Roadside	37.4	23.7	24.0
M271	N152	Roadside	36.9	25.3	37.4
Coniston Road	N153	Roadside	31.2	21.8	23.5
Oceana Boulevard,	N154	Roadside	32.9	21.4	24.2
4 Platform Road	N157	Roadside	27.8	22.7	23.0
24 Portsmouth Road	N158	Roadside	36.8	18.6	28.6
35 Portsmouth Road	N159	Roadside	25.9	16.6	20.2
2 Dorset Street	N160	Roadside	32.6	26.7	27.8
30 Addis Square	N161	Roadside	32.5	18.3	20.4
263A Portswood Road	N162	Roadside	37.7	21.2	25.3
285 Portswood Road	N163	Roadside	27.8	19.4	20.2
168-174 Portswood Road	N164	Roadside	32.3	21.4	21.5
8 The Broadway	N165	Roadside	32.3	19.1	20.4
14 New Road	N166	Roadside	38.1	27.9	28.4
13 Romsey Road	N167	Roadside	33.5	21.3	22.1
23 Romsey Road	N168	Roadside	36.4	21.4	23.5
150 Romsey Road	N169	Roadside	40.6	25.1	26.1
4 New Road	N172	Roadside	42.9	29.1	31.7
19A Burgess Road	N173	Roadside	27.3	26.7	22.2
166A Bitterne Road	N174	Roadside	37.6	26.6	29.3
38 Shirley High Street	N175	Roadside	38.0	24.2	25.2
126 Shirley High Street	N176	Roadside	38.0	27.0	27.8
95 Shirley High Street	N177	Roadside	36.7	24.7	22.9
2 Gover Road	N178	Roadside	25.9	20.5	20.8

3.1 Source apportionment

For both 2015 and 2020 base years we have conducted source apportionment for a number of monitoring locations to provide an indication of key sources contributing to pollution levels. The locations where source apportionment were carried out is shown in Figure 5, and include locations close to the Port, including along the Western Approach, areas in Southampton where modelled concentrations are close to exceedance or other areas of local interest to the Council (including Shirley High Street and Redbridge Roundabout). The site at Redbridge Roundabout (CM7) was installed in summer 2015, and this roundabout was subject to an improvement scheme which was included in the 2020 traffic model therefore this site has been included in the source apportionment to estimate the impact of the improvement scheme.

Figure 5: Location of source apportionment results



3.1.1 2015 baseline source apportionment

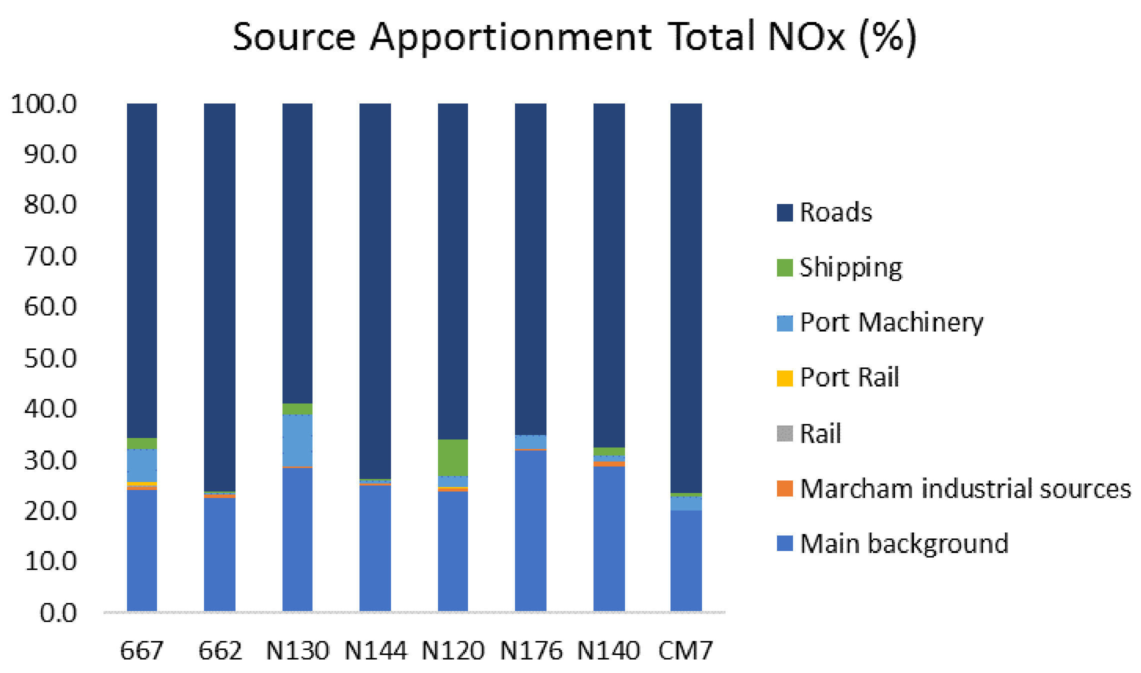
The source apportionment results for the locations from the 2015 baseline are provided in Table 5 and Figure 6. These results show that road sources are the predominant source of pollution at these locations, accounting for 59-76 %.

The exception of this is site CM6 where the road sources account for 27 % of the total NOx – there are a number of reasons why the road concentrations at this site are much lower than anticipated and for these reasons this site was treated as an outlier during model verification. CM6 is located at a junction however traffic data was not provided for one of the roads at this junction which could lead to an underestimation of emissions; the analyser is located at 1 m height which is closer to emission sources than the height of modelled concentrations, and additionally the link on which CM6 is located is a long link and so the average speed on the link could be higher than occurs in reality at the junction.

Table 5: NO_x concentrations in 2015, split into background and road sources (µg/m³)

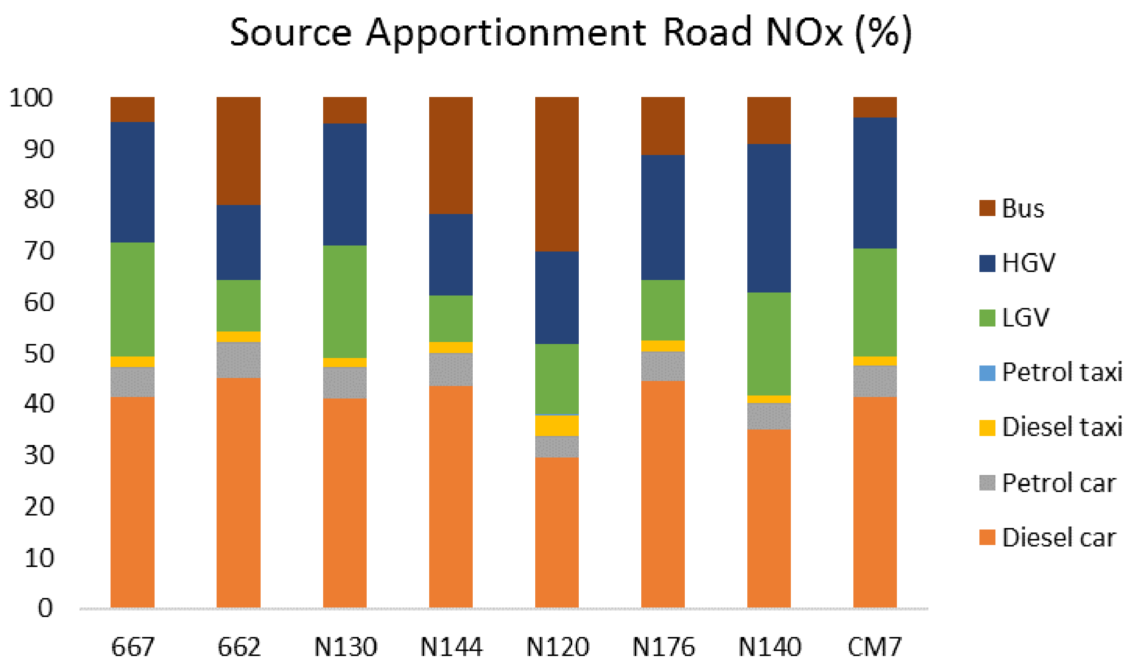
Location	Main Background	Marcham Industrial	Rail	Port Rail	Port Machinery	Shipping	Roads	Total
Southampton PCM link 56347 (Western Approach)	17.8	0.4	0.2	0.4	4.9	1.5	48.7	73.9
Southampton PCM link 46963 (Northam Road)	21.3	0.3	0	0	0.5	0.3	71.4	93.8
N130, 367A Millbrook Road	17.8	0.2	0	0	6.4	1.4	36.9	62.7
N144, 208 Northam Road	21.3	0.3	0	0	0.6	0.3	62.9	85.4
N120, 6-9 Canute Road	14.6	0.3	0	0.2	1.3	4.4	40.3	61.1
N176, 126 Shirley High Street	20.3	0.2	0	0	1.9	0	41.5	63.9
N140, 5 Commercial Road	23.0	0.7	0	0	1.0	1.3	53.9	79.9
CM7, Redbridge Road AURN	15.7	0.1	0	0	2.2	0.6	59.9	78.5

Figure 6: Breakdown of NO_x concentrations by source type – 2015 baseline (%)



The road contribution can be further broken down to show the contribution from each of the main vehicle types, as shown in Figure 7. Diesel cars account for the highest proportion of road traffic emissions (average 41%) followed by HGV emissions (average 22 %). The exception to this is site N120, where buses and diesel cars account for 30 % of the total emissions each. Emissions from taxis at the source apportionment sites are on average 2 %.

