LIVERPOOL CITY COUNCIL – TARGETED FEASIBILITY STUDY TO DELIVER NITROGEN DIOXIDE CONCENTRATION COMPLIANCE IN THE SHORTEST POSSIBLE TIME

Local authorities covered	Liverpool City Council

Glossary of Terms

CA	Combined Authority, representig the metropolitan mayors office
Emissions Factor Toolkit (EFT)	(a Defra built tool to enable the analysis of air quality emissions based on traffic volumes and speed) to provide NO_X emissions.
Euro IV/V/VI	European standards that impose limits on the level of emissions that can be issued per km or per KWh. The higher the Euro number, the lower the limits
LCR	Liverpool City Region, encompassing the six district authorities
LCC	Liverpool City Council
NO_X	Nitrogen Oxide Emissions
NO_2	Nitrogen Dioxide
Road-NO_X (R-NO_X)	The increment of NO_X from road sources (i.e. total minus background). This is the component that is mainly targeted in this study.
Selective Catalytic Reduction (SCR)	An emissions treatment process that sprays ammonia into the exhaust. The ammonia reacts with the NO_X to produce steam, which is emitted from the tailpipe.
Total-NO_X (T-NO_X)	The road-source increment of NO_X plus background.
Total-NO_2 (T-NO_2)	The road-source increment of NO_X, plus the background NO_2, converted to total NO_2 using the 'NO_X_to_NO_2' calculator

Part 1: Understanding the problem

The following road links in the Liverpool City Council (LCC) area have been identified in the Defra PCM National Model as having projected exceedances of the annual mean nitrogen dioxide (NO_2) EU Limit Value of 40 $\mu g/m^3$:

- Road Link 17657, A5036, The Strand. This link is predicted to achieve compliance in 2020.
- Road Link 18508, A5080, Bowring Park Road. This link is predicted to achieve compliance in 2020.
- Road Link 28563, A580, New Islington. This link is predicted to achieve compliance in 2020.
- Road Link 37794, A580, New Islington. This link is predicted to achieve compliance in 2019.
- Road Link 37905, A57 Dale Street. This link is predicted to achieve compliance in 2020.
- Road Link 46588, A5038, Lime Street. This link is predicted to achieve compliance in 2019.

Figure 1 shows the locations of these road links in relation to the LCC local authority boundary and Air Quality Management Areas (AQMA) and Table 1 summarises the PCM modelled exceedances of the EU Limit Value for these road links.

Figure 2 and Figure 3 show these road links in greater detail and in relation to the local authority's diffusion tube monitoring sites.

Further discussion of these data are provided in subsequent sections of Part 1.

The following sections set out for each road link:

- the likely causes of the exceedances;
- the geographic and temporal extents of the exceedances; and
- the level of emissions reductions required to achieve compliance.

Reference is made to documentation published by Defra relating to the exceedances, Draft Air Quality Interventions Feasibility Study undertaken in 2018 on behalf of Merseytravel and the Combined Authority[1], and the Council's statutory reports compiled in fulfilment of its Local Air Quality Management (LAQM) obligations. It also draws upon traffic count information sourced from LCC's own traffic count data and the Department for Transport (DfT).

[1] Merseytravel (2018), Draft Air Quality Interventions Feasibility Study

Table 1 Summary of PCM Road Link Exceedances in Liverpool City Council Administrative Area

Roads in exceedance	Census ID	Defra PCM Annual Mean NO_2 Concentration ($\mu g/m^3$)					Emission Source apportionment
		2017	2018	2019	2020	2021	
A5036, The Strand	17657	**46**	**44**	**42**	**40**	38	49% diesel cars, 18% diesel LGV, 13% HGV, 13% bus, 6% petrol cars
A5080, Bowring Park Road	18508	**46**	**44**	**42**	39	37	47% diesel cars, 26% diesel LGV, 19% HGV, 6% petrol cars, 1% bus
A580, New Islington Westbound	28563	**44**	**42**	**41**	39	36	56% diesel cars, 28% diesel LGV, 7% HGV, 8% petrol cars
A580, New Islington Eastbound	37794	**43**	**41**	39	37	35	
A57, Dale Street	37905	**46**	**43**	**40**	38	35	84% bus, 8% diesel cars, 4% diesel LGV, 3% HGV, 1% petrol cars
A5038, Lime Street	46588	**43**	**41**	38	35	32	79% bus, 11% diesel cars, 5% diesel LGV, 4% HGV, 1% petrol cars

Figure 1 Road Links with Projected Exceedances in the PCM modelling in Liverpool City Council Administrative Area

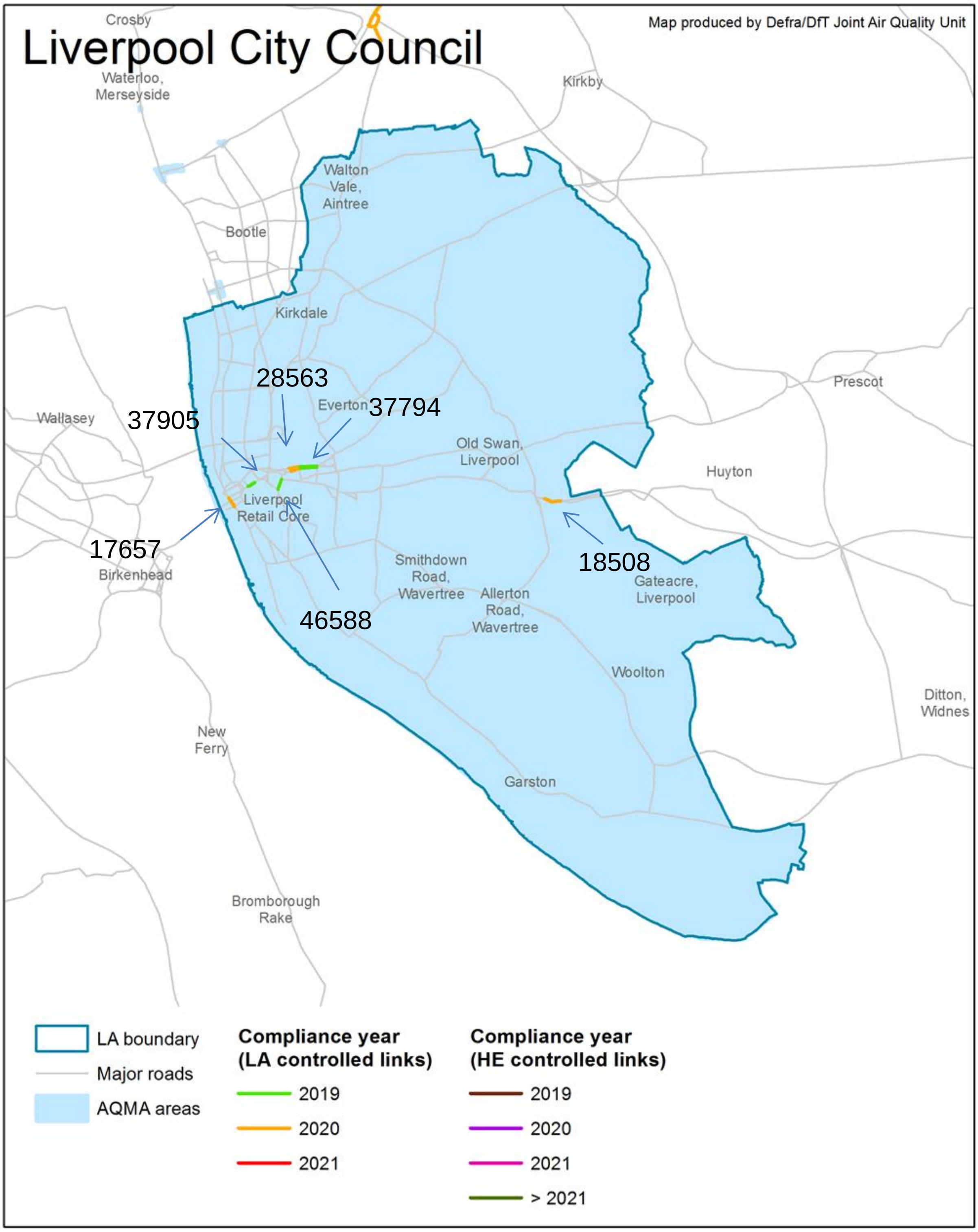


Figure 2 Road Links 17657, 28563, 37794, 37905 and 46588, and Nearby LCC Monitoring Locations

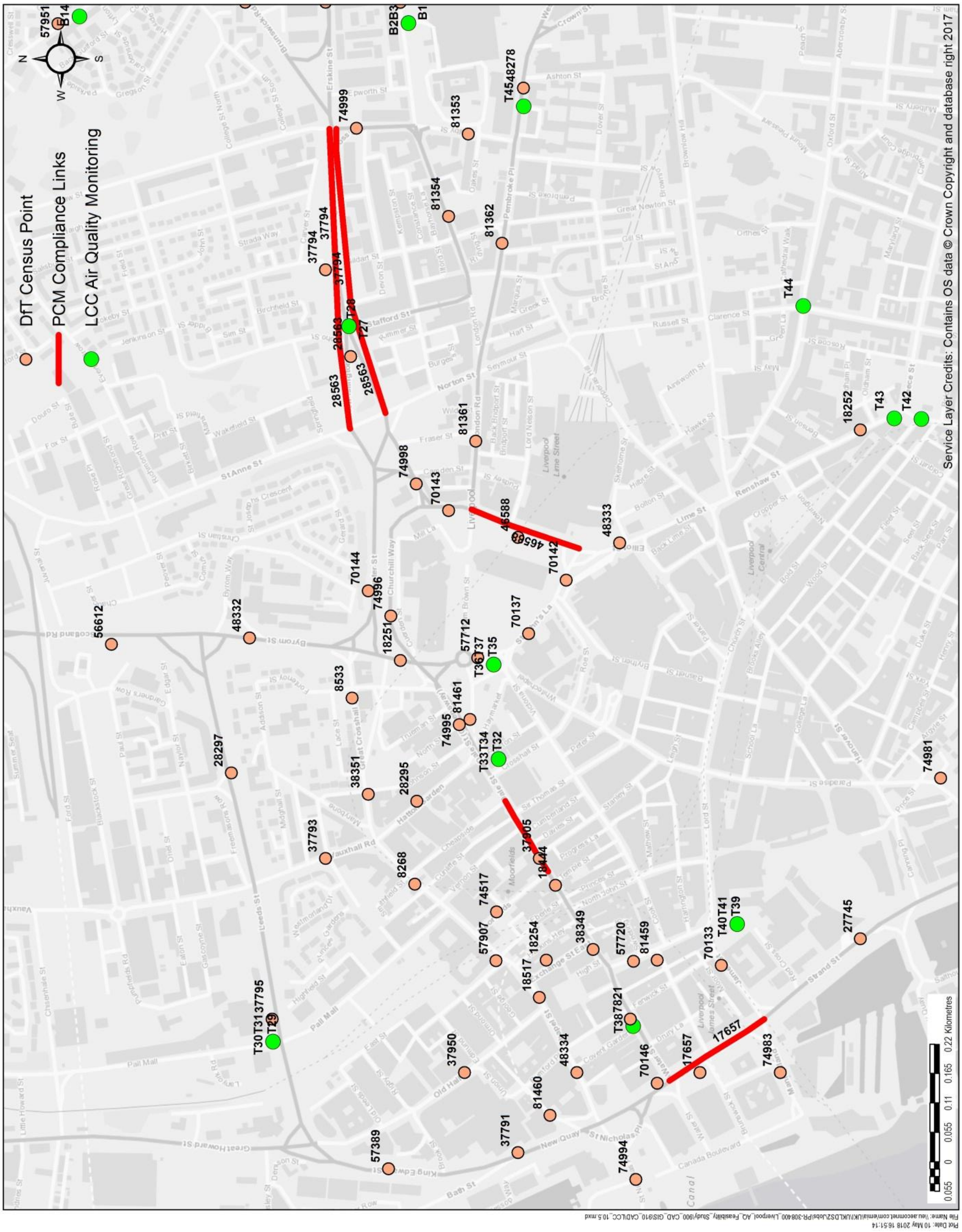
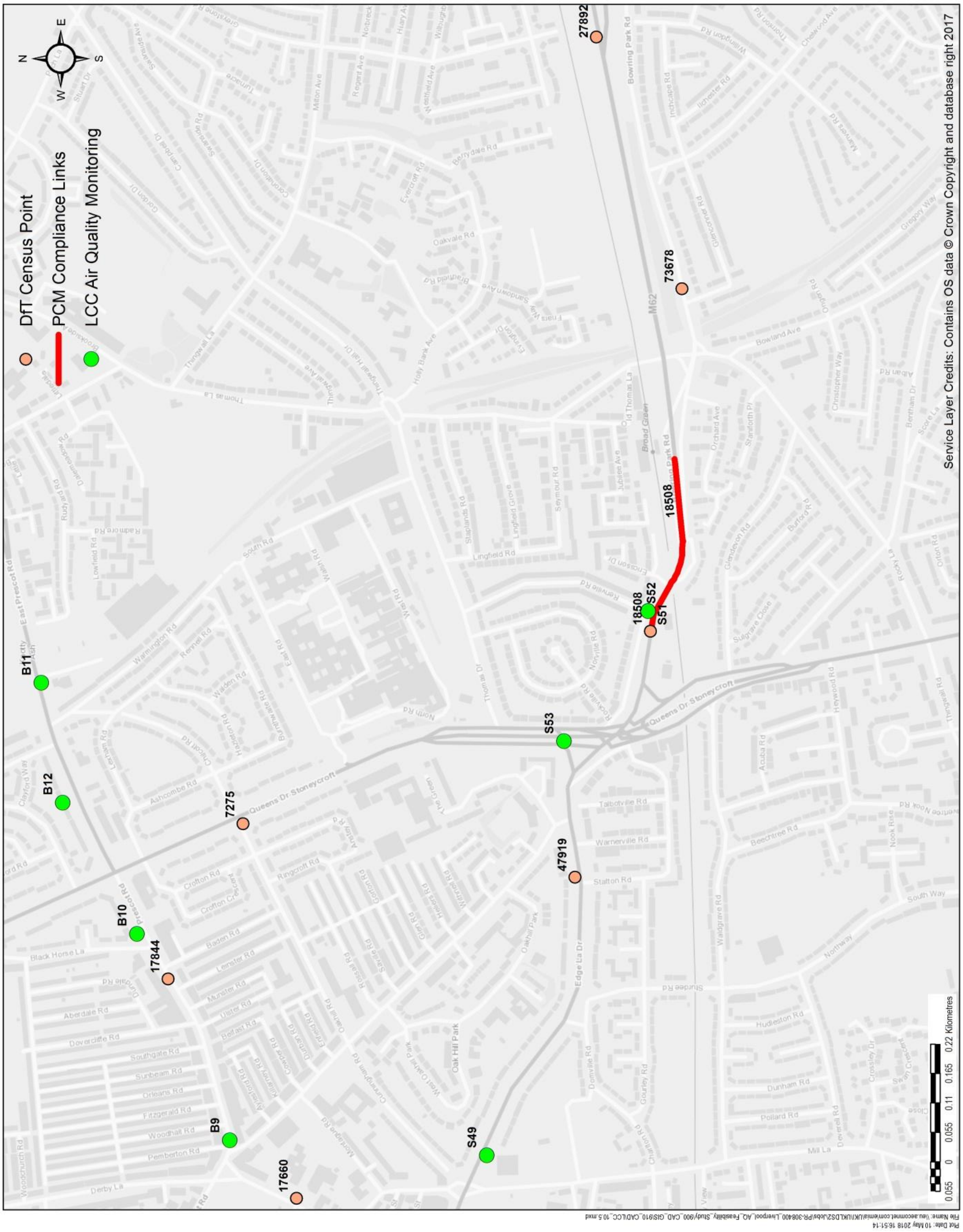


Figure 3 Road Link 18508 and Nearby LCC Monitoring Locations, Bowring Park



Baseline Air Quality Monitoring

The Council undertake air quality monitoring at key locations throughout the district that have previously been identified as potential areas of concern with regard to air quality.

The Air Quality monitoring is undertaken using a network of passive NO_2 diffusion tubes. The sites near the non-compliant road links identified by Defra are indicated in Figure 2 and Figure 3 and the associated annual mean NO_2 concentrations are presented in Table 2. The data presented in Table 2 indicates a decreasing overall trend in annual mean NO_2 concentrations since 2016, but concentrations remain above the EU Limit Value at some locations.

Furthermore, as shown in Figure 4 to Figure 10, there have been notably lower concentrations recorded in 2016 and 2017 in most locations close to the identified non-compliant roads. Admittedly the local bias adjustment applied to the raw Passive Diffusion Tube (PDT) data in 2016 & 2017 was relatively lower than previous years, although a comparison of the local and national bias adjustment values for using the same analytical methodology indicates that they are broadly consistent year-on-year.

The Liverpool Council local bias factor derived from using continuous NO_2 data at the urban background automatic monitoring station at Speke is comparable to urban background automatic monitoring stations in other Local Authorities that are using the same laboratory and methodology. For example for 2017, the calculated Liverpool local bias factor of 0.87 compares well against a national bias factor of 0.85 (other urban background monitoring stations using 20% TEA in water), and it also compares well for all automatic stations using 20% TEA in water as an analytical method (34 in total) – the Liverpool local bias factor of 0.87 as against 0.89.

Therefore the results for 2017 can be considered wholly valid and thereafter the reductions in NO_2 concentration observed are equally valid.