Figure 7: Breakdown of road NO_x contribution by vehicle type (%)



3.1.2 2020 baseline source apportionment

The 2020 NOx source apportionment results are presented in Table 6 and

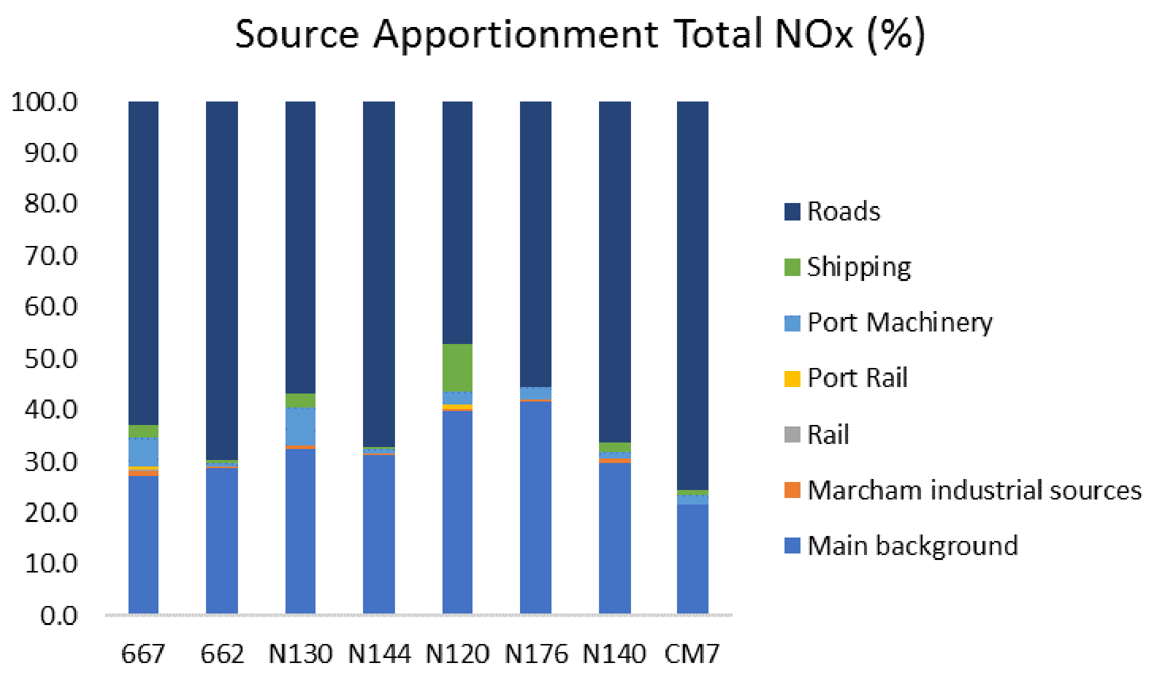
Figure 8. Similarly to the 2015 baseline, the majority of the total NOx emissions are from road sources (47 – 76 %), with the exception of site CM6 for the reasons discussed above.

Table 6: NO_x concentrations in 2020, split into background and road sources (µg/m³)

Location	Main Background	Marcham Industrial	Rail	Port Rail	Port Machinery	Shipping	Roads	Total
Southampton PCM link 56347 (Western Approach)	15.9	0.4	0.2	0.4	3.1	1.4	36.7	58.1
Southampton PCM link 46963 (Northam Road)	18.4	0.3	0	0	0.4	0.3	45.0	64.4
N130, 367A Millbrook Road	15.9	0.2	0	0	3.6	1.3	27.8	48.8
N144, 208 Northam Road	18.4	0.3	0	0	0.4	0.3	39.7	59.1
N120, 6-9 Canute Road	19.4	0.3	0	0.4	1.2	4.5	23.1	48.9
N176, 126 Shirley High Street	17.4	0.2	0	0	1.1	0	23.1	41.8

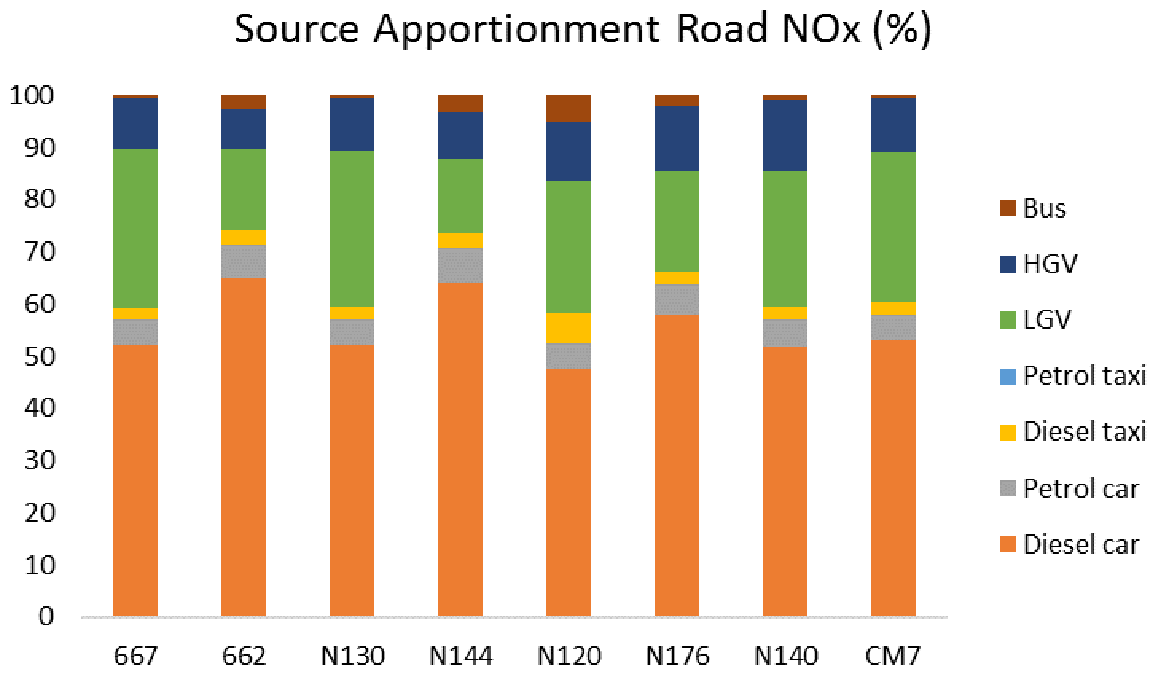
N140, 5 Commercial Road	19.6	0.7	0	0	0.7	1.3	43.7	66.0
CM7, Redbridge Road AURN	13.3	0.1	0	0	1.2	0.5	46.6	61.7

Figure 8: Breakdown of NO_x concentrations by source type – 2020 baseline (%)



The road contribution can be further broken down to describe the contribution from each of the main vehicle types (Figure 9). Diesel cars still contribute the largest amount to total road NOx in 2020 (average 56 %), followed by LGVs (average 22 %). The proportion of emissions from buses has reduced in 2020 as a result of the completion of Southampton's bus retrofit programme resulting in all buses being Euro 6.

Figure 9: Breakdown of road NO_x contribution by vehicle type (%)



4 Options results

The two CAZ scheme options have been modelled for both the Southampton area with the results being extracted for both the PCM links and the local monitoring locations in the same way as for the baseline results in Section 3 above.

4.1 Comparison with PCM

A summary of the modelled annual mean NO_2 results for each of the options is shown in Table 7 with details provided in *Note – the one link > 40 μ/m³ in the SCC boundary is on the M27 a Highways England road.

The impact of each option on the Southampton model area can be summarised as follows:

- Non-charging CAZ package: the package of non-charging measures has limited impact on concentrations with the maximum reduction being no more than 0.1 μ/m³. Therefore, it makes no difference to the overall results when compared to the 'do minimum' scenario.

- City-wide CAZ B: on average this reduces concentrations of NO_2 by 6.4%, but this varies from link to link ranging from a 2% reduction up to 13% reduction. This reduces the number of links greater than 35 μ/m³, which are potentially at risk of exceedance, in the Southampton City boundary from 6 to 2 with one of these being the M27. Outside of the city boundary on the surrounding motorway network the CAZ B reduces the number of links above 35 μ/m³ from 8 to 6.

Table 8 Annual mean NO2 for each PCM link in 2020 by option

CensusID	Road Name	LA Name	Length (m)	Do Minimum	Non-charging CAZ	CAZ B
Southampton links						
16340	A35	Southampton Council	1,082	25	25	23
16891	A3024	Southampton Council	2,346	30	30	28
16892	A335	Southampton Council	454	29	29	27
17531	A3024	Southampton Council	1,701	20	20	19
17532	A33	Southampton Council	531	28	28	27
17974	A33	Southampton Council	403	29	29	26
18113	A3035	Southampton Council	1,374	19	19	18
26062	M271	Southampton Council	585	32	32	29
26296	A27	Southampton Council	3,195	31	31	27
26351	A33	Southampton Council	805	31	31	28
26371	A35	Southampton Council	1,552	24	24	22
27635	A3057	Southampton Council	1,340	21	20	19
36987	A334	Southampton Council	1,657	20	20	20
37658	A3025	Southampton Council	2,303	26	26	26
38212	A33	Southampton Council	734	31	31	29
46375	A35	Southampton Council	1,394	28	28	26
46963	A3024	Southampton Council	1,663	38	38	36
46964	A335	Southampton Council	1,151	29	29	27
48317	A33	Southampton Council	498	21	21	20
48456	A33	Southampton Council	195	22	22	21
48513	A33	Southampton Council	285	23	23	22

56347	A33	Southampton Council	3,252	36	36	32
56374	A35	Southampton Council	711	24	24	22
57434	A33	Southampton Council	153	27	27	25
57672	A33	Southampton Council	162	25	25	23
6292	A27	Southampton Council	1,062	21	21	20
6349	A33	Southampton Council	1,506	26	26	24
6367	A35	Southampton Council	1,743	25	25	23
6368	A35	Southampton Council	1,678	36	35	32
6933	A33	Southampton Council	2,249	37	37	34
70064	A33	Southampton Council	239	20	20	20
70066	A33	Southampton Council	219	27	27	26
70108	A27	Southampton Council	421	15	15	15
70109	A35	Southampton Council	772	19	19	18
73605	A3025	Southampton Council	750	21	21	20
73613	A3057	Southampton Council	166	18	18	17
73615	A35	Southampton Council	289	36	36	33
75250	A33	Southampton Council	293	29	29	27
75251	A33	Southampton Council	275	32	32	30
75252	A33	Southampton Council	987	30	30	28
75253	A35	Southampton Council	1,010	25	25	23
75258	M27	Southampton Council	569	50	49	44
7569	A3035	Southampton Council	2,011	26	26	25
7580	A3057	Southampton Council	3,057	26	26	25
86003	A33	Southampton Council	276	30	30	29
99871	A3024	Southampton Council	1,401	32	31	29
99872	A335	Southampton Council	2,089	34	34	32
37658	A3025	Southampton Council	447	26	26	26
46964	A335	Southampton Council	246	29	29	27
6292	A27	Southampton Council	892	21	21	20
73613	A3057	Southampton Council	678	18	18	17
7569	A3035	Southampton Council	119	26	26	25
Other links in Southampton study area						
7988	A27	Eastleigh Borough Council	264	20	20	19
7992	A334	Eastleigh Borough Council	121	22	22	21
8129	A3025	Eastleigh Borough Council	58	17	17	17
8559	A3025	Eastleigh Borough Council	642	33	33	30
16269	A27	Eastleigh Borough Council	126	20	20	19
16321	M3	Eastleigh Borough Council	1211	47	47	43
17793	M27	Test Valley Borough Council	876	63	63	55
28018	M27	Test Valley Borough Council	387	36	36	32
29041	M3	Test Valley Borough Council	579	38	38	34
36039	A3024	Eastleigh Borough Council	552	30	30	26
36293	A27	Eastleigh Borough Council	647	20	20	19
38107	M27	Test Valley Borough Council	140	54	54	47
47635	A3057	Test Valley Borough Council	62	19	19	18
48064	M27	Eastleigh Borough Council	1212	76	76	68

56058	M271	Test Valley Borough Council	327	33	33	30
56931	A334	Eastleigh Borough Council	470	27	27	26
73606	A3024	Eastleigh Borough Council	285	23	23	21
73607	A27	Eastleigh Borough Council	12	18	18	17
73609	M27	Eastleigh Borough Council	343	59	59	53
73614	M271	Test Valley Borough Council	476	22	22	20
75259	M27	Test Valley Borough Council	704	66	61	53
36375	A35	New Forest District Council	31	35	35	31

below. The detailed results are broken down in the same way as the baseline results with three sections showing results for the PCM links in Southampton, PCM links in the wider Southampton modelled area and the PCM links in New Forest. The mapped results are shown in Figures 7 to 10.

Table 7 Summary of NO_2 results for the PCM links for options in 2020

Option	With SCC Boundary*		Beyond SCC Boundary		Average Change in NO_2 (%) in SCC
	PCM links > 40μ/m³	PCM links > 35μ/m³	PCM links > 40μ/m³	PCM links > 35μ/m³	
Do minimum	1	6	6	8	n/a
Non-charging CAZ	1	6	6	8	-0.1
City Wide CAZ B	1	2	6	6	-6.4

*Note – the one link > 40 μ/m³ in the SCC boundary is on the M27 a Highways England road.

The impact of each option on the Southampton model area can be summarised as follows:

- Non-charging CAZ package: the package of non-charging measures has limited impact on concentrations with the maximum reduction being no more than 0.1 μ/m³. Therefore, it makes no difference to the overall results when compared to the 'do minimum' scenario.

- City-wide CAZ B: on average this reduces concentrations of NO_2 by 6.4%, but this varies from link to link ranging from a 2% reduction up to 13% reduction. This reduces the number of links greater than 35 μ/m³, which are potentially at risk of exceedance, in the Southampton City boundary from 6 to 2 with one of these being the M27. Outside of the city boundary on the surrounding motorway network the CAZ B reduces the number of links above 35 μ/m³ from 8 to 6.

Table 8 Annual mean NO2 for each PCM link in 2020 by option

CensusID	Road Name	LA Name	Length (m)	Do Minimum	Non-charging CAZ	CAZ B
Southampton links						
16340	A35	Southampton Council	1,082	25	25	23
16891	A3024	Southampton Council	2,346	30	30	28
16892	A335	Southampton Council	454	29	29	27
17531	A3024	Southampton Council	1,701	20	20	19
17532	A33	Southampton Council	531	28	28	27
17974	A33	Southampton Council	403	29	29	26
18113	A3035	Southampton Council	1,374	19	19	18
26062	M271	Southampton Council	585	32	32	29
26296	A27	Southampton Council	3,195	31	31	27

26351	A33	Southampton Council	805	31	31	28
26371	A35	Southampton Council	1,552	24	24	22
27635	A3057	Southampton Council	1,340	21	20	19
36987	A334	Southampton Council	1,657	20	20	20
37658	A3025	Southampton Council	2,303	26	26	26
38212	A33	Southampton Council	734	31	31	29
46375	A35	Southampton Council	1,394	28	28	26
46963	A3024	Southampton Council	1,663	38	38	36
46964	A335	Southampton Council	1,151	29	29	27
48317	A33	Southampton Council	498	21	21	20
48456	A33	Southampton Council	195	22	22	21
48513	A33	Southampton Council	285	23	23	22
56347	A33	Southampton Council	3,252	36	36	32
56374	A35	Southampton Council	711	24	24	22
57434	A33	Southampton Council	153	27	27	25
57672	A33	Southampton Council	162	25	25	23
6292	A27	Southampton Council	1,062	21	21	20
6349	A33	Southampton Council	1,506	26	26	24
6367	A35	Southampton Council	1,743	25	25	23
6368	A35	Southampton Council	1,678	36	35	32
6933	A33	Southampton Council	2,249	37	37	34
70064	A33	Southampton Council	239	20	20	20
70066	A33	Southampton Council	219	27	27	26
70108	A27	Southampton Council	421	15	15	15
70109	A35	Southampton Council	772	19	19	18
73605	A3025	Southampton Council	750	21	21	20
73613	A3057	Southampton Council	166	18	18	17
73615	A35	Southampton Council	289	36	36	33
75250	A33	Southampton Council	293	29	29	27
75251	A33	Southampton Council	275	32	32	30
75252	A33	Southampton Council	987	30	30	28
75253	A35	Southampton Council	1,010	25	25	23
75258	M27	Southampton Council	569	50	49	44
7569	A3035	Southampton Council	2,011	26	26	25
7580	A3057	Southampton Council	3,057	26	26	25
86003	A33	Southampton Council	276	30	30	29
99871	A3024	Southampton Council	1,401	32	31	29
99872	A335	Southampton Council	2,089	34	34	32
37658	A3025	Southampton Council	447	26	26	26
46964	A335	Southampton Council	246	29	29	27
6292	A27	Southampton Council	892	21	21	20
73613	A3057	Southampton Council	678	18	18	17
7569	A3035	Southampton Council	119	26	26	25
Other links in Southampton study area						
7988	A27	Eastleigh Borough Council	264	20	20	19
7992	A334	Eastleigh Borough Council	121	22	22	21

8129	A3025	Eastleigh Borough Council	58	17	17	17
8559	A3025	Eastleigh Borough Council	642	33	33	30
16269	A27	Eastleigh Borough Council	126	20	20	19
16321	M3	Eastleigh Borough Council	1211	47	47	43
17793	M27	Test Valley Borough Council	876	63	63	55
28018	M27	Test Valley Borough Council	387	36	36	32
29041	M3	Test Valley Borough Council	579	38	38	34
36039	A3024	Eastleigh Borough Council	552	30	30	26
36293	A27	Eastleigh Borough Council	647	20	20	19
38107	M27	Test Valley Borough Council	140	54	54	47
47635	A3057	Test Valley Borough Council	62	19	19	18
48064	M27	Eastleigh Borough Council	1212	76	76	68
56058	M271	Test Valley Borough Council	327	33	33	30
56931	A334	Eastleigh Borough Council	470	27	27	26
73606	A3024	Eastleigh Borough Council	285	23	23	21
73607	A27	Eastleigh Borough Council	12	18	18	17
73609	M27	Eastleigh Borough Council	343	59	59	53
73614	M271	Test Valley Borough Council	476	22	22	20
75259	M27	Test Valley Borough Council	704	66	61	53
36375	A35	New Forest District Council	31	35	35	31

Figure 10: NO_2 concentrations at PCM receptors for 2020 Non-Charging CAZ scenario