Table 2. LCC Air Quality Monitoring Near Exceedance Links

ID	Location	Grid Ref X	Grid Ref Y	Area	Annual Mean NO_2 Concentration, µg/m^3 (bias adjustment) 2012 (1.09)	2013 (1.07)	2014 (1)	2015 (1.1)	2016 (0.95)	2017 (0.87)*
T26	Islington AQ Station Traffic Lights	335394	390956	New Islington	49	45	46	50	42	35
T27	Islington AQ Station Traffic Lights	335394	390956		48	47	46	46	41	34
T28	Islington AQ Station Traffic Lights	335394	390956		48	45	47	50	42	35
T32	Crosshall Street Downpipe 2nd Along from Dale St.	334585	390677	Dale St	66	72	69	70	63	47
T33	Crosshall Street Downpipe 2nd Along from Dale St.	334585	390677		69	72	69	73	65	46
T34	Crosshall Street Downpipe 2nd Along from Dale St.	334585	390677		68	69	67	80	66	44
T35	Liverpool Centre Old Haymarket	334762	390686		63	61	56	59	52	41
T36	Liverpool Centre Old Haymarket	334762	390686		60	62	59	56	50	42
T37	Liverpool Centre Old Haymarket	334762	390686		59	61	55	58	53	41
T38	Covent Garden/Dale St Lamp Post RH side	334086	390425	The Strand	52	50	46	48	44	36
T39	The Strand/Water St Junction - Rd sign L2	334277	390231		69	71	68	67	67	50
T40	The Strand/Water St Junction - Rd sign L2	334277	390231		69	71	67	64	60	45
T41	The Strand/Water St Junction - Rd sign L2	334277	390231		71	72	68	67	63	49
S50	Renville Rd/Bowring Park Rd	340397	390344	Bowring	62	57	58	56	55	45

ID	Location	Grid Ref		Area	Annual Mean NO_2 Concentration, µg/m^3 (bias adjustment)					
		X	Y		2012 (1.09)	2013 (1.07)	2014 (1)	2015 (1.1)	2016 (0.95)	2017 (0.87)*
S51	Renville Rd/Bowring Park Rd	340397	390344		68	58	60	57	55	44
S52	Renville Rd/Bowring Park Rd	340397	390344		56	56	59	59	56	46
S53	Bowring Park Rd Slip Rd	340154	390501		52	51	47	46	47	34

Figure 4 Monitoring Trends on New Islington (T26 – 28)

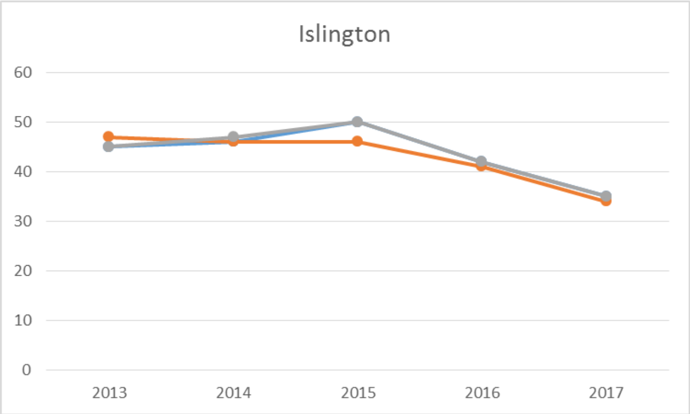


Figure 5 Monitoring Trends on Crosshall Street (T32 – 34)

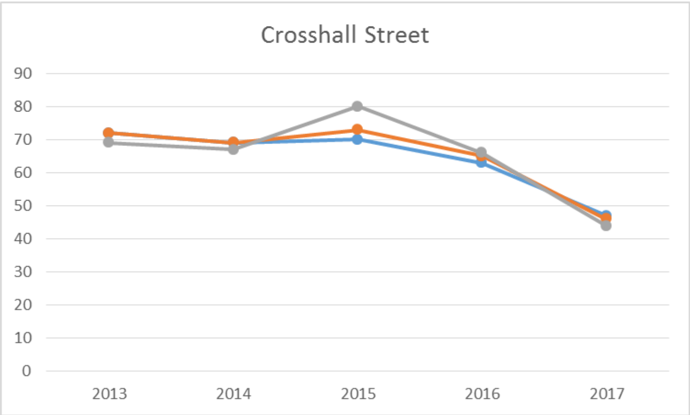


Figure 6 Monitoring Trends on Old Haymarket (T35 – 37)

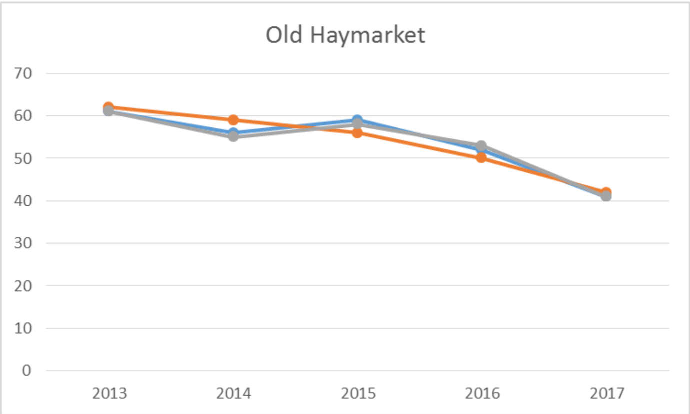


Figure 7 Monitoring Trends on Covent Garden (T38)

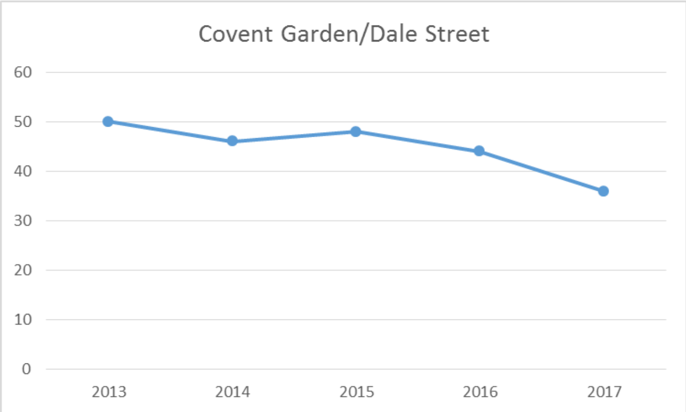


Figure 8 Monitoring Trends on Water Street (T39 -41)

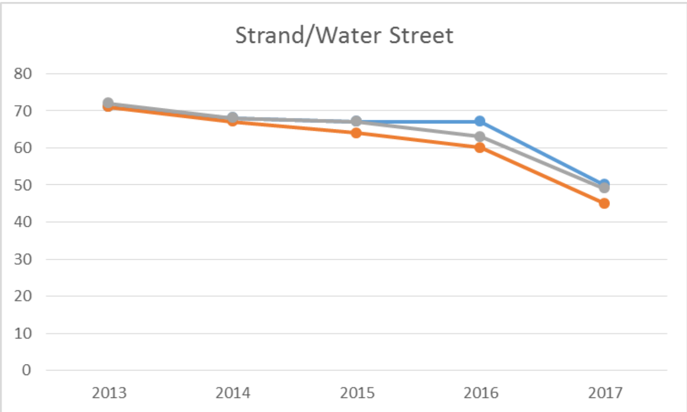


Figure 9 Monitoring Trends on Renville Road (S50 -52)

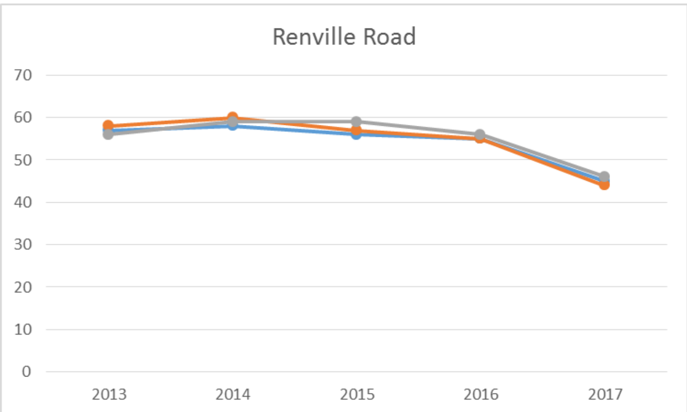
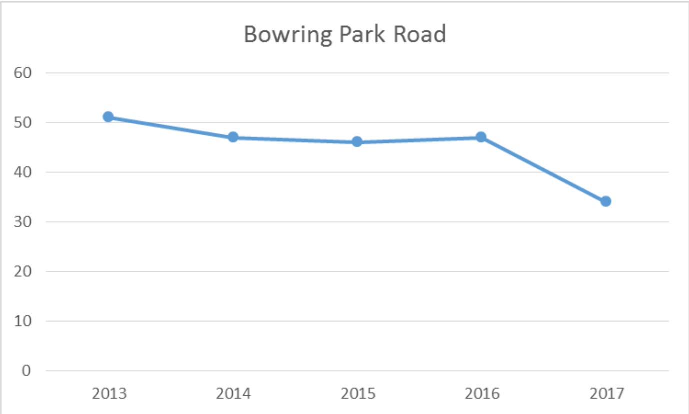


Figure 10 Monitoring Trends on Bowring Park Road (S53)



Automatic air quality monitoring is undertaken by Defra as part of the Automatic Urban and Rural Network (AURN) at one site: Liverpool Speke. This is to proximity to an industrial area and the John Lennon Liverpool Airport, although it is within approx. 50m of Speke Boulevard[2].

An AURN site at Queens Drive was closed in November 2016.

These sites are not in proximity to the compliance links, although the data has been presented in Table 3 to indicate the regional trends.

Table 3. Defra Air Quality Monitoring

Location	Pollutant	Grid Ref		Annual Mean NO_2 Concentration, mg/m3					
		X	Y	2012	2013	2014	2015	2016	2017
Liverpool Speke	NO_2	343887	383603	25	23	25	22	23	18
	PM_{10}			13	14	14	14	15	11
	$PM_{2.5}$			8	9	8	7	7	3
	O_3			47	48	46	49	43	49
	SO_2			3	3	3	2	2	2
Liverpool Queen's Drive (Closed)	NO_2	336172	394896	30	34	34	22	23	-

[2] https://uk-air.defra.gov.uk/networks/site-info?uka_id=UKA00247

Background Pollutant Sources

For any modelling exercise the ideal situation is to estimate emissions from all known sources (road, rail, industry etc.). In practice, information will only be available for those sources under the spot light. In this case it's the road traffic component. Under these circumstances all other sources are collectively considered to be a background element. The concentrations calculated by the PCM model due to vehicle emissions are therefore added to these background concentrations to give the total concentration.

The annual mean background pollutant concentration used in this assessment were modelled estimations provided by Defra (Defra, 2018)[3], who provide values for the centre point of each 1 km by 1 km grid square in the UK, for each year between 2015 and 2030. Estimated average background concentrations for the Ordnance Survey grid squares containing the exceedance links were downloaded in April 2018.

Pollutants of Concern

NO_2 and nitric oxide (NO) are both oxides of nitrogen, and are collectively referred to as NO_X. All combustion processes produce NO_X emissions, largely in the form of NO, which is then converted to NO_2, mainly as a result of its reaction with ozone in the atmosphere. Therefore the ratio of NO_2 to NO is primarily dependent on the concentration of ozone and the distance from the emission source.

The Government and the Devolved Administrations adopted two Air Quality Objectives for nitrogen dioxide (NO_2) which were to be achieved by the end of 2005. In 2010, mandatory EU air quality limit values on pollutant concentrations were to apply, although it continues to be breached in locations throughout the UK. The EU limit values for NO_2 in relation to human health are the same as the national objectives (Defra, 2007):

- An annual mean concentration of 40 µg/m^3 (micrograms per metre cubed); and
- An hourly mean concentration of 200 µg/m^3, to be exceeded no more than 18 times per year (99.79th percentile).

For the purposes of this study it is necessary to convert the NO_2 concentrations to NO_X, as the relationship between NO_2/NO_X is not linear, and also varies depending on region and year.

The emissions from road traffic are presented as R-NO_X, which excludes non-road sources, such as background emissions (see above). This is an essential calculation step to determine the required emissions reduction required for each component of the traffic.

[3] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

Liverpool City Region Transport Model

The LCR Transport Model (LCRTM) was used to help determine the source apportionment, using the 'Local' growth scenario that includes significant local developments; approximately a 28% increase in vehicle km for the period 2012-2030. The local growth scenario was considered to be most representative of the likely traffic growth in the region.

The LCRTM output provided predicted traffic flows for 2020, which were used to calculate the source apportionment based on a modified regional fleet using the Emission Factor Toolkit (EFT) for 2016. The fleet composition in the EFT was based on the following information:

- Heavy Goods Vehicle (HGV) fleet composition was confidently based on the national compositions, due to the large proportion of freight vehicles using both local roads and the Strategic Route Network, where the profiles are typically considered to reasonably accurate.
- Bus fleet composition is highly localised, and was determined using Merseytravel data.
- Car fleet composition was not known, and so it was based on the national fleet. It is expected that opportunities to extract detailed fleet data using ANPR (Automatic Number Plate Recognition) will result from this study, and will be used to inform future work in the region.

There is considered to be some uncertainty regarding the age composition and emission profile of the regional LGV fleet. The EFT nominal fleet breakdown was used in this study as there is currently no further information available, although it is suggested that the emissions from these vehicles may be higher than those presented in this report.

The composition of the Euro emissions profile in the regional bus fleet is presented in Table 4.

The fleet is predominantly composed of Euro V vehicles, but with a large Euro III component. There are also eight Euro II vehicles, and two pre-Euro vehicles in the fleet. The fuel type for buses in the LCR is predominantly diesel, although approximately 30% of the fleet are biodiesel, biogas and hybrid vehicles.

Merseytravel has recently been successful in two rounds of funding for bus retrofit technology, with one upgrade completed and another due to proceed. There is an overall benefit from the upgrades, although it is important to recognise some uncertainty in the efficacy of the retro-fit technology. The EFT includes specific emission factors for these upgrades, which are better than the Original Equipment Manufacturer OEM) condition, but are not expected to achieve the same emission profiles as an OEM Euro-VI compliant engine.

Table 4. Liverpool City Region Bus Fleet Composition

		Number of Vehicles		
		Baseline 2016 Fleet Composition	**Completed Retrofit Fleet, 2018 Composition**	**Pending Retrofit Fleet Composition**
Euro Composition	Pre-Euro	2	2	2
	Euro I	0	0	0
	Euro II	8	8	8
	Euro III	262	173	173
	Euro IV	135	93	82
	Euro V	645	701	583
	Euro VI	120	195	324
Fuel-type Composition	Diesel	70%	70%	69.8%
	% B100 Bus	20%	20%	19.9%
	% CNG Bus	1%	1%	1%
	% Biomethane Bus	0%	0%	0%
	% Biogas Bus	0%	0%	0%
	% Hybrid Bus	9%	9%	9%
	% FCEV Bus	0%	0%	0.3%

Source: Summarised from Liverpool City Region Preliminary Air Quality Options Study (draft), AECOM 2018

DfT Traffic Count Data

The DfT traffic count data published online[4] was used to inform the study and compare with the data extracted from the LCRTM. This data is based on counts and estimates at fixed

[4] www.dft.gov.uk/matrix

locations throughout the city. The 2016 data was used, as this was the most recent available.

The confidence attributed to the count data is subject to the count method, and so this was highlighted.

The LRCTM was verified by comparison with the traffic count locations. This ensures a high degree of confidence across the region, although some discrepancies may occur on specific roads where the model may have lower confidence when compared with the census data.

Road Link 17657: The Strand

Road link 17657 includes a section of The Strand, approximately between Lord Street and Chapel Street. This section of road comprises several lanes, and is a major north-south route through the city and connecting to the cross-river tunnels. This section of the road is separated by a central reservation with distinct north-bound and southbound traffic flows.

Traffic data

Data extracted from the LCRTM for 2020 includes 3 links, provided in Table 5, with a combined annual average daily traffic (AADT) flow of approximately 40,000 vehicles. This is predominantly cars, although there is a moderately large Light Goods Vehicle (LGV) component of around 10%.

DfT traffic count data used for the PCM model predictions for the road link for 2016 compare reasonably closely to the combined two-way flows from the LCRTM.

Table 5 Traffic data for Road Link 17657: The Strand

Information Source	Annual Average Daily Traffic	Fleet Composition (%)			
		Cars & Taxis	LGVs	HGV	Buses & Coaches
LCRTM, Northbound	18,871-21,495	86%	10%	3%	0%
LCRTM, Southbound	17,104	84%	11%	3%	2%
DfT, ID 17657	44,823	84%	12%	2%	1%

Note: LRCTM Northbound composed of two links

DfT census count 17657 was estimated using previous year's AADF on this link in 2016, which used a manual count in 2015.

PCM model predictions and estimated Road NOx Reductions required for compliance

The Defra PCM predicts that the annual mean NO_2 objective will be achieved in 2020 for this road link (Table 1).

Using Defra's background maps of pollutant concentrations, the percentage reduction in NOx emissions required to achieve compliance has been estimated for each year between 2017 and 2020, inclusive. These data are presented in Table 6.

It was calculated that the R-NO_X (Road-NO_X, sourced from road emissions and excluding other sources) emissions would need to be reduced by 24% in 2017, 17% in 2018 and 9% in 2019, in order to achieve compliance.

Table 6 Defra PCM Modelled NO_2 Concentrations and Percent Reductions in Road NOx to Achieve Compliance for Road Link 17657: The Strand

Year	NO_2		NO_X		
	Defra PCM Annual Mean NO_2 Concentration (μg/m^3)	**Background NO_2 Concentration (μg/m^3)**	**R-NOx Concentration at NO_2 = 40 μg/m^3 (μg/m^3)**	**R-NOx Required Reduction (μg/m^3)**	**Percent reduction in R-NOx to achieve compliance**
2017	46.0	17.8	62.0	14.8	24%
2018	44.0	17.0	58.4	9.7	17%
2019	42.0	16.3	55.0	4.8	9%
2020	40.2	NA	NA	NA	NA
2021	37.8	NA	NA	NA	NA

Note: Background NO_2 concentrations obtained from Defra's background maps of pollutant concentrations (https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2015). Road NOx concentrations calculated using Defra's NOx-to-NO_2 Calculator tool (Local Authority = Liverpool, Traffic mix = All other UK urban traffic)

Estimated Road NOx Reductions required for compliance, based on Monitoring Data

The required reduction of R-NO_X was also calculated with reference to the nearest air quality monitoring (to Road Link 17657) undertaken by LCC (Table 7) in 2016.

The required reduction calculated using the monitoring data was larger than that based on PCM, due to the annual mean concentrations monitored in these areas in 2016 being higher than the modelled values for 2017 onwards.

Table 7. Emissions Reduction Required to Achieve Objective, Using LCC Monitoring data, 2016

ID	Location	Area	Annual Mean NO_2, 2016, µg/m^3	Bknd NO_2 2016	R-NO_X	Required R-NO_X Reduction	
T38	Covent Garden/Dale St Lamp Post RH side	The Strand	44.0	16.2	60.4	16%	36% (average)
T39, T40, T41	Strand Street/Water Street Junction - Road sign L2		63.3 (averaged)	16.2	113.6	55%	

Source Apportionment and Likely Cause of Exceedance

The LCRTM data were used to calculate the emission sources for each component of the traffic on the model links corresponding to the PCM exceedance.

Diesel cars were predicted to be the most significant emission source, although diesel LGV were also significant.

Table 8 Source Apportionment of Annual Mean NO_X Emissions for Road Link 17657: The Strand

Exceedance Link	Direction	LRCTM 2020 traffic, using 2016 fleet and emissions profiles							
		Petrol Cars	Diesel Cars	Petrol LGVs	Diesel LGVs	Rigid HGVs	Artic HGVs	Buses/Coaches	Other
A5036 The Strand	Northbound	7%	56%	0%	20%	13%	3%	1%	0.8%
		6%	54%	0%	19%	13%	3%	4%	0.8%
	Southbound	5%	44%	0%	16%	9%	2%	23%	0.8%
		5%	43%	0%	16%	10%	2%	23%	0.8%
	Average	6%	49%	0%	18%	11%	2%	13%	0.8%

Exceedance Link	Direction	LRCTM 2020 traffic, using 2016 fleet and emissions profiles							
		Petrol Cars	Diesel Cars	Petrol LGVs	Diesel LGVs	Rigid HGVs	Artic HGVs	Buses/Coaches	Other
Note: Percentage contributions may not add up to exactly 100% due to rounding. Other comprises motorcycles and alternative fuelled cars. **The above figures are emissions contributions using the EFT. The traffic flow data used to calculate this are presented in Table 5.**									

Road Link 18508: Bowring Park Road

Road link 18508 comprises the westbound and eastbound carriageways of the A5080 to the east of Liverpool city centre, between the western end of the M62 and A562 Queens Drive.

This road is a major route leading from the Strategic Road Network directly into the Liverpool city urban area, and also feeds into a major junction for traffic heading to the north and south around the city.

Traffic data

Data extracted from the LCRTM comprised the eastbound and westbound links provided in Table 9, with a combined AADT of approximately 70-90,000 vehicles, with a notable difference between the westbound and eastbound flows.

The traffic is predominantly comprised of cars, although there is a moderately large LGV component around 15%, and HGVs of 5%.

DfT traffic count data used for the PCM model predictions for the road link for 2016 are lower compared to the LCRTM.

Table 9 Traffic data for Road Link 18508: Bowring Park Road

Information Source	Annual Average Daily Traffic	Fleet Composition (%)			
		Cars & Taxis	LGVs	HGV	Buses & Coaches
LCRTM, Westbound	36,887	80%	15%	4%	0%
	32,229	80%	15%	5%	0%
LCRTM, Eastbound	47,182	82%	13%	5%	0%
	42,919	80%	14%	5%	0%
DfT, ID 18508	64,337	80%	15%	4%	1%

Note: LRCTM composed of two links for each direction

DfT census count 18508 was estimated using previous year's AADF on this link in 2016, which used a manual count in 2015.

PCM model predictions and estimated Road NOx Reductions required for compliance

The Defra PCM predicts that the annual mean NO_2 objective will be achieved in 2020 for this road link (Table 1).

Using Defra's background maps of pollutant concentrations, the percentage reduction in NOx emissions required to achieve compliance has been estimated for each year between 2017 and 2020, inclusive.

It was calculated that the R-NO_X emissions would need to be reduced by 23% in 2017, 16% in 2018 and 8% in 2019, in order to achieve compliance.

Table 10 Defra PCM Modelled NO_2 Concentrations and Percent Reductions in Road NOx to Achieve Compliance for Road Link 18508 Bowring Park Road

Year	NO_2		NO_X		
	Defra PCM Annual Mean NO_2 Concentration (μg/m^3)	**Background NO_2 Concentration (μg/m^3)**	**R-NOx Concentration at NO_2 = 40 μg/m^3 (μg/m^3)**	**R-NOx Required Reduction (μg/m^3)**	**Percent reduction in R-NOx to achieve compliance**
2017	46.0	16.0	66.1	14.9	23%
2018	44.0	15.2	62.5	9.8	16%
2019	42.0	14.4	59.1	4.9	8%
2020	39.4	NA	NA	NA	NA
2021	37	NA	NA	NA	NA
Note: Background NO_2 concentrations obtained from Defra's background maps of pollutant concentrations (https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2015). Road NOx concentrations calculated using Defra's NOx-to-NO_2 Calculator tool (Local Authority = Liverpool, Traffic mix = All other UK urban traffic)					

Estimated Road NOx Reductions required for compliance, based on Monitoring Data

The required reduction of R-NO_X was calculated with reference to the nearest air quality monitoring sites undertaken by LCC (Table 11) in 2016.

The required reduction calculated using the monitoring data was larger than that based on PCM, due to the annual mean concentrations monitored in these areas in 2016 being higher than the modelled values for 2017 onwards.

Table 11. Emissions Reduction Required to Achieve Objective, Using LCC Monitoring 2016

ID	Location	Area	Annual Mean NO_2, 2016, µg/m^3	Bknd NO_2 2016	R-NO_X	Required R-NO_X Reduction	
S50, S51, S52	Renville Rd/Bowring Park Rd	Bowring	55.3	16.2	90.5	44%	35% (average)
S53	Bowring Park Road Slip Rd on Give Way sign		47.0	16.2	68.0	26%	

Source Apportionment and Likely Cause of Exceedance

The source apportionment indicates that diesel cars are the most significant emission source, contributing ~50% of the R-NO_X.

LGVs are also relatively significant, although uncertainty about the emissions profile from LGVs was recognised in LCR Feasibility Study, where it was suggested that the local fleet may not correlate well with the age profile used in the EFT.

Table 12 Source Apportionment of Annual Mean NO_X Emissions for Road Link 18508

Exceedance Link	Direction	LRCTM 2020 traffic, using 2016 fleet and emissions profiles							
		Petrol Cars	Diesel Cars	Petrol LGVs	Diesel LGVs	Rigid HGVs	Artic HGVs	Buses/Coaches	Other
A5080 Bowring Park Road	Eastbound	6%	49%	0%	25%	14%	3%	2%	0.7%
		6%	48%	0%	27%	15%	3%	0%	0.7%
	Westbound	5%	44%	0%	24%	21%	5%	1%	0.6%
		6%	47%	0%	30%	13%	3%	0%	0.7%
	Average	6%	47%	0%	26%	16%	3%	1%	0.7%

Note: Percentage contributions may not add up to exactly 100% due to rounding. Other comprises motorcycles and alternative fuelled cars.

The above figures are emissions contributions using the EFT. The traffic flow data used to calculate this are presented in Table 5.

Road Link 28563 and 37794 New Islington

Road link 28563 and 37794 both comprise the A580 New Islington. This is a major road connecting routes through, and around, the city centre, and leading from the Mersey Tunnel gateways.

For the purposes of this section of the study, these two links have been considered together, as they represent opposite directions of the same road and so the interventions will be necessarily linked.

<u>Traffic data</u>

Data extracted from the LCRTM comprised the eastbound and westbound links provided in Table 13, with a combined AADT of approximately 60,000 vehicles, with a notable difference between the westbound and eastbound flows.

The traffic is predominantly comprised of cars, although there is a moderately large LGV component around 12%.

DfT traffic count data used for the PCM model predictions for the road link (Count Points 28563 and 37794) for 2016 compare reasonably closely to the flow proportions, although the overall AADT were higher than the LCRTM.

Table 13 Traffic data for Road Link 28563 and 37794 New Islington

Information Source	Annual Average Daily Traffic	Fleet Composition (%)			
		Cars & Taxis	LGVs	HGV	Buses & Coaches
A580 New Islington Eastbound	32,764	86%	11%	2%	0%
A580 New Islington, Westbound	27,363	84%	12%	3%	0%
DfT, ID 37794	43,886	86%	12%	2%	0%
DfT, ID 28563	47,672	83%	14%	2%	0%
DfT census count 37794 used a manual count in 2016 DfT census count 28563 was estimated using previous year's AADF on this link in 2016, which used a manual count in 2015.					

PCM model predictions and estimated Road NOx Reductions required for compliance

The Defra PCM predicts that the annual mean NO_2 objective will be achieved in 2019 for road link 37794 and in 2020 for road link 28563 (Table 1).

Using Defra's background maps of pollutant concentrations, the percentage reduction in NOx emissions required to achieve compliance has been estimated for each year between 2017 and 2020, inclusive.

It was calculated that the R-NO_X emissions would need to be reduced by 15% in 2017 and 5% in 2018 in order to achieve compliance on road link 37794 (Table 14).

Table 14 Defra PCM Modelled NO_2 Concentrations and Percent Reductions in Road NOx to Achieve Compliance for Road Link 37794 New Islington

Year	NO_2		NO_X		
	Defra PCM Annual Mean NO_2 Concentration (µg/m³)	Background NO_2 Concentration (µg/m³)	R-NOx Concentration at NO_2 = 40 µg/m³ (µg/m³)	R-NOx Required Reduction (µg/m³)	Percent reduction in R-NOx to achieve compliance
2017	43	20.3	49.0	7.2	15%
2018	41	19.4	45.9	2.4	5%
2019	39	NA	NA	NA	NA
2020	37	NA	NA	NA	NA
2021	35	NA	NA	NA	NA

Note: Background NO_2 concentrations obtained from Defra's background maps of pollutant concentrations (https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2015). Road NOx concentrations calculated using Defra's NOx-to-NO_2 Calculator tool (Local Authority = Liverpool, Traffic mix = All other UK urban traffic)

It was calculated that the R-NO_X emissions would need to be reduced by 8% in 2017, 10% in 2018 and 5% in 2019 in order to achieve compliance on road link 28563 (5). The required emission reduction was predicted to increase slightly in 2018 due to the relationship between the R-NO_X and the background contribution.

Table 15 Defra PCM Modelled NO_2 Concentrations and Percent Reductions in Road NOx to Achieve Compliance for Road Link 28563 New Islington

Year	NO_2		NO_X		
	Defra PCM Annual Mean NO_2 Concentration (µg/m^3)	Background NO_2 Concentration (µg/m^3)	R-NOx Concentration at NO_2 = 40 µg/m^3 (µg/m^3)	R-NOx Required Reduction (µg/m^3)	Percent reduction in R-NOx to achieve compliance
2017	44	20.3	51.5	4.2	8%
2018	42	19.4	48.3	4.8	10%
2019	41	18.6	47.6	2.4	5%
2020	39	NA	NA	NA	NA
2021	36	NA	NA	NA	NA

Note: Background NO_2 concentrations obtained from Defra's background maps of pollutant concentrations (https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2015). Road NOx concentrations calculated using Defra's NOx-to-NO_2 Calculator tool (Local Authority = Liverpool, Traffic mix = All other UK urban traffic)

Estimated Road NOx Reductions required for compliance, based on Monitoring Data

The required reduction of R-NO_X was calculated with reference to the nearest air quality monitoring sites undertaken by LCC (Table 16) in 2016.

The required reduction calculated using the monitoring data was similar to that based on PCM.

Table 16. Emissions Reduction Required to Achieve Objective, Using LCC Monitoring 2016

ID	Location	Area	Annual Mean NO_2, 2016, µg/m³	Bknd NO_2 2016	R-NO_X	Required R-NO_X Reduction
T26, T27, T28	Islington AQ Station Traffic Lights	New Islington	41.7	17.5	51.6	8%

Source Apportionment and Likely Cause of Exceedance

The source apportionment indicates that diesel cars are the most significant emission source, contributing more than 50% of the R-NO_X. LGVs are the second most significant contributor. However, as discussed above, uncertainty about the emissions profile from LGVs was recognised in LCR Feasibility Study, where it was suggested that the local fleet may not correlate well with the age profile used in the EFT.

Rigid HGVs are also notable, contributing 6% of emissions.

Table 17 Source Apportionment of Annual Mean NO_X Emissions for Road Links 28563 and 37794 New Islington

Exceedance Link	Direction	LRCTM 2020 traffic, using 2016 fleet and emissions profiles							
		Petrol Cars	Diesel Cars	Petrol LGVs	Diesel LGVs	Rigid HGVs	Artic HGVs	Buses/Coaches	Other
A580 New Islington	Eastbound	8%	58%	0%	28%	5%	1%	0%	0.9%
	Westbound	8%	54%	0%	29%	8%	1%	0%	0.8%
	Average	8%	56%	0%	28%	6%	1%	0%	1%

Note: Percentage contributions may not add up to exactly 100% due to rounding. Other comprises motorcycles and alternative fuelled cars.

The above figures are emissions contributions using the EFT. The traffic flow data used to calculate this are presented in Table 13.

Road Link 37905 Dale Street

Road link 37905 comprises a short section of the A57 Dale Street between Cheapside and Moorfields.

This road is located to the north-west of the pedestrianised areas in the city centre and is used by local traffic for access to the commercial district.

Dale Street is relatively narrow with tall buildings on both sides. It is a one-way street, with numerous smaller, one-way and two-way roads leading from it.

Traffic data

Data extracted from the LCRTM comprised the eastbound and westbound links provided in Table 18, with a combined AADT of approximately 8,000 vehicles.

The traffic is predominantly comprised of cars, although there is a large bus component of around 24% as it is a city centre road

DfT traffic count data used for the PCM model predictions for the road link (Count Point 37905) for 2016 predict differences in both total flow and the composition, with higher number of cars and fewer buses than the LCRTM. The DfT census was estimated using data from previous years, and so this value may not be wholly accurate.

Table 18 Traffic data for Road Link 37905 Dale Street

Information Source	Annual Average Daily Traffic	Fleet Composition (%)			
		Cars & Taxis	LGVs	HGV	Buses & Coaches
LCRTM, A57 Dale Street	7,644	64%	10%	2%	24%
DfT, ID 37905	10,338	74%	11%	2%	13%
DfT census count 37905 was estimated using previous year's AADF on this link in 2016 and 2015.					

PCM model predictions and estimated Road NOx Reductions required for compliance

The Defra PCM predicts that the annual mean NO_2 objective will be achieved in 2019 for this road link (Table 1).

Using Defra's background maps of pollutant concentrations, the percentage reduction in

NOx emissions required to achieve compliance has been estimated for each year between 2017 and 2020, inclusive.

It was calculated that the R-NO_X emissions would need to be reduced by 24% in 2017 and 13% in 2018 in order to achieve compliance.

Table 19 Defra PCM Modelled NO_2 Concentrations and Percent Reductions in Road NOx to Achieve Compliance for Road Link 37905 Dale Street

Year	NO_2		NO_X		
	Defra PCM Annual Mean NO_2 Concentration (µg/m^3)	**Background NO_2 Concentration (µg/m^3)**	**R-NOx Concentration at NO_2 = 40 µg/m^3 (µg/m^3)**	**R-NOx Required Reduction (µg/m^3)**	**Percent reduction in R-NOx to achieve compliance**
2017	46	17.8	62.0	14.8	24%
2018	43	17	56	7.3	13%
2019	40	NA	NA	NA	NA
2020	38	NA	NA	NA	NA
2021	35	NA	NA	NA	NA

Note: Background NO_2 concentrations obtained from Defra's background maps of pollutant concentrations, for the 1-km grid square centred on 464500, 101500 (https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2015). Road NOx concentrations calculated using Defra's NOx-to-NO_2 Calculator tool (Local Authority = Liverpool, Traffic mix = All other UK urban traffic)

Estimated Road NOx Reductions required for compliance, based on Monitoring Data

The required reduction of R-NO_X was calculated with reference to the nearest air quality monitoring site undertaken by LCC (Table 7) in 2016.

The required reduction calculated using the monitoring data was substantially larger than that based on PCM, due to the annual mean concentrations monitored in these areas in 2016 being higher than the modelled values for 2017 onwards.

Table 20. Emissions Reduction Required to Achieve Objective, Using LCC Monitoring 2016

ID	Location	Area	Annual Mean NO_2, 2016, µg/m^3	Bknd NO_2 2016	R-NO_X	Required R-NO_X Reduction	
T32, T33, T34	Crosshall Street Downpipe 2nd Along from Dale St.	Dale St	64.7	16.2	117.6	57%	47%
T35, T36, T37	Liverpool Centre Old Haymarket		51.7	16.2	80.4	37%	

Source Apportionment and Likely Cause of Exceedance

The source apportionment indicates that buses contribute the vast majority of emissions; 83%, although they only make up 24% of the traffic flow (Table 18).