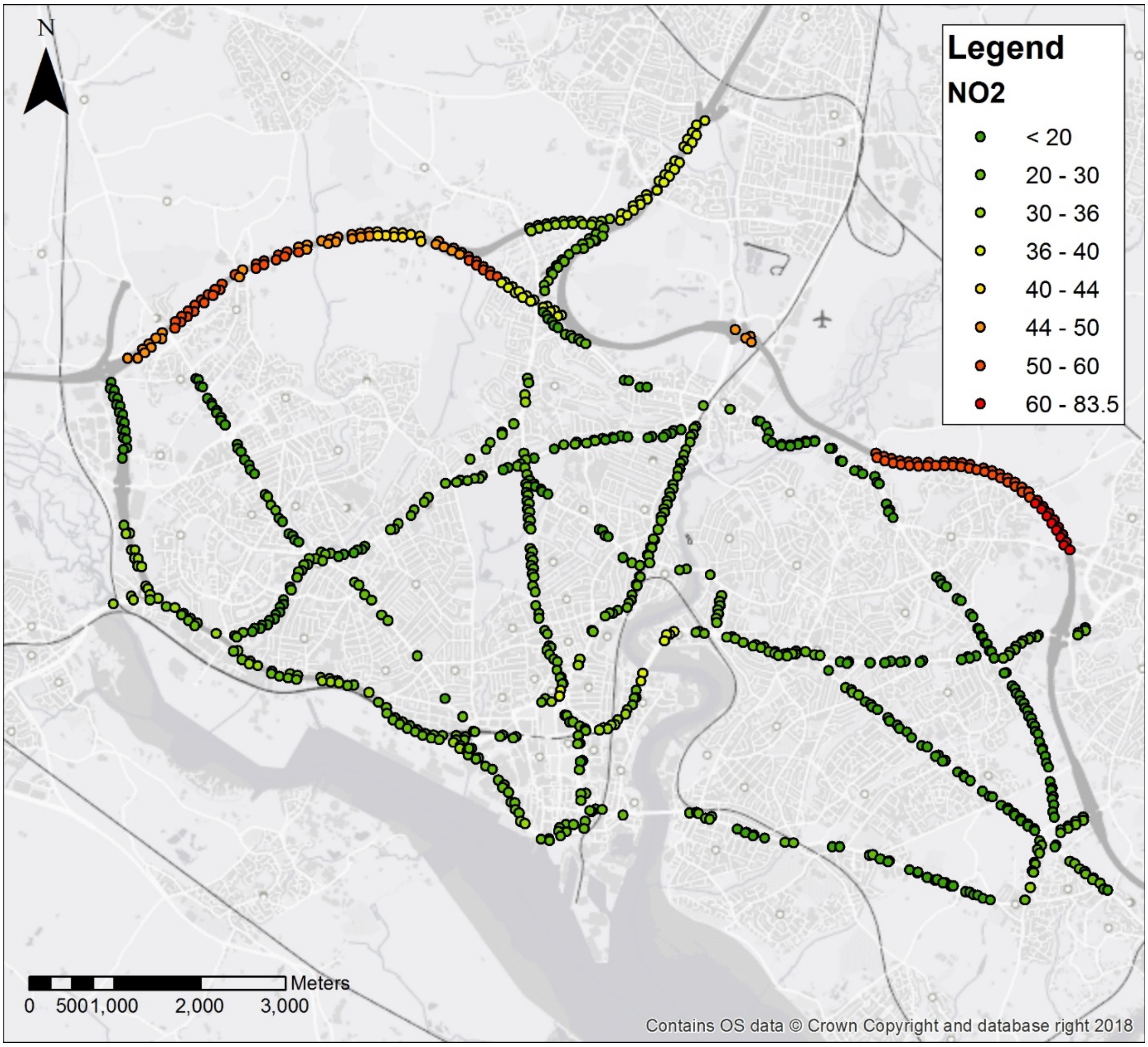
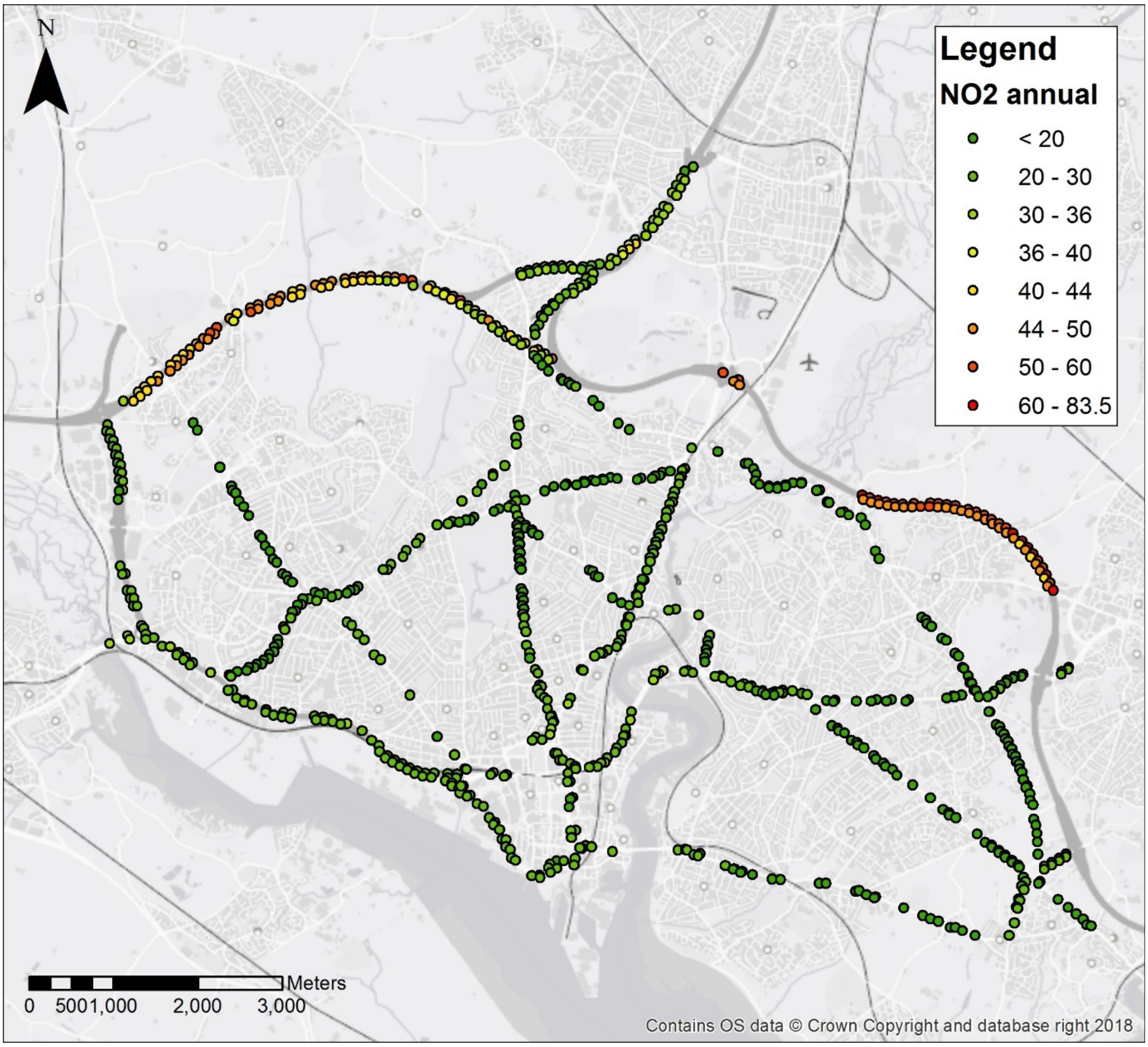


Figure 11: NO_2 concentrations at PCM receptors for 2020 CAZ B scenario



4.2 Results at local monitoring points

Modelled NO_2 results have also been extracted from the model for each of the monitoring locations in Southampton. These results provide an indication of the impact of the options in relation to areas of concern in relation to local air quality management.

These results show that all of the monitoring locations were below the 40 µg/m³ limit value in the baseline 'do minimum' scenario and remain so for all the options modelled.

Table 9: Predicted NO_2 annual mean concentrations at monitoring site locations in 2015 and 2020

Monitoring site name	Site ID	Site type	NO_2 annual mean (µg.m⁻³) Global adjustment		
			Do Min	Non-charging	CAZ
CM1 AURN Brintons Road	CM1	Urban Centre	27.4	27.4	26.4
CM4 Onslow Road	CM4	Roadside	32.8	32.8	30.4
CM6 Victoria Road	CM6	Roadside	17.6	17.6	17.3
Redbridge School Fence	N101	Roadside	31.2	31.1	28.1
64 Burgess Road	N102	Roadside	18.8	18.8	17.9
485 Millbrook Road	N103	Roadside	28.2	28.2	25.9
Regents Park Junction	N104	Roadside	28.5	28.5	26.5
2 Romsey Road	N106	Roadside	20.4	20.4	19.8
Cranbury Place	N107	Roadside	31.3	31.3	29.4
72 Bevois Valley Road	N109	Roadside	25.6	25.6	23.7
206 Bitterne Road	N113	Roadside	22.9	22.9	21.7
Bitterne Library, Bitterne Road	N114	Roadside	24.3	24.3	22.8
54 Redbridge Road	N115	Roadside	30.4	30.4	27.6
57 Redbridge Road	N116	Roadside	25.2	25.2	23.2
3 Rockstone Place	N118	Roadside	21.4	24.1	22.5
6-9 Canute Road	N120	Roadside	30.7	30.7	28.7
151 Paynes Road	N122	Roadside	29.3	29.3	27.2
102 St Andrews Road	N123	Roadside	26.5	26.5	25.8
305 Millbrook Road	N124	Roadside	31.3	31.2	28.8
Princes Court	N125	Roadside	28.8	28.8	26.9
107 St. Andrews Road	N126	Roadside	27.5	27.5	26.6
Canute Road	N129	Roadside	32.3	32.2	30.3
367A Millbrook Road	N130	Roadside	30.8	30.8	28.5
142 Romsey Road 1	N131	Roadside	24.3	24.3	23.2
539 Millbrook Road	N133	Roadside	23.6	23.6	22.2
433-435 Millbrook Road	N134	Roadside	27.8	27.8	25.6
24 Victoria Road	N135	Roadside	19.2	19.2	18.9
23 Victoria Road	N136	Roadside	20.8	20.7	20.3
66 Burgess Road 1	N138	Roadside	31.5	31.6	29.5
5 Commercial Road	N140	Roadside	38.8	38.8	36.1
Town Quay	N141	Kerbside	31.7	31.7	29.4

102 Romsey Road	N143	Roadside	22.2	22.2	21.5
208 Northam Road	N144	Roadside	35.7	35.7	33.3
222 Northam Road	N146	Roadside	32.4	32.4	30.4
44B Burgess Road	N149	Roadside	20.5	20.5	19.3
134 Romsey Road	N151	Roadside	23.7	23.7	22.7
M271	N152	Roadside	25.3	25.3	23.1
Coniston Road	N153	Roadside	21.8	21.8	20.1
Oceana Boulevard,	N154	Roadside	21.4	21.4	20.9
4 Platform Road	N157	Roadside	22.7	22.7	21.4
24 Portsmouth Road	N158	Roadside	18.6	18.6	18.2
35 Portsmouth Road	N159	Roadside	16.6	16.6	16.5
2 Dorset Street	N160	Roadside	26.7	26.7	25.7
30 Addis Square	N161	Roadside	18.3	18.3	17.5
263A Portswood Road	N162	Roadside	21.2	21.2	20.0
285 Portswood Road	N163	Roadside	19.4	19.4	18.7
168-174 Portswood Road	N164	Roadside	21.4	21.4	20.2
8 The Broadway	N165	Roadside	19.1	19.1	18.2
14 New Road	N166	Roadside	27.9	27.9	26.3
13 Romsey Road	N167	Roadside	21.3	21.3	20.5
23 Romsey Road	N168	Roadside	21.4	21.4	20.6
150 Romsey Road	N169	Roadside	25.1	25.0	23.8
4 New Road	N172	Roadside	29.1	29.0	27.3
19A Burgess Road	N173	Roadside	26.7	26.7	24.8
166A Bitterne Road	N174	Roadside	26.6	26.6	25.4
38 Shirley High Street	N175	Roadside	24.2	24.2	23.5
126 Shirley High Street	N176	Roadside	27.0	27.0	25.6
95 Shirley High Street	N177	Roadside	24.7	24.7	23.7
2 Gover Road	N178	Roadside	20.5	20.5	18.9

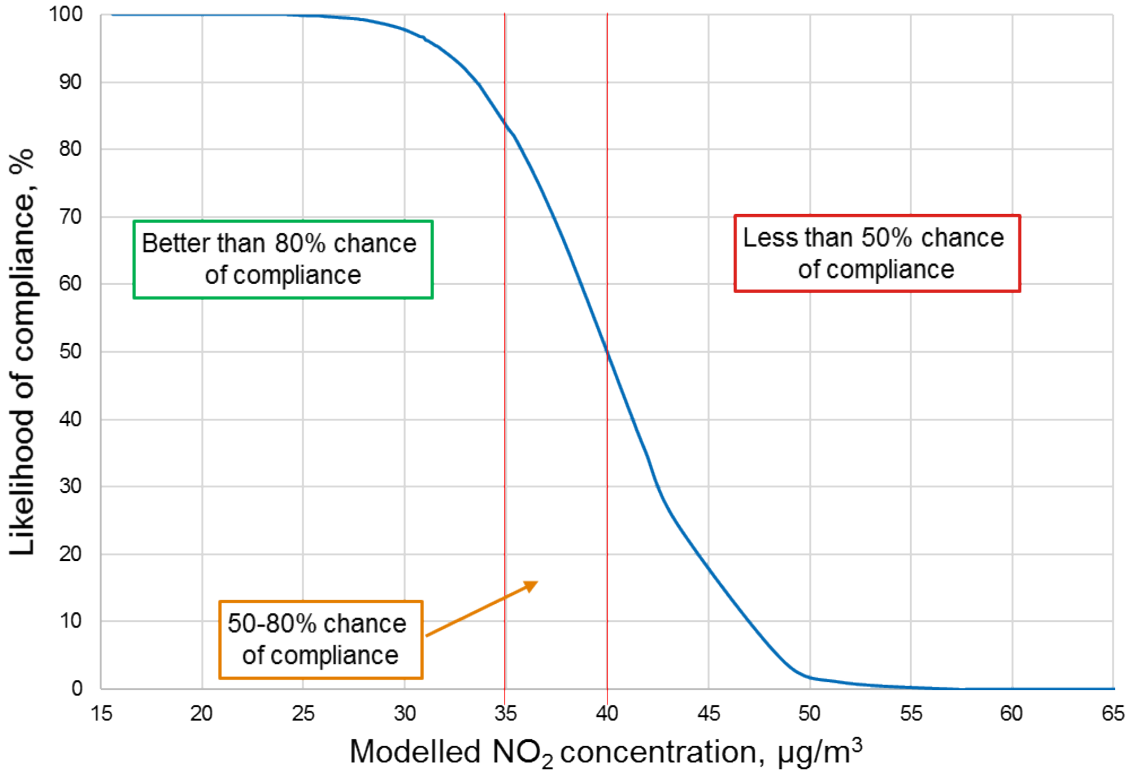
5 Modelling uncertainty and sensitivity tests

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 4.7 µg.m^{-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 12. This shows that for a model with an RMSE of 5 µg.m^{-3} a modelled result of 35 µg.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 µg.m^{-3} as being at risk of exceedance.

Figure 12 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 Baseline and option assumption sensitivity tests

The model performance describe above relates directly to the baseline and is only an indication of uncertainty in forecast years and option assessment. In these forecasts there will also be uncertainty related to the assumptions we have made in modelling these options. The assumptions relate both activity and behaviour assumptions and wider modelling assumptions such as those relating to emission factors. The sensitivity analysis of activity and behaviour assumptions is considered in this section and the wider modelling assumptions are considered in section 5.3 below.

The current updated baseline results reported in section 3 indicate that compliance will be achieved within the 'do minimum' baseline. Any mitigation options applied will improve compliance further and so reduce risk from uncertainty in the baseline. This refocuses the importance of the sensitivity tests to the 'do minimum' baseline scenario and in particular tests that could give rise to not achieving compliance. The key changes to the baseline discussed in section 5 above that could be considered for sensitivity tests comprise:

1. *Updates to the underlying transport model and the national road traffic forecasts* – these changes are essentially ensuring that the latest model is WebTag compliant so are not appropriate for sensitivity testing.

2. *Inclusion of measures that already have funding* – these could be considered for sensitivity testing. However, the cycling scheme and the taxi incentive had very little impact so there is little room for tests here. The CBTF scheme has a greater impact and lack of uptake of the scheme by operators would reduce its impact. However, bus traffic along the main area of concern (the Western Approaches) is limited so the impact here will be small and unlikely to affect the outcome.

3. *Port growth assumptions* – there was a significant reduction of growth in the latest projection, particularly for the container port, compared to the 2016 Master Plan which was the original source for the forecast. Although the latest data available supports these lower growth projections if higher growth did occur this could have an impact along the Western Approaches.

<u>*Based on these considerations the key sensitivity test that has been taken forward for the baseline is to return the port growth to that originally sourced from the 2016 Port Masterplan, with all other assumptions keep the same, as a worst-case scenario.*</u>

The sensitivity testing for the options, given modelled compliance in the baseline, is now much less important in terms of affecting the outcome. Any mitigation measures that are taken forward should be seeking to improve the confidence in compliance by 2020. Given this the consideration on sensitivity testing for the options is as follows:

- *CAZ B sensitivity test* – given the current position with the baseline this option is a much less likely outcome. Also, the proposed test of a 0% upgrade assumption as a worst case scenario is likely to yield results little different from the baseline. This is because the original modelling of the city-wide CAZ B showed little diversionary affect, with the greatest impact on concentrations being a result of the upgrade assumption. <u>Based on this it is not proposed to carry out any further sensitivity testing of the CAZ B option.</u>

- *Non-charging CAZ* – the final set of measures tested for the non-charging CAZ are significantly reduced in scope and scale of uptake, since the original test was considered very optimistic. As such the impact of the option is expected to be a small but useful benefit. Given this any tests that reduce the impact of the non-charging scheme further are limited. <u>Based on this only a very simple test is proposed that halves the benefit of the non-charging scheme on concentrations.</u>

The results for the higher port growth sensitivity test and the non-charging sensitivity test are shown in Table 10 below. The high port growth sensitivity tests indicates some minor increases in concentrations on the Western Approaches (A33) but this is not enough to change the compliance outcome for the 'do minimum' baseline. The non-charging CAZ has already been shown to have no impact on concentration and so reducing the impact of these measures further has the same outcome.