Table 21 Source Apportionment of Annual Mean NOX Concentrations for Road Link 37905 Dale Street

Exceedance Link	Direction	2020 traffic, using 2016 fleet and emissions profiles							
		Petrol Cars	Diesel Cars	Petrol LGVs	Diesel LGVs	Rigid HGVs	Artic HGVs	Buses/Coaches	Other
A57 Dale Street	1-way	1%	8%	0%	4%	2%	1%	83%	0.6%

Note: Percentage contributions may not add up to exactly 100% due to rounding. Other comprises motorcycles and alternative fuelled cars.

The above figures are emissions contributions using the EFT. The traffic flow data used to calculate this are presented in Table 18.

Road Link 45688 Lime Street

Road link 46588 comprises a section of road at the front of Lime Street railway station in the centre of the city.

This is an open, wide road which is not heavily trafficked by private vehicles, but does have a large number of buses and taxis.

Traffic data

Data extracted from the LCRTM comprised the northbound and southbound links provided in Table 22, with a combined AADT of approximately 21,000 vehicles.

The traffic is predominantly comprised of cars, although there is a large bus component of around 17%, and also a relatively large proportion of LGVs.

As mentioned above, it is likely that taxis comprise a significant proportion of the cars, although data is not available at this stage to verify this preposition.

DfT traffic count data used for the PCM model predictions for the road link (Count Point 46558) for 2016 predict differences in both total flow and the composition. The AADT is potentially due to the count location being on the northbound side of the separated carriageway, although there is a clear difference in the number of buses compared to the LRCTM. However, it was also noted that the DfT census was estimated using data from previous years.

Table 22 Traffic data for Road Link 46588 Lime Street

Information Source	Annual Average Daily Traffic	Fleet Composition (%)			
		Cars & Taxis	LGVs	HGV	Buses & Coaches
A5038 Lime Street, northbound	13,228	74%	11%	3%	12%
A5038 Lime Street, southbound	8,082	68%	10%	3%	19%
DfT, ID 46588	14,742	55%	9%	1%	35%
DfT census count 46588 was estimated using previous year's AADF on this link in 2016 and 2015.					

PCM model predictions and estimated Road NOx Reductions required for compliance

The Defra PCM predicts that the annual mean NO_2 objective will be achieved in 2019 at this road link (Table 1).

Using Defra's background maps of pollutant concentrations, the percentage reduction in NOx emissions required to achieve compliance has been estimated for each year between 2017 and 2020, inclusive.

It was calculated that the R-NO_X emissions would need to be reduced by 15% in 2017 and 5% in 2018 in order to achieve compliance.

There are no local authority air quality monitoring sites near this link.

Table 23 Defra PCM Modelled NO_2 Concentrations and Percent Reductions in Road NOx to Achieve Compliance for Road Link 46588 Lime Street

Year	NO_2		NO_X		
	Defra PCM Annual Mean NO_2 Concentration (µg/m³)	Background NO_2 Concentration (µg/m³)	R-NOx Concentration at NO_2 = 40 µg/m³ (µg/m³)	R-NOx Required Reduction (µg/m³)	Percent reduction in Road NOx to achieve compliance
2017	43.0	20.3	49.	7.2	15%
2018	41	19.4	45.9	2.4	5%
2019	38	NA	NA	NA	NA
2020	35	NA	NA	NA	NA
2021	32	NA	NA	NA	NA

Note: Background NO_2 concentrations obtained from Defra's background maps of pollutant concentrations, for the 1-km grid square centred on 464500, 101500 (https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2015). Road NOx concentrations calculated using Defra's NOx-to-NO_2 Calculator tool (Local Authority = Liverpool, Traffic mix = All other UK urban traffic)

Source Apportionment and Likely Cause of Exceedance

The source apportionment indicates that buses contribute the vast majority of emissions; 70-80%, although they are <20% of the traffic flow.

Table 24 Source Apportionment of Annual Mean NOX Emissions in 2019 for Road Link 46588 Lime Street

Exceedance Link	Direction	LRCTM 2020 traffic, using 2016 fleet and emissions profiles							
		Petrol Cars	Diesel Cars	Petrol LGVs	Diesel LGVs	Rigid HGVs	Artic HGVs	Buses/Coaches	Other
A5038 Lime Street	Northbound	2%	16%	0%	6%	5%	1%	69%	0.6%
	Southbound	1%	11%	0%	5%	3%	1%	79%	0.6%

Note: Percentage contributions may not add up to exactly 100% due to rounding. Other comprises motorcycles and alternative fuelled cars.

The above figures are emissions contributions using the EFT. The traffic flow data used to calculate this are presented in Table 22.

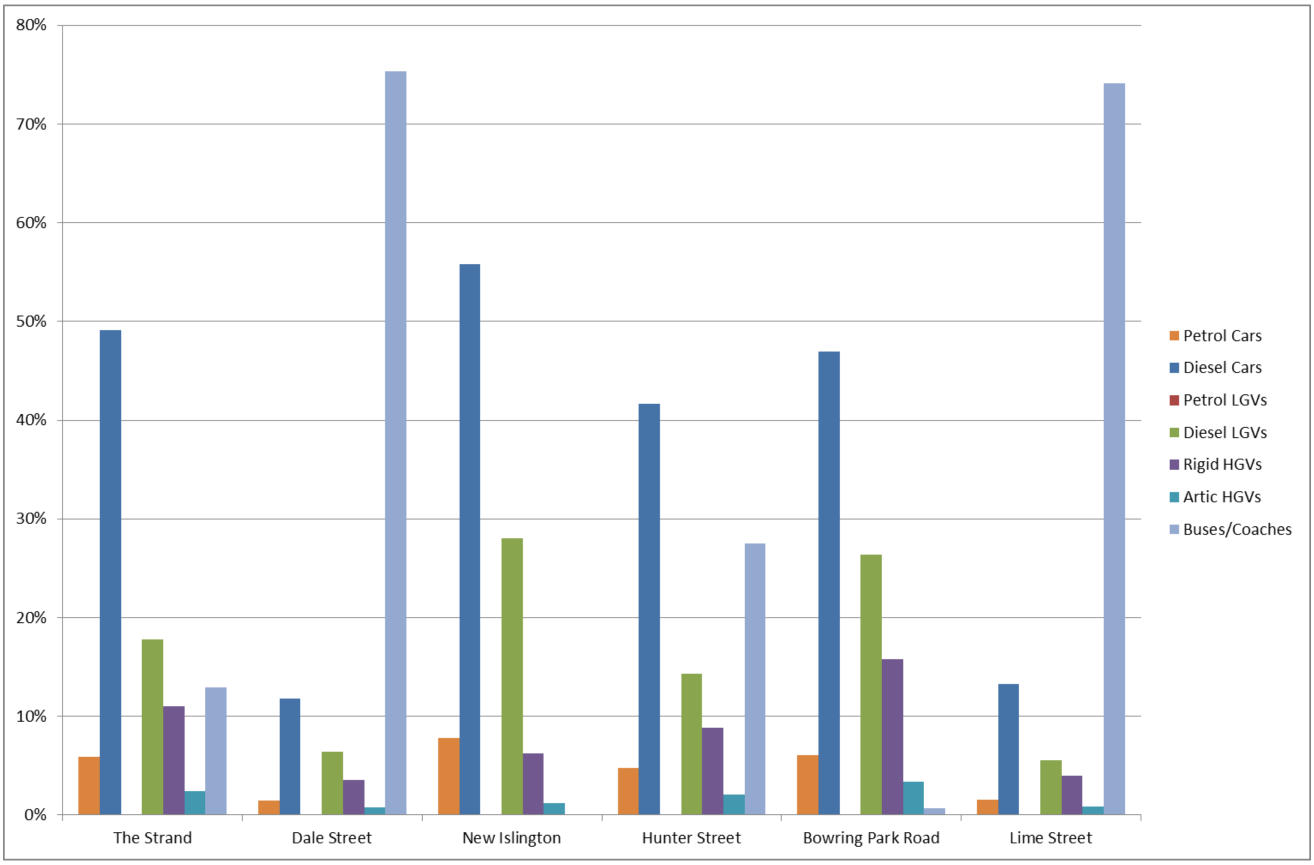
Summary of Source Apportionment

The vehicle emissions break-down shown in Figure 11 indicate that:

- Buses are the most significant emission sources on Lime Street (road link 46588) and Dale Street (road link 37905)
- Diesel cars are the most significant emission source on The Strand (road link 17657), New Islington (road links 28563 and 37794) and Bowring Park Road (road link 18508). They are also the second most significant source on Lime Street and Dale Street.
- Diesel LGV and Rigid HGV contributions are similar on each road.
- Petrol cars and articulated HGVs are the least significant sources.

These values are based on the nominal national fleet emissions, although there is uncertainty about the Euro-classification profile for vehicles in the region, expect for buses where high resolution data is available.

Figure 11 Source Apportionment, R-NO_X for each road



The comparison in Table 25 indicates that although diesel cars are a significant overall emission source, the emissions are approximately proportional to the number of vehicles. Larger (predominantly diesel) vehicles tend towards contributing significantly more emissions than is represented by the number of vehicles.

In particular, the emissions on Dale Street and Lime Street are predominately related to buses, although they are only 17-18% of the total flow on these roads. Similarly, buses are only 1% of the traffic flow on The Strand, but contribute 13% of the emissions.

Table 25. Ratio of Categorised Traffic Flow vs Emissions

Exceedance Link	Petrol Car*	Diesel Car*	LGV	HGV	Bus
The Strand (17657)	0.1	1.1	0.0	2.1	14.7
Dale Street (37095)	0.0	0.3	0.0	0.9	4.4
New Islington (28563, 37794)	0.1	1.0	0.0	1.4	1.5
Bowring Park Road (18508)	0.1	1.2	0.0	1.9	7.1
Lime Street (46588)	0.0	0.4	0.0	1.0	5.0

Note: Assumed diesel/petrol fleet is split 50/50

Stage 4 Modelling

Based on the review of data used in this study, it is proposed that the further air quality modelling in Stage 4 and 5 will use the following data sources:

- The DfT traffic census points will be reviewed to determine whether LCC have accurate count data in these locations.
- Where count data is not available, the LCRTM data will be scaled by comparison with the nearest suitable count location.
- The LRCTM will be used to determine an appropriate traffic growth factor for future years, which will be applied to the census data.

This is proposed to be the most robust approach to using the available data.

Part 2: Developing a long list of measures for addressing the exceedances

In order to achieve compliance as soon as possible, the measures should be implemented in 2018 (i.e. this year) on

- Road Link 28563, A580, New Islington;
- Road Link 37905, A57 Dale Street;
- Road Link 46588, A5038, Lime Street;

And by 2019 on:

- Road Link 17657, A5036, The Strand;
- Road Link 18508, A5080, Bowring Park Road;
- Road Link 28563, A580, New Islington.

After these dates it is predicted that compliance will be achieved.

Therefore, large-scale, complex interventions, such as a city-wide CAZ scheme may not be feasible to comply with the requirement to achieve the EU Limit Value as soon as possible.

LCR Preliminary Feasibility Study

A Draft Air Quality Interventions Feasibility Study was undertaken in 2018 on behalf of Merseytravel and the Combined Authority[5]. This study identified potential strategic interventions that may be implemented to improve air quality in the region, including Liverpool City. The interventions summarised in

Table 26 represent those that may be appropriate to reduce emissions on the exceedance road links in the shortest possible time.

These interventions were identified for use in this study as the means of implementation may be both feasible, and highly targeted to the areas of concern.

The specific implementation strategies have not been developed at this stage, and it is recognised that some of the measures outlined below may not be feasible within the timescales required to achieve compliance earlier than predicted.

[5] Merseytravel (2018), Draft Air Quality Interventions Feasibility Study

Table 26. Summary of Potential Interventions from LCR Preliminary Feasibility Study

Subject	Intervention	Applicable Links
Clean Air Zone	CAZ intervention scenarios were investigated for the whole of LCR, although in this context smaller zones may be considered that only affect a discrete number of road sections. In order to effectively implement a CAZ it was recommended that: - Additional fleet data is required using a co-ordinated ANPR survey across major routes in the LCR. This should provide essential information with regard to the most significant emission sources within the fleet, and how the application of the CAZ scenario may affect local and regional emissions. - Furthermore, depending on which fleet components are affected, additional information about journeys and destinations may be used to identify where a CAZ may be most effective, whilst limiting detrimental effects. Implementing a small CAZ may reduce the need for large-scale support for travel choice, planning and modal shift that would be required for a larger CAZ. Furthermore, effectively achieving a reduction in pollutant concentration near the compliance links may be achieved by focussing on whole-journeys, where regulation at a key junction may lead to effects at multiple locations in the city. However, this would require an enforcement mechanism, such as ANPR cameras.	28563, A580, New Islington 37794, A580, New Islington 37905, A57 Dale Street 46588, A5038, Lime Street

Subject	Intervention	Applicable Links
Urban Traffic Management Control (UTMC)	A UTMC may be used to actively prioritise air quality by redistributing congestion and slow-moving traffic away from areas of concern, even where it may lead to longer journey times. Where road capacity is made available through successful implementation of the UTMC, it should be utilised for alternative transport. Interventions targeted specifically at emissions using UTMC may include: • Green light hurry call for high-emission vehicles, such as HDVs, fitted with the appropriate equipment, which advises the driver of the upcoming light status. This allows the driver to anticipate light changes and avoid unnecessary slowing, idling and acceleration. • Prioritising green lights for HDVs travelling up-hill towards junctions, where the gradient may require higher engine-loading to pull away from a red light.	All links
Urban Clearway	The use of urban clearways (Red Routes) to prevent on-street parking and increase road space may have a beneficial effect on A57 Dale Street, as this is the only link with parking currently permitted. The increased road capacity may be prioritised or allocated specifically for public transport or low emission vehicle use.	37905, A57 Dale Street
Green Infrastructure	Green infrastructure, such as tree planting, green screens and canopies would affect the dispersion of emissions from the carriageway and alter the exposure pathway. The shape and permeability of the structure may be designed to block, trap or funnel emissions, and prevent high concentrations from reaching sensitive locations.	All links
Shared Space	Shared Spaces may be beneficial in high-street type areas which are not pedestrianised and suffer from congestion and discourage pedestrians and cyclists. The implementation of this measure would need to focus on a shift towards changing the perception of how the roads are used, and actively discouraging the use of private vehicles in favour of cycling and walking.	17657, A5036, The Strand 37905, A57 Dale Street 46588, A5038, Lime Street

Subject	Intervention	Applicable Links
Bus Fleet Upgrades	Improving bus fleet emissions can have a measurable impact on air quality, although the effects of retrofitting emissions abatement controls requires additional evidence to accurately determine the effects on emissions. The air quality feasibility study indicated that overall NO_X emissions reductions up to 7% may be achieved compared to the 2016 baseline fleet. The timescale required for retrofitting the vehicles may exceed the deadline for compliance, and so the most feasible approach may be to determine which bus routes travel through the areas with the worst air quality, and prioritise these routes for low emission vehicles.	All links
Segregated Bus Corridors	Buses were identified as significant emission sources on the compliance links, and so segregated road space may increase journey efficiency and prioritise public transport instead of cars. Furthermore, this may be integrated with opportunities to implement green light priorities or segregated turning lanes for buses. The timescales may not be available to implement this measure, as it would require detailed screening, appraisal and subsequent infrastructure works.	37905, A57 Dale Street 46588, A5038, Lime Street

Subject	Intervention	Applicable Links
Mersey Toll	Regulating the toll prices has been investigated as a potential CAZ implementation, although further controls on the numbers, types and emission profiles of vehicles using the Mersey tunnels would specifically affect roads around the centre of Liverpool. It would be necessary to understand the emissions profile for vehicles using the tunnels, and the whole journey route in order to then determine the potential effects on the compliance links. The following actions would be required: - Review the pricing structure on the Mersey River crossings to prioritise low emission vehicles based on the Euro-classification, and to penalise high-emission vehicles. The pricing structure should reflect the existing fleet composition, and the emissions thresholds should become increasingly stringent in the future to allow users to adapt. - The toll restructuring should be undertaken with consideration for any ongoing CAZ studies, due to the potential inclusion of these routes in a controlled emission zone. It is also essential that potential effects on social inclusion are carefully mitigated through links to travel planning and support for modal shift measures.	17657, A5036, The Strand 37905, A57 Dale Street 28563, A580, New Islington 37794, A580, New Islington

Additional Interventions

In addition to the broad concepts outlined above, specific interventions have been identified that may be feasible to specifically target some, or all, of the compliance links within the shortest possible time. These are summarised in Table 27.