Table 10 Results of the high port growth and non-charging CAZ sensitivity tests (NO_2, $\mu g.m^{-3}$)

CensusID	Road Name	LA Name	Length (m)	Do Minimum	High port growth	Non-charging sensitivity
Southampton links						
16340	A35	Southampton Council	1,082	25	25	25
16891	A3024	Southampton Council	2,346	30	30	30
16892	A335	Southampton Council	454	29	29	29
17531	A3024	Southampton Council	1,701	20	20	20
17532	A33	Southampton Council	531	28	28	28
17974	A33	Southampton Council	403	29	29	29
18113	A3035	Southampton Council	1,374	19	19	19
26062	M271	Southampton Council	585	32	32	32
26296	A27	Southampton Council	3,195	31	31	31
26351	A33	Southampton Council	805	31	31	31
26371	A35	Southampton Council	1,552	24	24	24
27635	A3057	Southampton Council	1,340	21	21	20
36987	A334	Southampton Council	1,657	20	20	20
37658	A3025	Southampton Council	2,303	26	26	26
38212	A33	Southampton Council	734	31	31	31
46375	A35	Southampton Council	1,394	28	28	28
46963	A3024	Southampton Council	1,663	38	38	38
46964	A335	Southampton Council	1,151	29	29	29
48317	A33	Southampton Council	498	21	21	21
48456	A33	Southampton Council	195	22	22	22
48513	A33	Southampton Council	285	23	24	23
56347	A33	Southampton Council	3,252	36	36	36
56374	A35	Southampton Council	711	24	24	24
57434	A33	Southampton Council	153	27	27	27
57672	A33	Southampton Council	162	25	25	25
6292	A27	Southampton Council	1,062	21	21	21
6349	A33	Southampton Council	1,506	26	26	26
6367	A35	Southampton Council	1,743	25	25	25
6368	A35	Southampton Council	1,678	36	36	35
6933	A33	Southampton Council	2,249	37	37	37
70064	A33	Southampton Council	239	20	20	20
70066	A33	Southampton Council	219	27	27	27
70108	A27	Southampton Council	421	15	15	15
70109	A35	Southampton Council	772	19	19	19
73605	A3025	Southampton Council	750	21	21	21
73613	A3057	Southampton Council	166	18	18	18

73615	A35	Southampton Council	289	36	36	36
75250	A33	Southampton Council	293	29	30	29
75251	A33	Southampton Council	275	32	33	32
75252	A33	Southampton Council	987	30	31	30
75253	A35	Southampton Council	1,010	25	25	25
75258	M27	Southampton Council	569	50	50	49
7569	A3035	Southampton Council	2,011	26	26	26
7580	A3057	Southampton Council	3,057	26	27	26
86003	A33	Southampton Council	276	30	31	30
99871	A3024	Southampton Council	1,401	32	32	31
99872	A335	Southampton Council	2,089	34	34	34
37658	A3025	Southampton Council	447	26	26	26
46964	A335	Southampton Council	246	29	29	29
6292	A27	Southampton Council	892	21	21	21
73613	A3057	Southampton Council	678	18	18	18
7569	A3035	Southampton Council	119	26	26	26
Other links in Southampton study area						
7988	A27	Eastleigh Borough Council	264	20	21	20
7992	A334	Eastleigh Borough Council	121	22	22	22
8129	A3025	Eastleigh Borough Council	58	17	18	17
8559	A3025	Eastleigh Borough Council	642	33	33	33
16269	A27	Eastleigh Borough Council	126	20	20	20
16321	M3	Eastleigh Borough Council	1211	47	47	47
17793	M27	Test Valley Borough Council	876	63	63	63
28018	M27	Test Valley Borough Council	387	36	36	36
29041	M3	Test Valley Borough Council	579	38	38	38
36039	A3024	Eastleigh Borough Council	552	30	30	30
36293	A27	Eastleigh Borough Council	647	20	20	20
38107	M27	Test Valley Borough Council	140	54	54	54
47635	A3057	Test Valley Borough Council	62	19	19	19
48064	M27	Eastleigh Borough Council	1212	76	76	76
56058	M271	Test Valley Borough Council	327	33	33	33
56931	A334	Eastleigh Borough Council	470	27	28	27
73606	A3024	Eastleigh Borough Council	285	23	23	23
73607	A27	Eastleigh Borough Council	12	18	18	18
73609	M27	Eastleigh Borough Council	343	59	59	59
73614	M271	Test Valley Borough Council	476	22	22	22
75259	M27	Test Valley Borough Council	704	66	61	61
36375	A35	New Forest District Council	31	35	35	35

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 will be modelled to quantify the potential change in predicted NO_2 annual mean concentrations; and for a number of the remaining recommended tests, discussion will 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 test 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 for the 2020 Do-minimum scenario only.

- *Lower f-NO_2 values in projected year by 40%* - this has been applied to the 2020 baseline model outputs only.

Predicted maximum concentrations on PCM links for each of these tests are presented in **Error! Reference source not found.**. These results can be summarised as follows:

- Future emission standards test – by setting all all Euro 6 light duty vehicles to the Euro 6a standard increases concentrations in 2020 by on average 4% (or 1-2 µg.m^{-3}). This is not sufficient for any location to exceed the 40 µg.m^{-3} limit value but it does take on link (ID46963) up to the limit. Given model uncertainty discussed in section 5.1 this increases the risk of exceedance in the do minimum situation.

- Lower f-NO_2 – by lower the proportion of primary NO_2 in the NOx to NO_2 conversion significantly reduces concentrations by an average of 5% but this varies from, 0% to 15% depending on traffic composition. This reduction would effectively reduce all concentrations below 35 µg.m^{-3}, except for those on motorway links, and so remove any remaining risk on exceedance.

Table 11: NO_2 concentrations on PCM links during sensitivity tests (Euro 6 engines, and reduced fNO_2 ratios)

CensusID	LA Name	Length (m)	Annual Mean NO_2 in 2020				
			Baseline	Euro 6 no C/D	% change Euro 6	fNO_2 40 % reduction	% change fNO_2
Southampton Links							
16340	Southampton Council	1082.4	25	26	4%	24	-5%
16891	Southampton Council	2346.2	30	31	4%	28	-6%
16892	Southampton Council	454.3	29	31	4%	28	-6%
17531	Southampton Council	1700.7	20	20	3%	19	-2%
17532	Southampton Council	530.8	28	28	1%	27	-2%
17974	Southampton Council	403.3	29	30	4%	27	-7%
18113	Southampton Council	1374.0	19	20	3%	19	-3%
26062	Southampton Council	584.8	32	33	4%	29	-8%
26296	Southampton Council	3194.8	31	32	5%	28	-9%
26351	Southampton Council	804.7	31	33	5%	29	-9%
26371	Southampton Council	1552.0	24	25	3%	23	-3%

CensusID	LA Name	Length (m)	Annual Mean NO_2 in 2020				
			Baseline	Euro 6 no C/D	% change Euro 6	fNO_2 40 % reduction	% change fNO_2
27635	Southampton Council	1340.1	21	21	3%	20	-3%
36987	Southampton Council	1656.8	20	21	3%	20	-3%
37658	Southampton Council	2303.4	26	27	3%	25	-3%
38212	Southampton Council	734.2	31	32	4%	29	-6%
46375	Southampton Council	1393.8	28	29	4%	27	-5%
46963	Southampton Council	1662.6	38	40	5%	35	-9%
46964	Southampton Council	1150.7	29	31	4%	28	-6%
48317	Southampton Council	497.7	21	21	1%	21	-1%
48456	Southampton Council	195.4	22	22	2%	22	-1%
48513	Southampton Council	285.2	23	24	2%	23	-2%
56347	Southampton Council	3251.6	36	37	5%	33	-7%
56374	Southampton Council	711.3	24	25	4%	23	-5%
57434	Southampton Council	152.7	27	29	4%	26	-6%
57672	Southampton Council	161.7	25	26	3%	24	-4%
6292	Southampton Council	1061.9	21	21	3%	20	-4%
6349	Southampton Council	1506.1	26	27	4%	25	-5%
6367	Southampton Council	1742.9	25	26	4%	24	-6%
6368	Southampton Council	1678.0	36	37	5%	32	-10%
6933	Southampton Council	2249.1	37	38	3%	34	-6%
70064	Southampton Council	238.9	20	20	0%	20	0%
70066	Southampton Council	218.6	27	27	2%	26	-3%
70108	Southampton Council	421.0	15	15	1%	15	0%
70109	Southampton Council	771.9	19	19	2%	19	-2%
73605	Southampton Council	750.2	21	22	4%	20	-5%
73613	Southampton Council	166.0	18	19	3%	18	-3%
73615	Southampton Council	288.6	36	38	5%	33	-10%
75250	Southampton Council	292.7	29	30	4%	28	-5%
75251	Southampton Council	274.6	32	33	4%	30	-5%
75252	Southampton Council	987.1	30	32	4%	29	-6%
75253	Southampton Council	1009.8	25	26	4%	24	-4%
75258	Southampton Council	568.7	50	52	6%	42	-15%
7569	Southampton Council	2010.9	26	27	4%	25	-5%
7580	Southampton Council	3056.8	26	27	3%	25	-5%
86003	Southampton Council	275.9	30	31	3%	29	-4%
99871	Southampton Council	1401.4	32	32	3%	30	-5%
99872	Southampton Council	2089.2	34	35	3%	33	-5%
37658	Southampton Council	446.8	26	27	3%	25	-3%
46964	Southampton Council	245.5	29	31	4%	28	-6%
6292	Southampton Council	891.9	21	21	3%	20	-4%
73613	Southampton Council	678.0	18	19	3%	18	-3%
7569	Southampton Council	119.3	26	27	4%	25	-5%
Links outside Southampton City							
7988	Eastleigh Borough Council	263.7	20	21	3%	20	-4%