Table 27 Summary of Additional Interventions

Subject	Intervention	Applicable Links
Temporary road closures until compliance is achieved.	A temporary road closure to all, or some, traffic for defined periods of the day would effectively remove it from the affected road. This is unlikely to be possible on most roads, but may be achieved where vehicles can be redirected, or where 24-hour access is not essential. The redirected vehicles may contribute to exceedances on other road links, and so the implementation would require careful diversion planning. Banning cars or LGVs during peak hours may be sufficient to achieve the required emissions reductions.	37905, A57 Dale Street 46588, A5038, Lime Street
Gating road sections	Traffic signalising would be used to hold traffic in areas where there is no relevant exposure. This would be used to prevent a build-up of congestion and improve drive-cycle efficiency. As with the diversion planning, it would require the holding areas to be carefully identified to ensure that new exceedances do not occur in areas of sensitive relevant exposure.	17657, A5036, The Strand
Speed controls	Vehicle speeds directly affect the drive-cycle efficiency and emissions, where low speeds, idling and accelerating can significantly affect emissions. Using traffic controls to ensure that movement is relatively 'smooth', with a constant speed to limit acceleration, would minimise emissions. Potential mechanisms may include alteration of the red / green times on the traffic lights, or introducing traffic calming measures on roads leading into the areas of concern.	All links

Subject	Intervention	Applicable Links
Bus re-routing	Buses were identified as the most significant emission sources on two road links, and were disproportionally significant emission sources compared to the number of movements. Re-routing all, or some, buses away from the compliance areas may have significant benefits. A review of the bus routes to identify those with lowest / highest emission profiles may be a feasible method of continuing bus operation on the affected road links whilst also focussing emissions reductions. Consultation with the bus operators would be required to determine what routes could be modified based on the available fleet.	28563, A580, New Islington 37794, A580, New Islington 37905, A57 Dale Street 46588, A5038, Lime Street
Diesel car regulation	The source apportionment identified diesel cars as a significant emission source, and diesel bans have been discussed in public forums. Indirect measures that target parking diesel cars would alter the traffic flow of these vehicles to parking destinations, although this may be difficult to implement on a sufficient scale to affect the journeys using the compliance links. This measure would have potential socio-economic effects as it targets a specific component of the fleet. In order to fully understand the potential effects, the breakdown of the diesel car fleet on the affected road links would need to be understood, and then the re-routing carefully designed to ensure that detrimental effects do not occur on other roads. The effects of the implementation would be similar to the temporary road closures and CAZ. This option may not be feasible on all routes, as there may not be sufficient routing options for diverted vehicles. Furthermore, enforcement would require an automated system, such as ANPR, to ensure that designated vehicle types do not enter the affected road links. This would require potentially significant infrastructure that may not be feasible to be installed within the compliance deadline.	28563, A580, New Islington 37794, A580, New Islington 37905, A57 Dale Street 46588, A5038, Lime Street
Freight restrictions	HGVs were not identified as a significant emissions source, although LGVs were potential concerns on some links. Freight consolidation, access restrictions and regulated delivery times may represent practical interventions, although they are unlikely to be feasibly implemented in the timescales available.	28563, A580, New Islington 37794, A580, New Islington 37905, A57 Dale Street 46588, A5038, Lime Street

In addition to the broad concepts outlined above, specific interventions have been identified that may be feasible to specifically target some, or all, of the compliance links within the shortest possible time.

There are several major highways schemes that are programmed to be completed in a similar timeframe as the compliance deadlines, and which may affect, or be affected by the interventions discussed in this report.

These are summarised in Table 28.

Table 28 Summary of Committed Highways Schemes

Subject	**Intervention**	**Applicable Links**
The Liverpool City Centre Connectivity programme	The LCCCP includes the following schemes that may directly impact the compliance links: *'Improving links for pedestrians and cyclists between the city centre shopping areas and the waterfront leisure district by reassigning existing road space along The Strand'.* *'Creating a new gateway into the city from Liverpool Lime Street Station and a new events space for St George's Plateau'* outside Liverpool Lime Street station. '*Enhancing the area for public use and improving connectivity through the city by introducing a new cycle link between Lime Street and the Waterfront'* on Victoria Street and Tithebarn Street. Further improvement programmes are also planned for the following areas that may have effects on the compliance links: - City Bus Hub; creating a new bus layover with welfare facilities in Old Haymarket for buses leaving Queen Square bus station so reducing congestion and pollution in the city centre. (south of the 17657, A5036, The Strand) - Canning Dock Bridges, building four new bridges to link Salthouse Quay with Mann Island and opening up land for future development - Moorfields; improving the footways and introducing new trees to enhance the area and the entrance into Moorfields Station. - Brownlow Hill; enhancing the area for public use and introducing of new cycle link from Liverpool Lime Street to the Knowledge Quarter.	17657, A5036, The Strand, with effects on 37905, A57 Dale Street 46588, A5038, Lime Street

Subject	Intervention	Applicable Links
	Further details are published at https://liverpool.gov.uk/parking-travel-and-roads/better-roads/better-roads-schemes/liverpool-city-centre-connectivity-scheme-phase-one/ Furthermore, these schemes will be implemented in accordance with existing funding programmes with completion dates varying between 2018 to 2020, which overlaps the compliance years and will affect the future projections.	
Concept Study, Rocket Junction	Two options have been shortlisted to improve 'Rocket Junction' at the western end of the M62: - A5080/M62 underpass and signalised hamburger gyratory. This will A5080/M62 underpass, but may increase proximity to receptors along Glendevon Road and The Green; or, - Maintain the elevated Queens Drive viaduct with an at-grade traffic signal gyratory. The east/west traffic movement associated with the M62 will be managed with the introduction of an underpass. The current project brief indicates the approximate timescale to completion is in the range 2024-2034. Therefore, the potential implications for this study are dependent on the projected compliance dates.	18508, A5080, Bowring Park Road
Green Spaces Network	There is a current scheme to put in cycle and pedestrian facilities across New Islington as part of the Green Spaces Network to reduce traffic and improve access. It is currently in the design stage and is expected to be completed by summer 2018. .	28563, A580, New Islington 37794, A580, New Islington
Royal Hospital	The current road conditions on A580 New Islington are being affected by the closure of a parallel route A5047 West Derby Street (inbound) while the Royal Hospital is being rebuilt. This condition has been in place since February 2014 and is due to be completed in 2022, which is currently expected ot be beyond the compliance dates.	28563, A580, New Islington 37794, A580, New Islington

Part 3: Assessing deliverability/feasibility and delivering a short list

The following Table provide a sifted list of interventions based on discussions with officers in at Liverpool City Council on an individual basis. It sets out timelines and any constraints, and clearly identified those interventions that may be taken forwards to Part 4.

Table 29 Long List of Measures and Sifting

Subject	Intervention	Census ID	Potential AQ Benefit	Constraints	Taken Forward	Implementation/Reasoning	Est. Timescale (Months)
Clean Air Zone	CAZ intervention scenarios were investigated for the whole of LCR, although in this context smaller zones may be considered that only affect a discrete number of road sections. In order to effectively implement a CAZ it was recommended that:	17657	NA	NA	**NA**	Not possible to implement within the time frame, as it is currently a major through-route with no viable alternative without a large-scale strategic approach	>3 years
		18508	NA	NA	**NA**	Not appropriate for this road, as it is a strategic link.	
		28563	Effects are scalable depending on the level of intervention	Time cost for the feasibility study and preferred option, plus the physical installation. Social effects must be thoroughly appraised and mitigation designed	**No**	Not possible to implement within the time frame	
		37794			**No**		
		37905			**No**		
		46588			**No**		

Urban Traffic Management Control (UTMC)	A UTMC may be used to actively prioritise air quality by redistributing congestion and slow-moving traffic away from areas of concern, even where it may lead to longer journey times. Where road capacity is made available through successful implementation of the UTMC, it should be utilised for alternative transport.	17657	The traffic lights currently prioritise pedestrian crossings without waiting, so approx. 3rd of the light times are dedicated to road crossing. There are plans to attribute priority to cars by splitting the pedestrian crossing across the central island.	None	**Yes**		Lights currently fixed time, but SCOOT can be used with new in-road sensors. <days to install, plus following time to validate.
		18508	This junction is planned to be re-aligned >2020. During the construction phase there will be a diversion plan, although this has not been finalised. Possible opportunities to use increased signage to divert traffic, although this may not achieve tangible effects.	Congestion on edge lane due to 3 to 2 lane merge feeding back onto the motorway. Edge Lane movement has been improved partly, but there is limited opportunity to improve this further. Reduce timing to hold traffic on Bowring improves Edge Lane, but makes it worse on Bowring.	**No**	UTMC is unlikely to support reduced emissions on Bowring without leading to detrimental effects on other links.	

		28563	There is congestion at the Kingsway tunnel due to traffic backing-up Byron Street and Hunter Street, which is partly related to incidentally braking at the tunnel entrance corner. Needs to control vehicle braking at tunnel corner. Also, non-tunnel traffic is using the wrong lane, so it is proposed that new auto-VMS can be used to instruct lane usage, so benefit to upgrading signage to get better driver response. This would be linked to journey-time data to inform drivers of the best routes using live SCOOT data.	The road was recently partly resurfaced, but the control loops were incorrectly installed.	**Yes**		
		37794			**Yes**		
		37905	SCOOT will Integrate junctions and pedestrian crossings.	Road surface needs repairing to allow installation of appropriate sensors	**Yes**		
		46588			**Yes**		
Urban Clear way	The use of urban clearways (Red Routes) to prevent on-street parking and increase road space may have	17657	NA	NA	**NA**	No AQ benefits on this link as it is already clearway	2-3 years, subject to the level of

	a beneficial effect on A57 Dale Street, as this is the only link with parking currently permitted. The increased road capacity may be prioritised or allocated specifically for public transport or low emission vehicle use.	18508	NA	NA	**NA**	No AQ benefits on this link as it is already clearway	infrastructure changes required.
		28563	NA	NA	**NA**	No AQ benefits on this link as it is already clearway	
		37794	NA	NA	**NA**	No AQ benefits on this link as it is already clearway	
		37905	Potentially smoother flow through increased capacity Option to implement through-lane in centre of road with increased junction efficiencies, such as slip lanes and extended merges to reduce need for traffic light controlled junctions Decreased road-space so carriageway is moved further from the facade	Consider whether the route only includes Dale Street or whether this road will form part of a longer route. If implemented, it would need to be enforced using camera technology rather than having Civil Enforcement Officers on the ground, which would require infrastructure lead-time.	**No**	The congestion is not a significant issue on Dale Street, and to achieve a change through re-assigning road-space would require infrastructure and carriageway changes that are not possible before the compliance date.	
		46588	NA	NA	**NA**	No AQ benefits on this link as already clearway	
Green Infrastructure	Green infrastructure, such as tree planting, green screens and canopies would affect the dispersion of emissions from the carriageway and alter the exposure pathway.	17657	Physical screening including a mix of screens, louvres, trees, mosses and fungi	Limited road space available The option is not sustainable for solely LAQ results	**No**	The Strand is due to be remodelled in the City Connectivity Project and so any infrastructure would be temporary	1-2 years

	The shape and permeability of the structure may be designed to block, trap or funnel emissions, and prevent high concentrations from reaching sensitive locations.	18508		Possible planning and sight-line issues. Must ensure there is physical space to install and support the required structures	**Yes**	Tall screens on the kerb could be a viable, but unsustainable, long-term option	
		28563			**Yes**	Tall screens on the kerb could be a viable, but unsustainable, long-term option	
		37794			**Yes**	Tall screens on the kerb could be a viable, but unsustainable, long-term option	
		37905		Very limited road space available, so needs either thin screens or take from the carriageway	**No**	The street is a narrow canyon without sufficient space to create screening	
		46588		Screens should not block pedestrian traffic or driver sights around the complex junction	**No**	Lime Street is due to be remodelled in the City Connectivity Project and so any infrastructure would be temporary	
Shared Space	Shared Spaces may be beneficial in high-street type areas which are not pedestrianised and suffer from congestion and discourage pedestrians and cyclists. The implementation of this measure would need to focus on a shift towards changing the perception of how the roads are used, and actively discouraging the use of private vehicles in favour of cycling and walking.	17657	Would promote long-term modal change, although direct AQ effects may be limited	May not have direct benefits	**No**		1-2 years, pending detailed design
		18508	NA	NA	**NA**	Not possible on this road link as it is a major through-route	
		28563	NA	NA	**NA**		
		37794	NA	NA	**NA**		

		37905	Would promote long-term modal change, although direct AQ effects may be limited	Digging up the road, connectivity due in 2020/2021 to reduce traffic	**No**	Air quality benefits would be limited	
		46588	Would promote long-term modal change, although direct AQ effects may be limited.	Lime Street is due to be remodelled in the City Connectivity project, and so any shared space infrastructure would be temporary	**No**	Air quality benefits would be limited	
Bus Fleet Upgrades	Improving bus fleet emissions can have a measurable impact on air quality, although the effects of retrofitting emissions abatement controls requires additional evidence to accurately determine the effects on emissions. The air quality feasibility study indicated that overall NO_x emissions reductions up to 7% may be achieved compared to the 2016 baseline fleet. The timescale required for retrofitting the vehicles may exceed the deadline for compliance, and so the most feasible approach may be to determine whether the bus routes that travel through the areas with	17657	Funded upgrades are predicted to achieve 7% reduction in bus emissions compared to 2016 The low-emission buses should be prioritised on affected routes	It is not possible to complete the upgrades sooner due to limited supplier resources.	**Yes**	May not be possible to accelerate upgrades, but it should be possible to focus low-emission buses on key routes and undertake real-world emission testing for validation	<2020
		18508		Most buses will need to access Liverpool One, off The Strand	**Yes**		
		28563		Most buses will need to access the city centre bus station via Lime Street	**Yes**		
		37794			**Yes**		
		37905			**Yes**		

	the worst air quality, and prioritise these routes for vehicles that have already been upgraded.	46588			**Yes**		
Segregated Bus Corridors	Buses were identified as significant emission sources on some compliance links, and so segregated road space may increase journey efficiency and prioritise public transport instead of cars. Furthermore, this may be integrated with opportunities to implement green light priorities or segregated turning lanes for buses. The timescales may not be available to implement this measure, as it would require detailed screening, appraisal and subsequent infrastructure works.	17657	NA		**NA**	Not possible on this road link due to limited road space	1-3 years
		18508	NA		**NA**		
		28563	NA		**NA**		
		37794	NA		**NA**		
		37905	Reassign road space to bus corridor, with links to a clearway	Designating a bus-only corridor may lead to congestion on remaining carriageways as there is limited road space available The time required to install enforcement may not be feasible.	**No**	There is limited road-space to assign a bus corridor, although this may be designated as a part-time bus-only zone	
		46588	A significant proportion of traffic is already solely buses	City Connectivity scheme will go ahead ~2020, and so it is not possible to implement physical	**No**	There is limited road-space to assign a bus corridor, although this may be designated as a part-time bus-only zone	

				measures earlier			
Mersey Toll	Regulating the toll prices has been investigated as a potential CAZ implementation, although further controls on the numbers, types and emission profiles of vehicles using the Mersey tunnels would specifically affect roads around the centre of Liverpool. It would be necessary to understand the emissions profile for vehicles using the tunnels, and the whole journey route in order to then determine the potential effects on the compliance links. The following actions would be required: Review the pricing structure on the Mersey River crossings to prioritise low emission vehicles based on the Euro-classification, and to penalise high-emission vehicles. The pricing structure should reflect the existing fleet composition, and the emissions thresholds should become increasingly stringent in the future to allow users to adapt. The toll restructuring should be undertaken with consideration for any ongoing CAZ studies, due to the potential inclusion of these routes in a controlled emission zone. It is also essential that potential effects on social inclusion are carefully mitigated through links to	17657	Increased toll to focus on high emitters, with lower charges for low emitters	Requires enforcement mechanism Potential social inclusion issues so a means-tested discount scheme must be made available Sufficient alternative transport must be supported	**No**	This is a regional aspiration, but the mechanism to implement an emissions-based control would be similar to a CAZ in terms of timescales	>2 years
		18508			**No**		
		28563			**No**		
		37794			**No**		
		37905			**No**		
		46588			**No**		

	travel planning and support for modal shift measures.						
Temporary road closures until compliance is achieved.	A temporary road closure to all, or some, traffic for defined periods of the day would effectively remove it from the affected road. This is unlikely to be possible on most roads, but may be achieved where vehicles can be redirected, or where 24-hour access is not essential. The redirected vehicles may contribute to exceedances on other road links, and so the implementation would require careful diversion planning. Banning cars or LGVs during peak hours may be sufficient to achieve the required emissions reductions.	17657	NA	Potential displacement effects due to redistribution. Closures at defined times may not achieve a major benefit as the AADT will not change. This will also require enforcement.	**NA**	Not possible on this road link as it is a major thoroughfare and closures or limited access would significantly affect other roads as no other routes are available that can support this amount of additional traffic.	>12-months
		18508	NA		**NA**		
		28563	Closing footpath would remove exposure		**No**	Close footpath whilst screening is installed	
		37794	Closing footpath would remove exposure		**No**		
		37905	100% effective on route, but maybe only for part of the fleet, such as cars		**Yes**	Apply controls for cars and goods during peak hours, but consider access to centre car parks, and re-routing signage	
		46588	100% effective on route, but maybe only for part of the fleet, such as cars		**Yes**	Apply controls for cars and goods during peak hours, in preparation for the City Connectivity project to break-ground	
Gating road sections	Traffic signalising would be used to hold traffic in areas where there is no relevant exposure. This would be used to prevent a build-up of congestion and improve drive-cycle efficiency. As with the diversion planning, it would require the holding areas to be carefully identified to ensure that new exceedances do not occur in	17657	Use UTMC to hold vehicles in areas with no relevant exposure, and ensure efficient flow in the link of concern	Need to identify non-exposure areas, where increased emissions will not lead to a compliance breach	**No**	There is not an area where the traffic can be held, and where there is not a significant risk of exposure	
		18508	NA	NA	**NA**	There is not an area where the traffic can be held, and where	
		28563	NA	NA	**NA**		

	areas of sensitive relevant exposure.	37794	NA	NA	**NA**	there is not a significant risk of exposure	
		37905	NA	NA	**NA**		
		46588	NA		**NA**	Not areas to hold traffic back are available, and may conflict with the CC scheme	
Speed controls	Vehicle speeds directly affect the drive-cycle efficiency and emissions, where low speeds, idling and accelerating can significantly affect emissions. Using traffic controls to ensure that movement is relatively 'smooth', with a constant speed to limit acceleration, would minimise emissions. Potential mechanisms may include: - altering the red / green times on the traffic lights; - introducing traffic calming measures on roads leading into the areas of concern;	17657	This can have a significant effect, and may be most effective where it can target specific groups Refer to speed curves that indicate lower speeds have higher emissions, so reduced speed must focus on calming and congestion.	Requires enforcement, especially for behavioural controls	**Yes**	Consider the effect of achieving a higher/lower daily average speeds through UTMC and enforcement/restriction.	12-months
		18508			**Yes**		
		28563			**Yes**		
		37794			**Yes**		
		37905			**Yes**		
		46588			**Yes**		