CensusID	LA Name	Length (m)	Annual Mean NO_2 in 2020				
			Baseline	Euro 6 no C/D	% change Euro 6	fNO_2 40 % reduction	% change fNO_2
7992	Eastleigh Borough Council	120.8	22	23	5%	21	-6%
8129	Eastleigh Borough Council	57.5	17	18	4%	17	-3%
8559	Eastleigh Borough Council	642.0	33	35	5%	30	-10%
16269	Eastleigh Borough Council	126.2	20	21	4%	19	-4%
16321	Eastleigh Borough Council	1211.5	47	50	7%	41	-14%
17793	Test Valley Borough Council	875.8	63	67	6%	51	-19%
28018	Test Valley Borough Council	387.2	36	38	5%	32	-11%
29041	Test Valley Borough Council	578.5	38	40	6%	34	-12%
36039	Eastleigh Borough Council	552.4	30	31	4%	28	-8%
36293	Eastleigh Borough Council	646.7	20	20	4%	19	-4%
38107	Test Valley Borough Council	140.0	54	57	6%	45	-16%
47635	Test Valley Borough Council	61.7	19	19	4%	18	-4%
48064	Eastleigh Borough Council	1211.8	76	80	6%	60	-21%
56058	Test Valley Borough Council	327.1	33	35	5%	30	-10%
56931	Eastleigh Borough Council	470.3	27	29	5%	26	-7%
73606	Eastleigh Borough Council	284.7	23	24	4%	22	-6%
73607	Eastleigh Borough Council	12.2	18	19	3%	17	-3%
73609	Eastleigh Borough Council	342.6	59	62	6%	50	-15%
73614	Test Valley Borough Council	476.2	22	23	4%	21	-6%
75259	Test Valley Borough Council	704.1	66	70	6%	53	-19%

5.3.2 Recommended sensitivity tests (not modelled)

Discussion will be provided for the following sensitivity tests which have not been modelled:

- Emissions at low speeds.
- Zonal vs full model domain calibration
- Background NO_2 calibration
- f-NO_2 and calibration
- Surface roughness length
- Meteorology

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 therefore filtered all road links in the Southampton 2020 base year model with speeds less than 12kph. 50 model road links were identified, the majority of which were very short road sections approaching junctions. Of these 50 links, five were identified as being on PCM links where sensitivity testing using the 'high emissions' test was considered appropriate.

Low emissions sensitivity

No concentrations in excess of the 40 µg.m^{-3} limit value have been modelled at any of the links 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

At road sections on PCM links with speeds < 12 kph, five were identified as being on PCM links where sensitivity testing using the 'high emissions' test would increase emissions and potentially concentrations. Of the five links all had modelled speeds of 10 or 11 kph. We have used JAQU's second order polynomial to calculate the impact on NOx emissions for Rigid HGV, Artic HGV and Buses at both 10 & 11kph.

As a simpler and quicker alternative screening approach to adjusting individual heavy vehicle type emissions, we have extracted modelled NO_2 and fNO_2 concentrations at 4m from the roadside, multiplied total Road NOx for all vehicles by the maximum scaling factor derived, which at 10 kph is 103.6% 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 23 µg.m^{-3}, so were significantly 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

As per responses sent to JAQU in July 2018 a single road NOx adjustment factor was derived 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 AQMA's. Whereby 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. For the Southampton CAZ assessment this would mean we were unable to produce a continuous NO_2 annual mean concentration raster for use in the distributional analysis aspect of the economics modelling. 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 also presented results for the future year baseline scenario using road NOx adjustment factors specific to each monitoring site, 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

The supplementary note re. 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 and that LAs 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 shipping, port activities, rail and 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 are only three roadside chemiluminescence monitors in Southampton (one of which was excluded from the model verification as there was insufficient traffic model coverage at that location). Using only two sites would give very poor coverage when verifying and calibrating a citywide model over a very large (~12km domain), and is not therefore considered appropriate for Southampton.

We 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 2015 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).'

We acknowledge that this study may not be representative of the meteorological datasets used for the Southampton study but, assuming it was for a site in England it does indicate that the 2015 metrological conditions led to poorer dispersion than the other years modelled. A 2015 dataset was used for all of the Southampton dispersion modelling so suggests this would be a worst case and so modelling with other metrological data sets would be unlikely to increase concentrations further.

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. 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.

6 Conclusions

This feasibility study has carried out a fully updated assessment of air quality in and around Southampton in relation to the European limit value for NO_2 using the latest data on emission factors and traffic activity. This assessment has been used to establish the extent of any air quality compliance issues in Southampton and to assess the options needed to solve these compliance problems. A first full assessment of the baseline air quality and potentially mitigation measures was reported in March 2018. This was further refined for the outline business case (OBC) submission in July 2018 and used as the basis of a public consultation of the proposed measures.

This report has provided an overview of the air quality results, in terms of NO_2 concentrations, for the Southampton study area covering the 2015 base year, 2020 'do minimum' baseline, a package of non-charging CAZ measures in 2020 and a city-wide class B charging CAZ in 2020. The results have been provided for the national air quality model (PCM) links and local monitoring locations.

The assessment indicates that under the 'do minimum' scenario, which accounts for measures that have already been funded and are in the process of implementation, compliance with the NO_2 limit value will be achieved. However, when model uncertainty is considered this identifies 5 locations that are potentially at risk of exceedance.

The two modelled CAZ scenarios have the impact in addition to the 'do minimum' scenario:

- Non-charging CAZ package: the package of non-charging measures has limited impact on concentrations with the maximum reduction being no more than 0.1 μ/m^3. Therefore, it makes no difference to the overall results when compared to the 'do minimum' scenario.
- City-wide CAZ B: on average this reduces concentrations of NO_2 by 6.4%, but this varies from link to link ranging from a 2% reduction up to 13% reduction. This reduces the number of links greater than 35 μ/m^3, which are potentially at risk of exceedance, in the Southampton City boundary from 6 to 2 with one of these being the M27. Outside of the city boundary on the surrounding motorway network the CAZ B reduces the number of links above 35 μ/m^3 from 8 to 6.

However, when assessing future year scenario there will be uncertainty related to the assumptions we have made in modelling these scenarios. The reliability of the assumptions used has been tested through sensitivity tests. The key outcome of these tests is as follows:

- Higher levels of port growth – this increases concentrations by a maximum of 0.5 $\mu g.m^{-3}$ so did not have an impact on the final results;
- Lower performance of Euro 6 – setting all light duty vehicles to base Euro 6 standard increased concentrations by up to 2 $\mu g.m^{-3}$ which pushed one PCM location up to 40 $\mu g.m^{-3}$ and another to just over 35 $\mu g.m^{-3}$ in the 'do minimum' so increases the risk of an exceedance arising in 2020.
- Lower fNO_2 by 40% - this significantly reduces concentrations and removes all the locations potentially at risk of exceedance in the baseline.
- Lower impact of the non-charging CAZ option – the impact of this option was essentially zero so lowering it would not reduce the benefit.

These results indicate that compliance is likely to be achieved in the 'do minimum scenario, but there are residual risks around uncertainty in the modelling and if Euro 6 does not perform as expected. Given this outcome measures to manage this risk should be pursued, although implementing a full city-wide CAZ B would seem disproportionate in this respect even though it would reduce concentrations and consequently the risk of exceedance. A package of non-charging measures would seem more appropriate for managing this risk, although the package of the non-charging measures modelled had limited impact. This suggests further complementary measures should be pursued, including measures could reduce emissions from light duty vehicles, to help management this risk.

Appendices

Appendix 1: Southampton updated air quality model verification and adjustment

Appendix 1: Southampton updated 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 Southampton have been used for model verification. A single road NOx adjustment factor was derived 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 AQMA's. Whereby 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. For the Southampton CAZ assessment this would mean we were unable to produce a continuous NO_2 annual mean concentration raster for use in the distributional analysis aspect of the economics modelling. 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 also presented results for future year scenarios using road NOx adjustment factors specific to each monitoring site, which could be considered as a 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.

It is appropriate to verify the performance of the RapidAir 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 2015. 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 A1.

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 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, petrol station, 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.
- Uncertainties in the background maps, and the uncertainties introduced by modelling background concentrations over such a wide area at 1km resolution i.e. the mapped background concentrations change very suddenly at the edges of each 1km background map square. In reality annual average background concentrations would change gradually over an urban area. A possible solution to this issue wold be to interpolate the 1km background maps to a finer resolution e.g. 200m; this would have the effect of smoothing out the sudden changes in background concentrations at the 1km square edges of the background maps
- A primary NOx adjustment factor (PAdj) of 2.3051 based on model verification excluding the outliers discussed above from the 2015 NO_2 measurements was 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 2015 is presented in Figure A2.