Bus re-routing	Buses were identified as the most significant emission sources on two road links, and were disproportionally significant emission sources compared to the number of movements. Re-routing all, or some, buses away from the compliance areas may have significant benefits. A review of the bus routes to identify those with lowest / highest emission profiles may be a feasible method of continuing bus operation on the affected road links whilst also focussing emissions reductions. Consultation with the bus operators would be required to determine what routes could be modified based on the available fleet.	17657	NA	NA	**No**	Not possible to re-route due to Liverpool 1 access	
		18508	NA	NA	**NA**	This is a major through-route, so it is not possible to re-route buses onto alternative roads	
		28563	NA	NA	**NA**	This is a major through-route, so it is not possible to re-route buses onto alternative roads	
		37794	NA	NA	**NA**	This is a major through-route, so it is not possible to re-route buses onto alternative roads	
		37905	Source apportionment has indicated that buses are a significant emission source	Potential redistribution issues, especially where buses need to access Liverpool 1. However, the City Connectivity project will contribute to bus route changes	**Yes**	This would be subject to negotiation and agreement with the bus operators	12-months
		46588			**No**	Not possible on this link due to essential city centre bus station access	
Diesel car regulati	The source apportionment identified diesel cars as a significant emission source, and diesel bans have been discussed in public forums.	17657	NA	NA	**NA**	Not possible on this road link as it is a major thoroughfare and closures or limited access would significantly affect other	

	Indirect measures that target parking diesel cars would alter the traffic flow of these vehicles to parking destinations, although this may be difficult to implement on a sufficient scale to affect the journeys using the compliance links.	18508	NA	NA	**NA**	roads as no other routes are available that can support this amount of additional traffic.	
	This measure would have potential socio-economic effects as it targets a specific component of the fleet.	28563		Enforcement infrastructure is not achievable within the time-frame, and the potential socio-economic effects are similar to a CAZ	**No**		
	In order to fully understand the potential effects, the breakdown of the diesel car fleet on the affected road links would need to be understood, and then the re-routing carefully designed to ensure that detrimental effects do not occur on other roads. The effects of the implementation would be similar to the temporary road closures and CAZ.	37794			**No**		
	This option may not be feasible on all routes, as there may not be sufficient routing options for diverted vehicles.	37905			**No**		
	Furthermore, enforcement would require an automated system, such as ANPR, to ensure that designated vehicle types do not enter the affected road links. This would require potentially significant infrastructure that may not be feasible to be installed within the compliance deadline.	46588			**No**		
Freight restrictions	HGVs were not identified as a significant emissions source, although LGVs were potential concerns on some links.	17657			**No**	Not possible on this road link as it is a major thoroughfare and closures or limited access would significantly affect other roads as no other routes are	
		18508			**No**		

	Freight consolidation is unlikely to be feasibly implemented in the timescales available. However, access restrictions and regulated delivery times may be a practical intervention.	28563			**No**	available that can support this amount of additional traffic.	
		37794			**No**		
		37905	Measurable benefits could be achieved LGVs may be targeted separately from HGV at peak hours	May require a freight holding areas - ideally linked to distribution centre and last-mile programme Non-diesel LGVs may not be available.	**Yes**	Not a major freight route, although time restrictions could be applied	>1–2 years
		46588			**Yes**		
The Liverpool City Centre Connectivity programme	Improving links for pedestrians and cyclists between the city centre shopping areas and the waterfront leisure district by reassigning existing road space along The Strand'. Creating a new gateway into the city from Liverpool Lime Street Station and a new events space for St George's Plateau' outside Liverpool Lime Street station. Enhancing the area for public use and improving connectivity through the city by introducing a new cycle link between Lime Street and the Waterfront' on Victoria Street and Tithebarn Street. https://liverpool.gov.uk/parking-travel-and-roads/better-roads/better-roads-	17657	Plans are not confirmed, but may integrate some of the above measures, and initiation complementary measures in preparation for the work		**NA**		Programmed for 2020
		18508			**NA**		Work due after 2020
		28563		Major works on the hospital leading to traffic re-routing started in 2015, and is due to be completed in 2018/2019. This will affect the existing and future baselines on this link.	**NA**	This road is not specifically part of the project, but the effects will be considered	
		37794		Major works on the hospital leading to traffic re-routing started in 2015, and is due to	**NA**		

	schemes/liverpool-city-centre-connectivity-scheme-phase-one/ This may reduce demand for these roads, but there are risks that it could contribute to delays or congestion and detrimental effects on emissions. Therefore, benefits for local air quality should be maximised through planning and assessment during the detailed design and appraisal stages. These schemes will be implemented in accordance with existing funding programmes, and so it is uncertain how they may be used to bring forward compliance.			be completed in 2018/2019. This will affect the existing and future baselines on this link.			
		37905	Impacts will be linked to work on The Strand	The detailed plans and work start date have not yet been agreed	**NA**	Include narrow lanes, gating, screens and shared spaces	Work due 2019 - 2021
		46588	Plans are not confirmed, but may integrate some of the above measures, and initiation complementary measures in preparation for the work		**NA**		

The following preferred measures will be taken forwards to Part 4 for assessment.

It was noted there were few intervention that were successfully screened for link 18508 (Bowring Park Road), as this is a major through-route connecting to the Strategic Road Network. The connecting junction to the west of this link would be adversely affected by any of the UTMC interventions. It is planned to be substantially altered after 2020, which should be beneficial, although this is after the compliance date.

Table 30 Preferred Measures

Preferred Measures	Census ID
Use a UTMC to control traffic speeds and flow at key junctions, and to specifically target vehicle speeds and minimise the very low speed movement.	17657 28563 37794 37905 46588
Install green infrastructure, such as tree planting, green screens and canopies would affect the dispersion of emissions from the carriageway and alter the exposure pathway.	18508 28563 37794
Improving bus fleet emissions through retrofit and upgrade is already planned, and so this will be taken into consideration for the future-year assessment scenarios.	17657 18508 28563 37794 37905 46588
Prioritise buses with lowest emission vehicles on routes through the compliance link	37905
A temporary road closure to all, or some, traffic for defined periods of the day	37905
Freight access restrictions and regulated delivery times	37905 46588

Part 4: Evidencing the short listed measures to identify options that could bring forward compliance

Part 4 is split into three sections, in order to achieve the objectives sought in the guidance. The sections are as follows:

1) Presenting the results of the detailed dispersion modelling, and summarising the level of reduction required to achieve compliance on each link.
2) Reviewing the effectiveness of each intervention independently from the road network based on either historical data or a Rapid Evidence Assessment to determine the potential impact on emissions.
3) Application of the measures on each of the links where such intervention is deemed appropriate, as set out in section 3, in order to determine the effects, and whether it achieves the required emissions reduction.

Future baseline

Detailed dispersion modelling was undertaken for the compliance links using data from the LCC Transport Model, based on a 2017 baseline year and a 2020/2030 future year.

The future model years included two future scenarios; with and without Phase 1 of the Liverpool City Centre Connectivity Programme, which is a major road traffic improvement scheme that will affect numerous routes in the city.

The existing regional bus fleet composition data was applied to the 2017 baseline year, and the committed bus fleet retrofit programme was applied to the 2020 scenarios.

The concentrations were interpolated between to 2030 to determine the compliance year.

The bus fleet improvement programme was included in fleet profile for each modelled year based on the funding allocation that was awarded compared to the baseline bus fleet that was being retrofitted with abatement equipment. The break-down for the Liverpool City Region fleet is provided in Table 4, and as a large number of these vehicles enter the city.

The 2017 emission profile included the completed 2018 retrofit fleet composition, as it was considered reasonable to use this data for the model as the best-available information rather than using the default nominal breakdown in the EFT.

The 2020 emission profile included the pending retrofit fleet composition from the recent funding allocation, as this should be complete by then.

<u>Meterological Data</u>

Meteorological data was obtained from the Crosby recording site for 2015.

Model Verification

The model was verified using the nearest passive diffusion tube monitoring data to each area.

The monitoring location T38 on Water Street is in close proximity to The Strand, but was displaying significant different characteristics to this road (gradient, slow movement, low AADT, street canyon), and as a result was not considered suitable for verification. Therefore, the adjustment factor for The Strand used the linear regression of the other factors for the other three areas. The factors applied to the model were:

- 17657 (A5036, The Strand) and 46588 (A5038, Lime Street); 1.28
- 18508, A5080, Bowring Park Road; 1.47
- 28563 and 37794, A580, New Islington; 0.66
- 37905, A57, Dale Street; 1.28

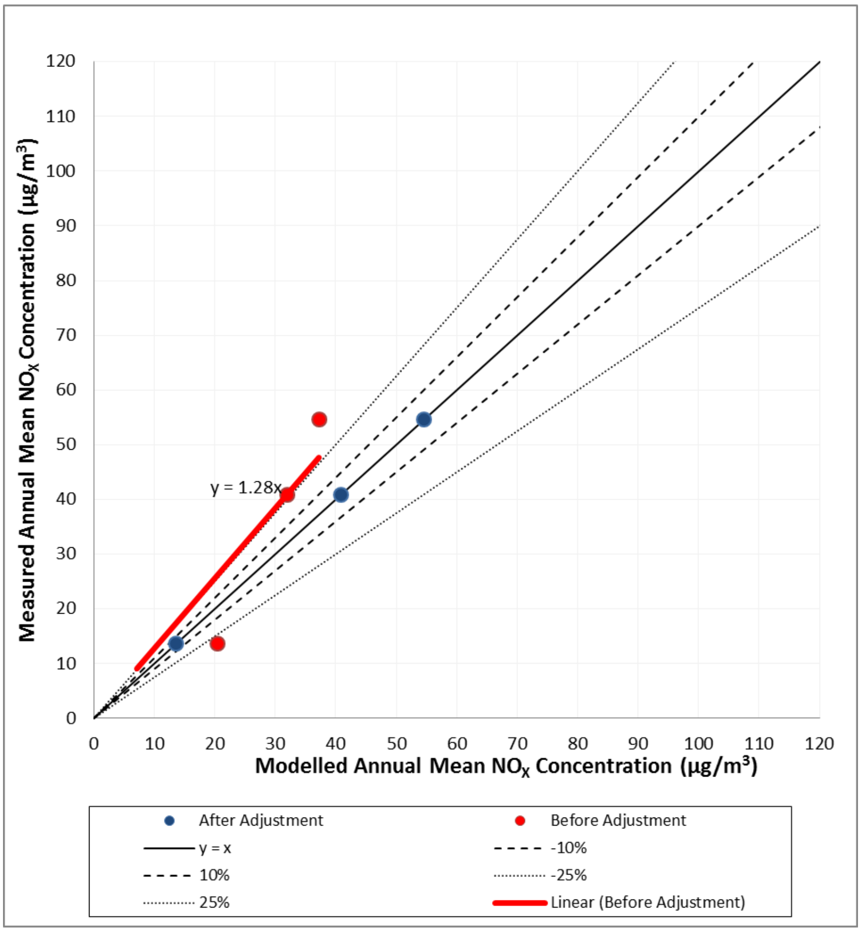
The adjusted NO_2 concentrations were within 19% of the monitored value, although it was not appropriate to state an RMSE based on individual monitoring points.

The verification is presented in Table 31 and Figure 12.

Table 31 Model Verification

ID	Background NO_2	Before Adjustment		Monitored		Adjusted	
		Mod R-NO_X	Mod NO_2	Meas NO_2	Meas R-NO_X	Meas/Mod NO_X	Used Adjustment Factor
T32-34	26.8	32.0	41.9	45.7	40.9	1.09	**1.28**
T26-28	28.1	20.5	37.9	34.7	13.6	0.92	**0.66**
S50-52	19.8	37.2	37.7	45.0	54.6	1.19	**1.47**

Figure 12 Model Verification Adjustment Plot for Three Model Domains



The results presented in Table 32 predict that the kerbside concentrations would achieve the annual mean objective for all road links in 2017, except for Bowring Park, which would be compliant in 2020.

It was recognised that quite substantial drops in NO_2 concentrations were predicted from year-on-year. The model used the nominal EFT emissions profile and Defra background concentrations for each year, and which are predicted to improve in the future at a rate exceeding the effects of the growth projections of the transport model.

Table 32 Detailed Dispersion Modelling Projected Compliance

Location	ID	Predicted Annual Mean NO_2									
		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Bowring WB	R1	31.2	30.5	29.8	29.1	28.3	27.6	26.9	26.2	25.4	24.7
Bowring WB	R2	31.5	30.7	30.0	29.3	28.5	27.8	27.1	26.4	25.6	24.9
Bowring WB	R3	41.1	40.2	39.4	38.5	37.7	36.9	36.0	35.2	34.3	33.5
Bowring EB	R4	41.2	40.3	39.4	38.5	37.6	36.8	35.9	35.0	34.1	33.2
Bowring EB	R5	42.9	42.0	41.1	40.2	39.3	38.5	37.6	36.7	35.8	34.9
Bowring EB	R6	34.7	33.9	33.1	32.4	31.6	30.8	30.0	29.2	28.5	27.7
Islington WB	R7	33.8	32.9	32.0	31.0	30.1	29.2	28.3	27.4	26.4	25.5

Islington WB	R8	33.2	32.3	31.4	30.5	29.6	28.7	27.8	26.8	25.9	25.0
Islington WB	R9	34.4	33.5	32.5	31.6	30.7	29.8	28.9	28.0	27.0	26.1
Islington EB	R10	35.1	34.2	33.4	32.5	31.6	30.7	29.8	29.0	28.1	27.2
Islington EB	R11	37.0	36.1	35.2	34.2	33.3	32.4	31.4	30.5	29.6	28.7
Islington EB	R12	35.3	34.4	33.5	32.7	31.8	31.0	30.1	29.3	28.4	27.5
Lime Street SB	R13	30.0	29.5	28.9	28.3	27.8	27.2	26.7	26.1	25.5	25.0
Lime Street SB	R14	30.0	29.5	28.9	28.4	27.8	27.3	26.7	26.2	25.6	25.1
Lime Street NB	R15	32.0	31.8	31.7	31.6	31.4	31.3	31.2	31.0	30.9	30.8
Lime Street NB	R16	30.7	30.2	29.7	29.2	28.7	28.3	27.8	27.3	26.8	26.3
Dale Street S	R17	35.0	34.8	34.6	34.4	34.2	34.0	33.8	33.6	33.4	33.2
Dale Street N	R18	36.1	35.9	35.8	35.6	35.5	35.4	35.2	35.1	34.9	34.8
The Strand SB	R19	39.5	38.9	38.4	37.8	37.2	36.7	36.1	35.6	35.0	34.4
The Strand SB	R20	37.8	37.1	36.4	35.7	35.0	34.3	33.6	32.9	32.2	31.6
The Strand NB	R21	40.3	39.5	38.7	37.9	37.1	36.3	35.5	34.7	33.9	33.1
The Strand NB	R22	35.6	35.0	34.5	33.9	33.4	32.8	32.2	31.7	31.1	30.6

Converting NO_X and NO_2 Emissions to Concentrations

The projected further concentrations of roadside Total-NO_2 were obtained from the Defra PCM projections for the appraised road links. The Total-NO_2 was converted into Total-NO_X and Road-NO_X concentrations using the NO_X to NO_2 calculator.

The change of Road-NO_X emissions for each scenario was calculated using the EFT, and the change converted to a percentage relative to the projected non-intervention scenario.

The percentage change in Road-NOX emissions was used to adjust the Road-NO_X concentration by the same proportion at the roadside compliance location. This adjusted Road-NO_X concentration was then converted back to Total-NO_2 using the NO_X to NO_2 calculator.

This method converted all of the values to NO_X, and so the proportional change in the emissions from road sources could be applied to the roadside concentration attributed to those sources. This ensured that the non-linear relationship between NO_X and NO_2 was maintained correctly, and that the key difference between ‘concentration’ and ‘emissions’ was translated through the use of percentage change of road sources. This method has previously been accepted in Annual Status Reports and Air Quality Action Plans submitted to Defra.

Modelled Receptor Locations

The modelled receptor locations are shown in Figure 13, Figure 14 and Figure 15.

The red lines indicate the compliance links highlighted by Defra, and the yellow lines are model extents used in the detailed modelling study.

Receptors T38, T26-28, T32-34 and S50-52 were monitoring locations used for model verification.

The receptors identified with Rx were selected receptors at kerbside locations (within 10m of the kerb) that will represent worst-case exposure locations for the purpose of determining compliance.

With regard to those receptors within 25m of a major junction:

- R19 is within 25m of the junction between The Strand and Water St. The remaining three receptors (R20, R21 and R22) near link 17657 are >25m from a major junction.
- R17 is within 25m of junction with Sir Thomas Street, although locations >25m from a junction are difficult to identify in this area due to the large number of junctions within a small area. Receptor R18 on link 37905 is>25m from a major junction.
- Receptors in the New Islington (link 37794) and Bowring Park areas (link 18508) are >25m from a major junction.