Figure A1 Comparison of modelled Road NO_x Vs Measured Road NO_x before and after adjustment (outliers removed)

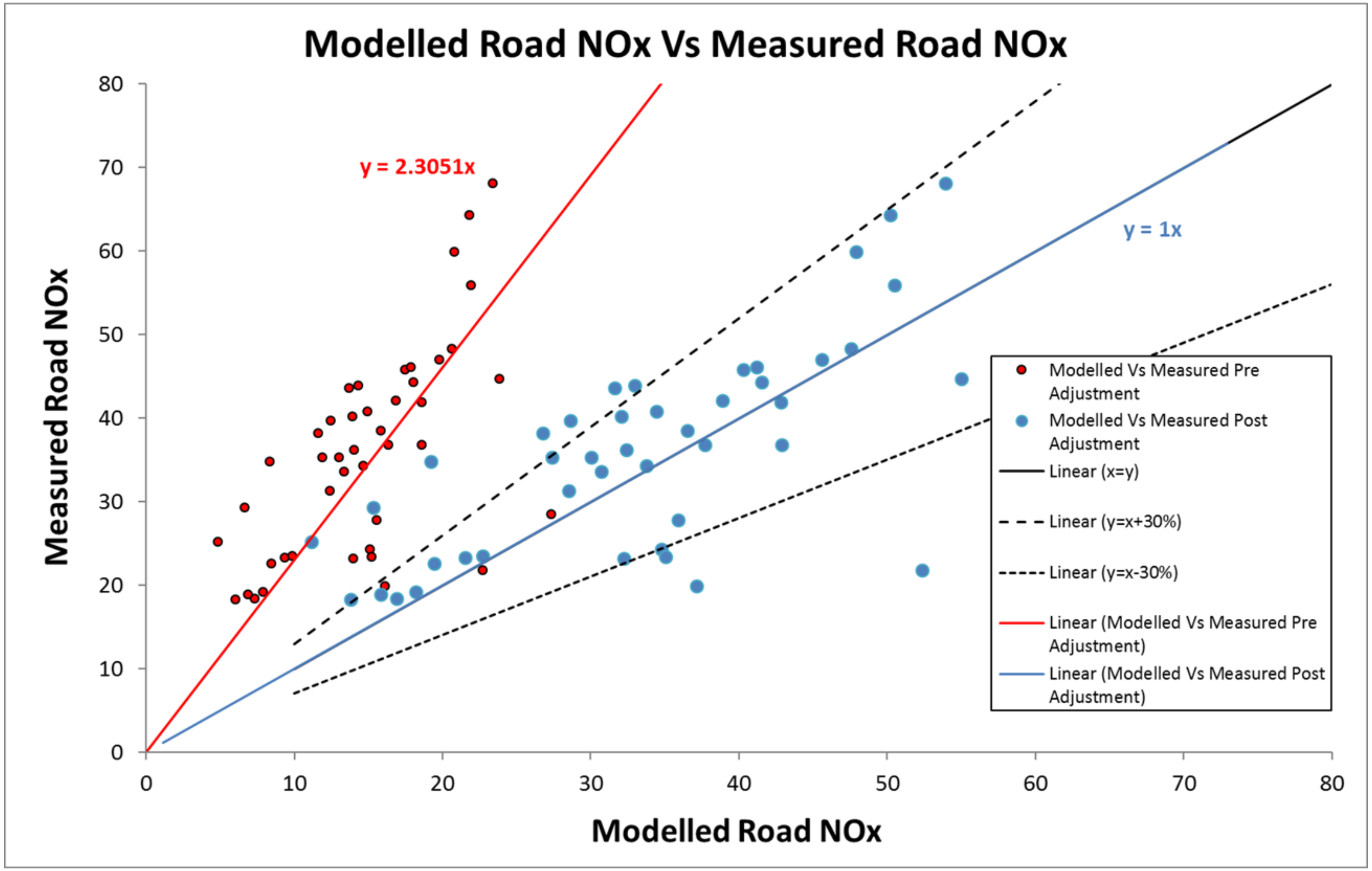
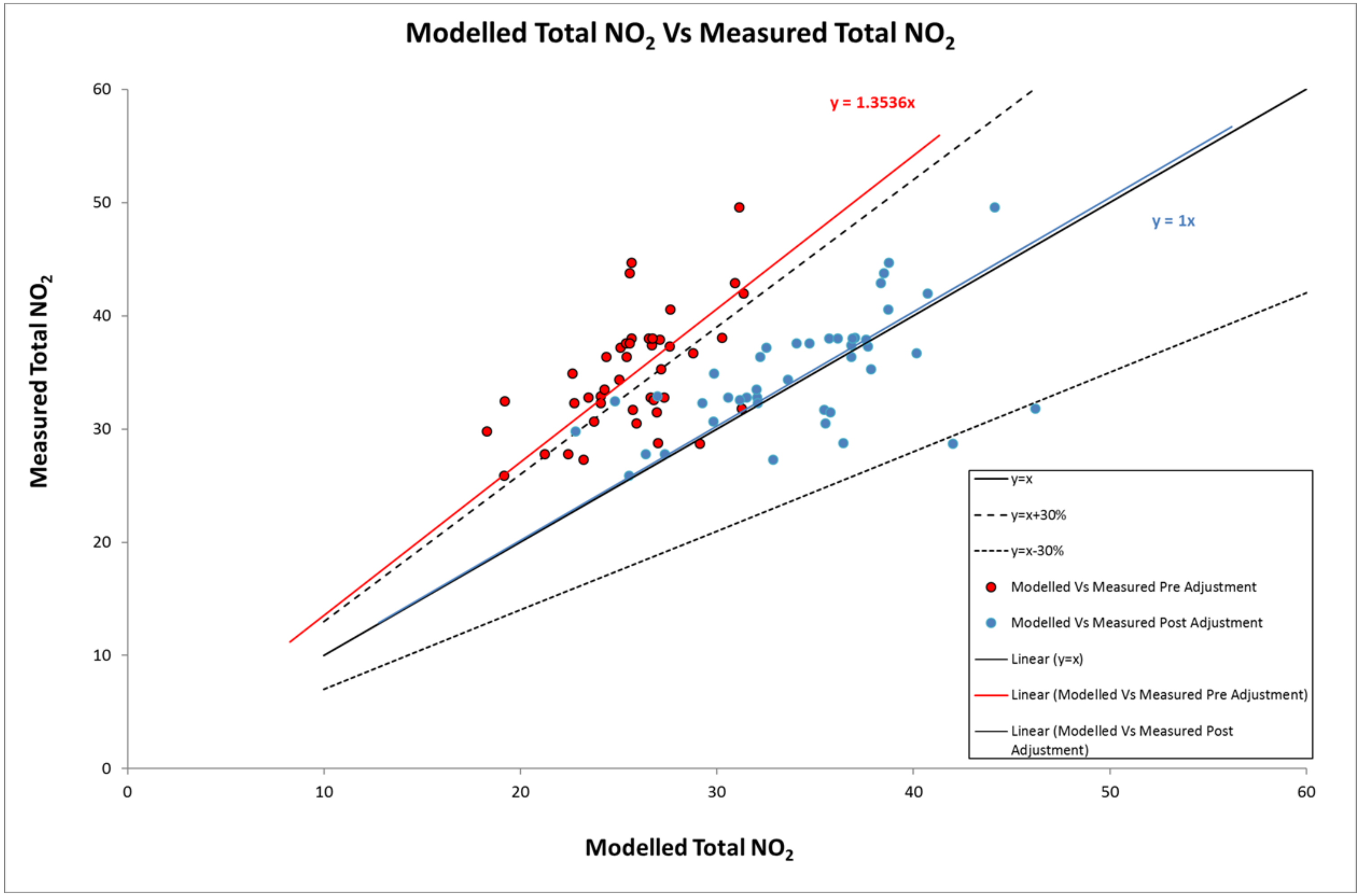


Figure A2: Modelled vs. measured NO_2 annual mean 2015 (outliers removed)



Model performance

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 was calculated at 6.7 µg.m^{-3}. An RMSE was also calculated when clear outliers were excluded which reduced the average model error to 4.7 µg.m^{-3}.

Table A3.1: Measured and modelled concentrations at receptor locations. The root mean square error for the model is also provided. Receptor sites that were identified as outliers are highlighted with an *

NO_2 monitoring site	Measured NO_2 annual mean concentration 2015 (µg.m^{-3})	Modelled NO_2 annual mean concentration 2015 (µg.m^{-3})
CM1*	32.0	34.6
CM4	42.0	40.7
CM6*	42.0	21.9
N101	44.7	38.7
N102	29.8	22.8
N103	31.7	35.5
N104*	38.4	34.9
N106*	37.9	29.4
N107*	53.7	32.5
N109	37.2	32.5
N113	34.9	29.8
N114	32.8	31.5
N115	36.4	36.8
N116*	38.1	30.8
N118*	34.8	26.7
N120	38.0	35.7
N122	31.5	35.8
N123	32.8	30.6
N124	37.3	37.7
N125	35.3	37.8
N126	32.8	32.0
N129	28.8	36.4
N130*	44.8	37.6
N131	37.9	37.6
N133	30.7	29.8
N134	37.6	34.7
N135*	31.4	25.3
N136*	31.1	28.0
N138	43.8	38.5
N140	49.6	44.1

NO_2 monitoring site	Measured NO_2 annual mean concentration 2015 ($\mu g.m^{-3}$)	Modelled NO_2 annual mean concentration 2015 ($\mu g.m^{-3}$)
N141	30.5	35.5
N143	34.4	33.6
N144	31.8	46.2
N146	28.7	42.0
N149	32.5	24.8
N151	37.4	36.8
N152*	49.1	33.2
N153*	31.2	28.8
N154	32.9	27.0
N157	27.8	27.3
N158*	36.8	22.9
N159*	25.9	20.1
N160	32.6	31.2
N161*	32.5	27.6
N162*	37.7	30.5
N163	27.8	26.4
N164	32.3	32.1
N165	32.3	29.2
N166	38.1	37.0
N167	33.5	32.0
N168	36.4	32.2
N169	40.6	38.7
N172	42.9	38.3
N173	27.3	32.9
N174	37.6	34.0
N175	38.0	36.1
N176	38.0	36.9
N177	36.7	40.2
N178	25.9	25.5
	RMSE (all sites)	**6.7**
	RMSE (excluding clear outliers)	**4.7**

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