Figure 13 Modelled Receptor Locations, Link 17657 and 37905

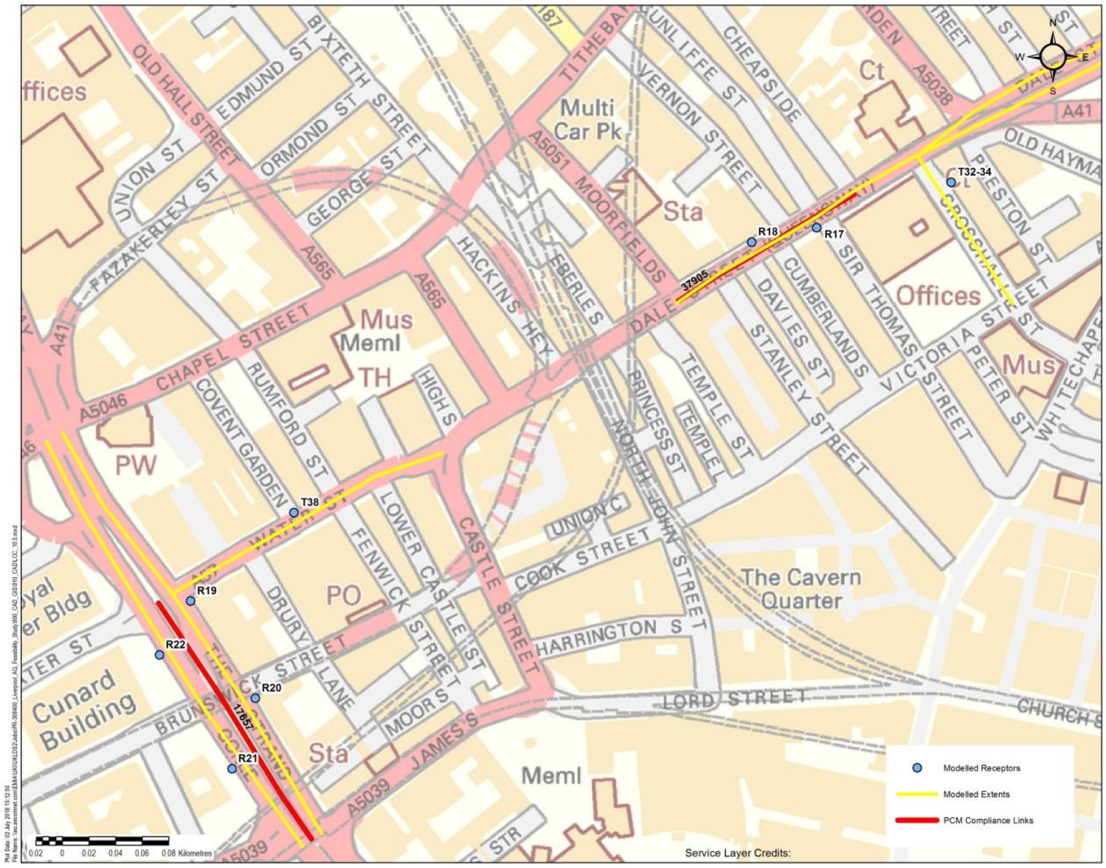


Figure 14 Modelled Receptor Locations, Link 46588, 28563 and 37794

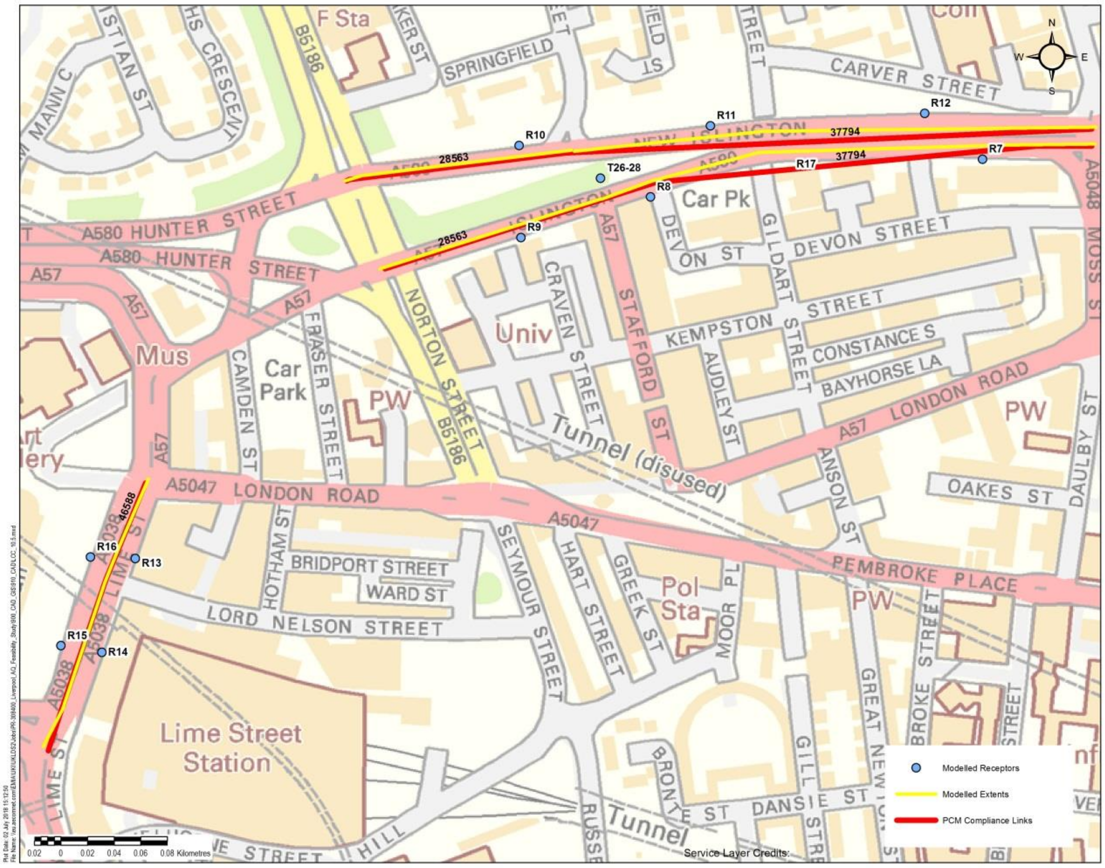
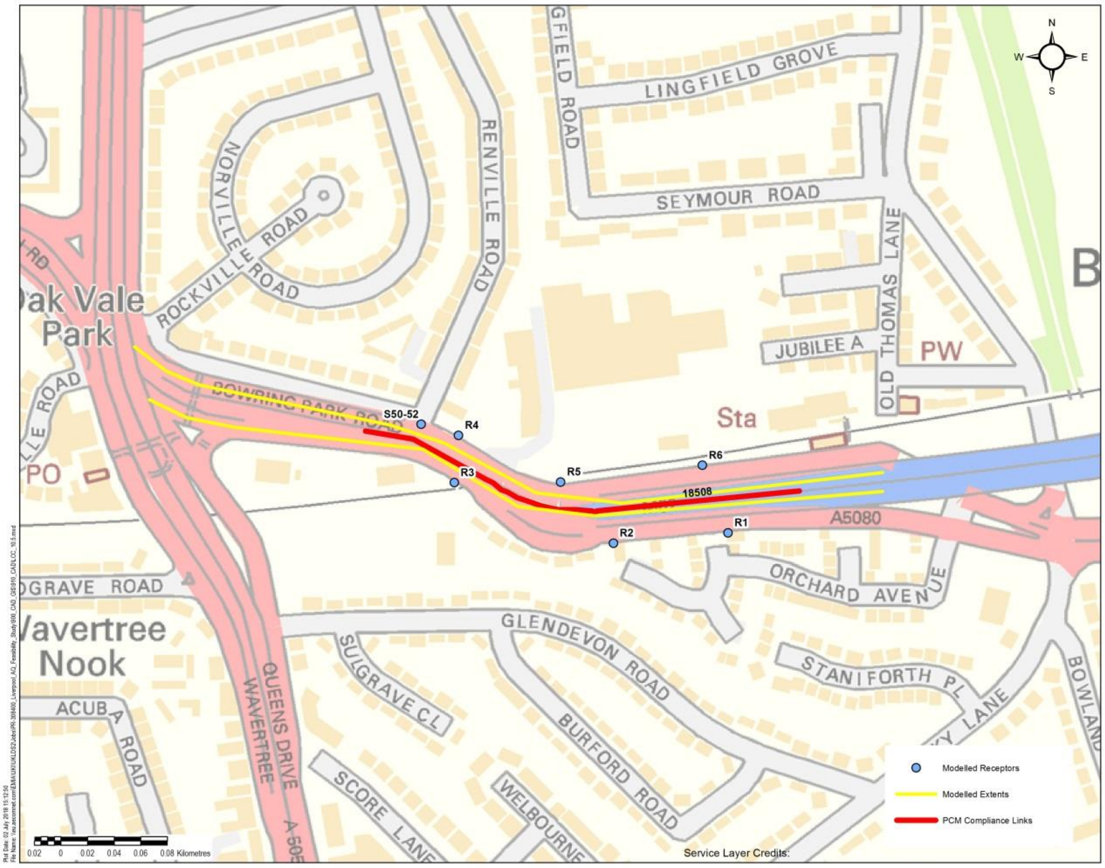


Figure 15 Modelled Receptor Locations, Link 18508



The source apportionment for the roads was recalculated in Table 33. The results are broadly consistent with the results in Part 1.

Table 33 Detailed Dispersion Modelling Source Apportionment

Area	Link	2020 Future Scenario						
		Petrol Cars	Diesel Cars	Petrol LGVs	Diesel LGVs	Rigid	Artic	Bus
Bowring	18508 WB	6.5%	45.6%	0.1%	35.9%	9.0%	1.5%	0.4%
Bowring	18508EB	6.4%	44.7%	0.1%	38.3%	7.8%	1.3%	0.6%
Islington	37794 WB	7.0%	54.3%	0.1%	26.7%	9.3%	1.9%	-
Islington	28563 WB	6.4%	55.0%	0.0%	24.6%	10.8%	2.4%	-
Islington	28563EB	6.9%	53.3%	0.1%	27.9%	9.1%	1.9%	-
Islington	37794EB	6.8%	53.3%	0.1%	27.2%	9.7%	2.1%	-
Lime St	46588	1.2%	10.4%	0.0%	3.3%	1.2%	0.3%	83.0%
Lime St	46588	1.8%	13.2%	0.0%	5.5%	0.6%	0.1%	78.1%
Dale St	37905	4.0%	29.3%	0.0%	12.2%	2.4%	0.5%	50.8%
Strand	17657NB	7.7%	54.5%	0.1%	31.1%	3.8%	0.6%	1.1%
Strand	17657SB	7.0%	52.5%	0.0%	24.9%	5.1%	1.0%	8.6%

Retrofitting buses to meet Euro VI Standards

The Liverpool Combined Authority have commenced a rolling programme of retrofitting older buses with selective catalytic reduction (SCR) technology. This effectively converts older Euro IV or Euro V buses to meet the Euro VI standard for NO_X by chemically changing the NO_X into steam through a reaction with ammonia that is sprayed into the exhaust. .This programme is ongoing as well as being undertaken by a number of other local authorities. Funding has been obtained, with each retrofit costing around £16,500, although the capacity of suppliers to fit the required number of buses limits the rate of conversion.

Manufacturers claim that SCR reduces NO_X between 80% and 95%[6]. However, this assumes that the SCR is as effective as a factory developed Euro VI engine. Data from the emissions factor toolkit shown in Table 33 suggests that reductions could be better than the baseline emissions standard, but not as effective as the emissions standard target.

The data indicate that SCR will reduce emissions by around 50% compared to its non-retrofit equivalent which is significant, but much less than manufacturer claims. Additionally, these will vary with topography, driving style and weather. It will also be impacted by the number of vehicles operating along the affected links that have been retrofitted.

Table 34 Efficacy of SCR Retrofit

Source ID	Nominal Traffic Flow	% Bus	Speed , km/hr	Annual NO_X Emissions, kg/yr	Emissions Compared to Euro VI
1Pre-Euro I	1000	100	48	3,933.	3795%
2Euro I	1000	100	48	2,635.	2543%
3Euro II	1000	100	48	2,848	2748%
4Euro III	1000	100	48	2,235	2157%
5Euro IV	1000	100	48	1,543	1489%
6Euro V_EGR	1000	100	48	1,240	1197%
7Euro V_SCR	1000	100	48	1,310	1265%
8Euro VI	1000	100	48	103	-
9Euro II SCRRF	1000	100	48	1,427	1377%
10Euro III SCRRF	1000	100	48	1,121	1082%
11Euro IV SCRRF	1000	100	48	775	748%
12Euro V EGR + SCRRF	1000	100	48	623	602%

Buses are a significant emission source on Dale Street, and so these must be targeted to achieve lower emissions. The options include:

[6] http://www.aem.dinex.dk/en/retrofit/scr%20retrofit
https://greenerjourneys.com/wp-content/uploads/2017/04/Improving-Air-Quality-in-Towns-and-Cities-PROF-DAVID-BEGG-Final.pdf

- Increase the rate of retrofitting, although this may not be feasible due to supplier and installation bottlenecks.
- Prioritise low-emission vehicles on defined routes that include the compliance links, which will require consultation with the operators. This approach should ensure that unacceptable detrimental effects do not occur on other routes.

The data in Table 35 indicate the effects operating only Euro VI-compliant vehicles on the modelled compliance links, and the effects of operating Euro V/VI and retrofitted vehicles. The reduction would be imperceptible on Bowring Park, and minor on The Strand.

It could achieve significant emissions reductions on Dale Street and Lime Street, although it may not be feasible as these routes are used for access to the city centre bus station and Liverpool 1.

Table 35 Effects of Restricting Bus Euro Classification

Area	Link	NO_X Emissions Reduction Compared to 2020 Baseline	
		100% Euro VI	Euro V & VI & Retrofits
Bowring	18508WB	0%	0%
Bowring	18508EB	0%	0%
Islington	37794WB	0%	0%
Islington	28563WB	0%	0%
Islington	28563EB	0%	0%
Islington	37794EB	0%	0%
Lime St	46588	57%	14%
Lime St	46588	56%	16%
Dale St	37905	37%	11%
Strand	17657NB	1%	0%
Strand	17657SB	6%	2%

UTMC to regulate speed

Reviewing the signal timings, alongside the installation of adaptive signalling and appropriate SCOOT/UTC has been found to be effective in improving traffic congestion significantly.

A study undertaken in 1993 of five cities, shows the potential journey time and delay improvements across 5 UK cities.

Table 36 Traffic Signal Optimisation Improvements

Location		Previous Control	% Reduction in journey time			% Reduction in delay		
			AM Peak	Off Peak	PM Peak	AM Peak	Off Peak	PM Peak
Glasgow		Fixed-time	-	-	-	-2	14	10
Coventry (1981)	Foleshill	Fixed-time	5	4	8	23	33	22
	Spon End	Fixed-time	3	0	1	8	0	4
Worcester (1986)		Fixed-time	5	3	11	11	7	0
		Isolated V-A*	18	7	13	32	15	23
Southampton (1984,5)		Isolated V-A*	18	-	26	39	1	48
London (1985)		Fixed-time	Average 8% cars, 6% buses			Average 19%		

These studies, along with a more recent 2016 study by Siemens, shows improvements in journey time/delay of between 12% and 20%[7]. As such, we are estimating the impact of any traffic signal optimisation to result in a 16% improvement in journey time/delay.

Taking the midpoints between each of the speed groups we can target the hours where the average does not exceed the posted speed of the road and apply an improvement to the delay of vehicles.

However rather than simply increase speeds, which would also result in an increase of traffic volume, which for every 10% increase in speed could be as much as 5% or even 10% increase in volumes due to latent demand. [8] We have assumed that optimisation will smooth the flow, reducing incidents of particularly high speed and low speed, effectively narrowing the distribution towards the centre and thus reducing stop/start or accelerating/decelerating traffic, without greatly increasing the overall average speed and therefore reducing emissions as a result.

This new distribution is therefore fed into the Emission Factor Toolkit (EFT) to produce an estimate of emissions reductions for each of the roads based on their own average speed and volume information.

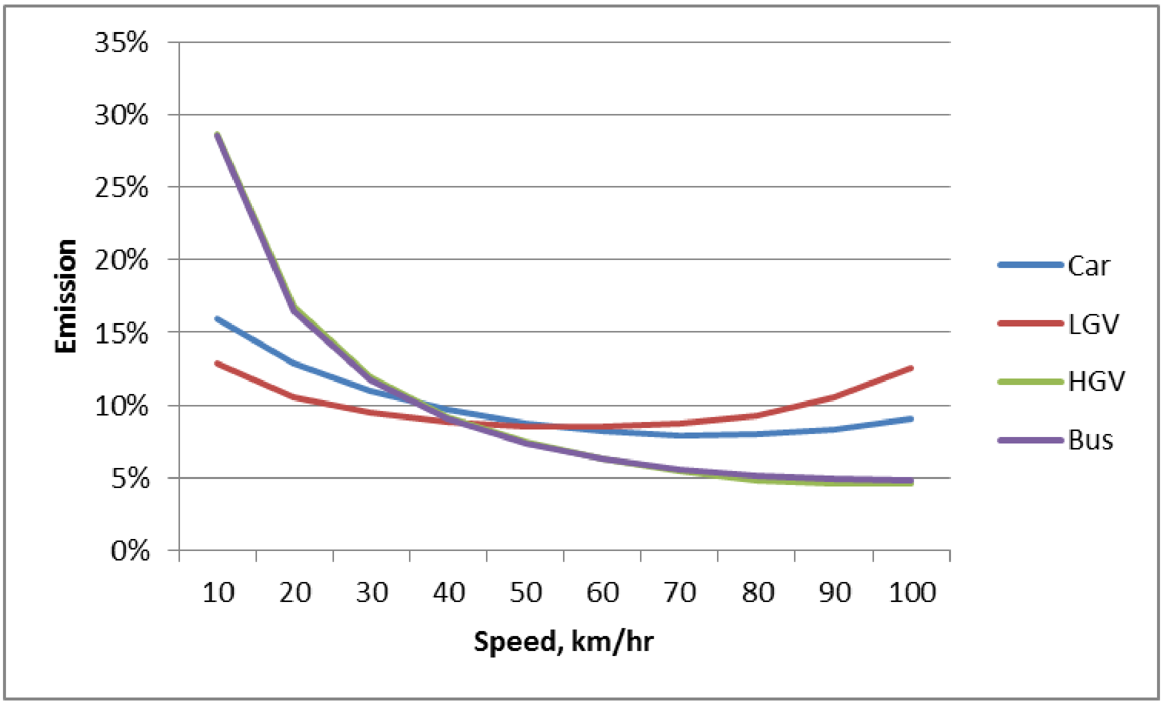
Speed optimisation may be achieved with UTMC at key traffic-light controlled junction and crossings. The primary intention would be to:

- Increase average speed, but without increasing traffic flow. The UTMC would aim to maintain existing overall journey times, whilst reducing the journey time for the compliance link.
- Reduce the number of congested or very slow movement events by calming and regulating the traffic, but not necessarily increasing the overall average speed.

[7] https://www.streetlightdata.com/wp-content/uploads/2018/06/Siemens-and-StreetLight_SCOOT-White-Paper_161005.pdf [accessed 19/06/18]

The plot in Figure 16 indicates how emissions trend downwards for HDVs with increased speed, whilst cars tend to achieve an efficient point around 75 km/hr, and LGVs around 55 km/hr.

Figure 16 Comparison of Relative Effects of Speed vs. Emissions



It was recognised that a 5-10% change may not achieve a significance effect as the traffic is already moving at the most efficient speed. In these cases, a variable speed model may be used to represent the period of each day where there is congestion, and to remove these events.

The data in Table 37 indicate the effects of assuming 5% of traffic on link 37905 is congested, and travelling at 5 km/hr, whereby the remaining 95% of traffic travel at 43.5 km/hr to achieve the average speed of 41.6 km/hr. The model demonstrates how the low-speed traffic is disproportionally significant, leading to 11% higher emissions compared to the constant speed model.

Table 37 Example of Modelling Effects of Variable Speed Changes

	Traffic Flow	% of Flow Affected	Speed, km/hr	Emissions (g/km)	Change
Constant speed scenario	16138	100%	41.6	9,100	-
Variable speed scenario	807	5% congestion	5.0	1,686	111%
	15332		43.5	8,389	
Adjusted speed scenario	16138	100%	43.5	8,831	97%

The effects of changing the average speeds on the compliance links are outlined in Table 38, where the % change is presented that would achieve the greatest benefits (up to a max. 50% increase in speed).

It is recognised that the adjusted speeds would exceed the limit on some links, but this is intended to indicate the effects that may be achieved. Where significantly higher speeds are indicated to achieve beneficial emissions effects, any interventions must be balanced against road safety considerations and the risks associated with higher speeds.

The data in Table 39 use congestion data recorded by SCOOT to determine the adjusted speeds that may be achieved in the non-congestion periods, and the effects on emissions. SCOOT recognises congestion as someone sitting on the loop continuously for 4 seconds, this then increases congestion by one interval.

> *"The degree of congestion on a link is determined from the number of congested intervals each cycle. A detector has to be continuously occupied for the whole of a SCOOT interval (4 seconds) for one congested interval to be recorded."*

The model indicates that Links 17657SB, 37905, 28563EB, 28563WB and 37794WB could benefit from increased speeds by reducing congestion. However, the congested traffic does not appear to be sufficent on Links 28563EB and 37794EB for this aproach to be viable.

Further benefits may be achieved where speeds can be increased, although Links 18508WB and 18508EB are already predicted to be operating at the most efficient speed with regard to emissions.

Where speeds are increased, this may lead to increased traffic flow, with associated detrimental effects on emissions at the start or end of the link, and so a system of gating will be required to prevent additional traffic from entering the link.

The emissions on Link 17657NB may be reduced slightly (1-2%) if speeds are reduced by 80-85%.

Table 38 Change in NO_X Emissions vs. Change in Speed, 2020

	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%	105%	110%	115%	120%	125%	130%	135%	140%	145%	150%
18508WB	125%	119%	115%	111%	108%	105%	103%	101%	100%	100%	100%	101%	102%	105%	108%	112%	118%	124%	131%	139%	148%
18508EB	121%	115%	111%	108%	105%	102%	101%	100%	99%	99%	100%	102%	104%	108%	112%	118%	124%	132%	141%	150%	161%
37794WB	132%	127%	123%	119%	115%	112%	110%	107%	104%	102%	100%	98%	96%	94%	93%	91%	90%	88%	87%	85%	84%
28563WB	121%	117%	115%	112%	111%	109%	108%	106%	104%	102%	100%	98%	96%	95%	93%	92%	91%	89%	88%	87%	86%
28563EB	132%	127%	123%	119%	116%	112%	110%	107%	104%	102%	100%	98%	96%	94%	93%	91%	90%	88%	87%	86%	84%
37794EB	131%	127%	122%	119%	115%	112%	109%	107%	104%	102%	100%	98%	96%	94%	93%	91%	90%	88%	87%	86%	84%
46588	151%	141%	133%	127%	121%	117%	113%	109%	106%	103%	100%	97%	93%	90%	87%	85%	82%	80%	78%	76%	74%
46588	171%	159%	149%	140%	132%	125%	119%	114%	109%	104%	100%	96%	93%	90%	87%	84%	82%	79%	77%	75%	74%
37905	158%	149%	141%	133%	127%	121%	116%	111%	107%	103%	100%	97%	94%	91%	89%	87%	85%	83%	81%	80%	79%
17657NB	115%	111%	107%	104%	101%	99%	98%	98%	98%	98%	100%	102%	106%	110%	115%	122%	130%	139%	148%	159%	171%
17657SB	136%	130%	125%	121%	117%	114%	111%	108%	105%	102%	100%	98%	96%	94%	92%	90%	89%	88%	86%	85%	84%

Table 39 Change in NO_X Emissions with Increased Average Speed by Removing Congested Period

Loop ID	Road		Direction	Section	Period of congested conditions	Period of Congestion	Average Speed	Average Non-congestion Speed	Speed Ex. Congestion	Approx. NO_X Emission Reduction
N13251E	The Strand	17657NB	NB	St James - Brunswick	16%	0%	Slowing required			NA
N13251G	The Strand	17657SB	SB	Water - Brunswick	57%	5%	82.1	86.0	105%	2%
N31221G	Dale St	37905	WB	East of Stanley St	76%	6%	41.6	43.8	105%	3-6%
N14221A	New Islington	28563EB	EB	East of St Anne	48%	3%	28.3	29.0	103%	0-2%
N14221D	New Islington	28563WB	WB	Stafford - St Anne	60%	8%	12.2	13.0	106%	2-4%
N14234Q	New Islington	28563EB	EB	St Anne - Soho	3%	0%	Not viable			NA
N14284B	New Islington	37794EB	EB	Soho - Moss	27%	1%	Not viable			NA
N15183A	New Islington	37794WB	WB	Canterbury - Stafford	42%	1%	12.2	12.5	102%	0-2%

Green Infrastructure and Screening to Reduce Exposure

Studies outlined in Table 35 indicate the potential efficacy of various types of screening in reducing concentrations of NO_2.

It is understood that measures to reduce emissions are a priority; although where none can be found to bring forward compliance then alternative measures (such as Green infrastructure) may be considered to bring forward compliance.

Table 40 Studies into the efficacy of screening to reduce emissions

Study Name	Author	Date	Screen Type	% NO_2 Reduction
The impact of a green screen on concentrations of nitrogen dioxide at Bowes Primary School, Enfield	Anja H. Tremper and David C. Green Kings College, London	Jan 2018	Green Foliage	22-23

With reference to the data in Table 40, the effects at Bowring Park would be a significant reduction of roadside NO_2 concentrations. Whilst it is not appropriate to directly apply the results of the study to this area, it may be expected that a concentration between the projected baseline and the background (15.6 $\mu g/m^3$ in 2019 and 16.3 $\mu g/m^3$ in 2018) may be achieved with an appropriately designed barrier.

Further considerations may apply to such barriers, such as road safety and visibility, as well as the complex physical design of the barrier that would likely entail fluid dynamics modelling to ensure it was effective. The timescales would also be a factor, with consideration to the detailed design and construction time relative to the projected compliance year, as well as the planned improvements to the ‘Rocket’ junction.

Driver Training

Driver training has been shown in a number of studies to reduce fuel consumption by around 5%[9] and this is likely to in turn reduce NO_X emissions. Putting a measurable figure on it however is difficult as it depends on numerous factors such as terrain, weather and engine temperature. One study[10] estimates a reduction in emissions by 8% and showed that drivers

[9] Beusen, B., et al. (2009). Using on-board logging devices to study the longer-term impact of an eco-driving course. Transportation Research
Zarkadoula, M., Zoidis, G., & Tritopoulou, E. (2007). Training urban bus driver
pilot program. Transportation Research Part D, Volume 12 (pp. 449-541).
Part D: Transport and Environment, Volume 14, Issue 7, October 200 (pp. 514-520)
[10] Rolim et al (2014) Impacts of on-board devices and training on Light Duty Vehicle Driving Behaviour, Procedia - Social and Behavioural Sciences 111 (2014) 711 – 720

decreased the time spent in excessive speed and excessive engine speed by 24% and 38% respectively. A reduction in the number of events such as extreme accelerations and decelerations was also observed. The results indicated an average 4.8% fuel consumption decrease.

However, it should be noted that the study compared a control group and an experimental group and the control group were aware they were being monitored. This may mean that the control group would naturally look to increase the standard of driving as a result of the monitoring and so real world improvements could be even greater.

As such the study will take the 8% figure in terms of reduction in NO_X and apply that to driver training for bus drivers, as this is a significant fleet that is directly within the influence of the Council.

The effects of driver training were estimated to achieve an 8% reduction, which were modelled for buses. The emissions reductions predicted to be achieved are presented in Table 41.

The effects would be negligible on most links, but may achieve approx. a 7% reduction Lime Street, 5% on Dale Street and 1.5% on The Strand in 2020.

Table 41 Effects of Bus Driver Training

Area	Link	Residual Emissions After Reduction
Bowring	18508WB	99.1%
Bowring	18508EB	99.1%
Islington	37794WB	99.2%
Islington	28563WB	99.2%
Islington	28563EB	99.2%
Islington	37794EB	99.2%
Lime St	46588	92.7%
Lime St	46588	93.1%
Dale St	37905	95.2%
Strand	17657NB	98.8%
Strand	17657SB	98.5%

The effects of the bus driver training were modelled for link 18508 (A5080, Bowring Park Road) in 2018, 2019 and 2020 to determine if this may bring forwards compliance. The model results in Table 42 indicate that benefits would be achieved, but compliance would not be achieved sooner than 2019.

Table 42 Effects of Bus Driver Training at 18508 (A5080, Bowring Park Road)

Location	ID	2018		2019		2020	
		Projected	Adjusted	Projected	Adjusted	Projected	Adjusted

		T-NO2	**R-NOX**	**R-NOX**	**NO2**	**T-NO2**	**R-NOX**	**R-NOX**	**NO2**	**T-NO2**	**R-NOX**	**R-NOX**	**NO2**
Bowring WB	R 1	30.5	28.3	28.0	30.4	29.8	28.1	27.9	29.7	27.6	20.8	20.6	27.5
Bowring WB	R 2	30.7	28.7	28.5	30.6	30.0	28.6	28.3	29.9	27.8	21.2	21.1	27.7
Bowring WB	R 3	**40.2**	50.0	49.5	**40.0**	39.4	49.4	49.0	39.2	36.9	40.9	40.5	36.7
Bowring EB	R 4	**40.3**	50.1	49.7	**40.1**	39.4	49.5	49.1	39.2	36.8	40.7	40.3	36.6
Bowring EB	R 5	**42.0**	54.3	53.8	**41.8**	**41.1**	53.6	53.1	**40.9**	38.5	44.6	44.2	38.3
Bowring EB	R 6	33.9	35.7	35.3	33.8	33.1	35.4	35.0	33.0	30.8	27.5	27.3	30.7

Note: 0.9% Road-NO_X Emissions from Table 41.

The Liverpool City Centre Connectivity Programme

The Phase 1 upgrades to the city centre were included in the 2020 future scenario, and included the effects of:

- Creation of a new gateway into the city from Liverpool Lime Street Station
- Victoria Street and Tithebarn Street, introduction of a new cycle link between Lime Street and the Waterfront
- Brownlow Hill, introduction of a new cycle link from Liverpool Lime Street to the Knowledge Quarter
- City Bus Hub, a new bus layover with welfare facilities in Old Haymarket for buses leaving Queen Square bus station
- The Strand, improving links for pedestrians and cyclists between the city centre shopping areas and the waterfront leisure district by reassigning existing road space along The Strand

Discussion with the team leading the Phase1 works indicated that the real-world benefits on The Strand may not be recognised in the air quality model. The programme is expected to reduce periods of congestion and queuing, whilst maintaining a similar overall journey time, although the ADMS model does not recognise very short-period speed events such as congestion and queuing. The desk-study of congestion events in Table 39 indicates how this could be used to demonstrate additional beneficial effects.

The options screening concluded there would be no measures that could be implemented to reduce emissions from Road Link 18508 (Bowring Park Road) within the time-frame of the compliance dates. This is a link between a major junction and the Strategic Road Network, with a very large traffic flow, and so it is not viable to restrict access in such a way that may redistribute traffic on to alternative routes.

With regard to longer-term options, the ‘Rocket’ junction is proposed to undergo a significant realignment and reconstruction after 2020.

Summary

To achieve improvements to air quality could require a combination of measures on each link:

- Road Link 17657, A5036, The Strand. Bus driver training and speed optimisation.
- Road Link 18508, A5080, Bowring Park Road. Bus driver training would be beneficial, but no targeted measures were identified. Physical barriers and green infrastructure may warrant further assessment.
- Road Link 28563, A580, New Islington. Speed optimisation.
- Road Link 37794, A580, New Islington. Speed optimisation.
- Road Link 37905, A57 Dale Street. Bus driver training and speed optimisation.
- Road Link 46588, A5038, Lime Street. Bus driver training and speed optimisation.

It was noted there were few intervention that were successfully screened for link 18508 (Bowring Park Road), as this is a major through-route connecting to the Strategic Road Network. The connecting junction to the west of this link would be adversely affected by any of the UTMC interventions. It is planned to be substantially altered after 2020, which should be beneficial, although this is after the compliance date. Bus driver training would be beneficial on this link, but would not bring forwards compliance sooner than 2020.

The effects of physical barriers and green infrastructure were considered for link 18508 (Bowring Park Road). This would reduce exposure, also it is recognised that barriers would not be a ‘sustainable’ approach, as it is does not reduce emissions, but is based around interrupting the exposure pathway and so strategic measure may be more appropriate. This option would entail significant additional review and assessment of other considerations, such as road safety and visibility, as well as careful design to ensure effectiveness. The timescales would also be a factor, with consideration to the detailed design and construction time relative to the projected compliance year, as well as the planned improvements to the ‘Rocket’ junction.

The bus upgrade programme cannot be progressed sooner due to supply-chain and operational constraints.

Operating low-emission buses preferentially on Dale Street could achieve significant emissions reduction. However, the operational viability will be subject to agreement with the bus operators.

Further assessment and reviews will be undertaken:

- The Liverpool City Centre Connectivity Programme will also be reviewed further during the detailed design process to identify opportunities to maximise potentially beneficial air quality effects.
- Focussed modelling will be undertaken to support the design and implementation of the city-wide UTMC, whereby improvements to air quality will be balanced with journey times to achieve the most positive overall effects.

The model results in Table 43 and Table 44 indicate the effect on annual mean NO_2 that may be achieved at the receptor locations from bus driver training and speed optimisation.

The effects are presented as emission change in terms of Road-NO_X, resultant Total-NO_2 concentration and the change in Total-NO_2. Bus driver training clearly has greater benefits on road with high proportion of buses. Speed optimisation is feasible only on some links, and subject to further detailed study on others, although it should be noted (as discussed above) that the effects are likely to be under-estimated.

Table 43 Effects of Bus Driver Training on Annual Mean NO_2

Road	ID	2020 Annual Mean NO_2		Bus Driver Training			
		$T\text{-}NO_2$	$R\text{-}NO_X$	Emissions Change	$R\text{-}NO_X$	NO_2	NO_2 Reduction
Bowring WB	R1	27.6	20.8	99.1%	20.6	27.5	0.3%
Bowring WB	R2	27.8	21.2	99.1%	21.1	27.7	0.3%
Bowring WB	R3	36.9	40.9	99.1%	40.5	36.7	0.4%
Bowring EB	R4	36.8	40.7	99.1%	40.3	36.6	0.4%
Bowring EB	R5	38.5	44.6	99.1%	44.2	38.3	0.4%
Bowring EB	R6	30.8	27.5	99.1%	27.3	30.7	0.4%
Islington WB	R7	29.2	10.1	99.2%	10.0	29.2	0.1%
Islington WB	R8	28.7	9.0	99.2%	8.9	28.6	0.1%
Islington WB	R9	29.8	11.3	99.2%	11.2	29.8	0.1%
Islington EB	R10	30.7	13.2	99.2%	13.1	30.7	0.2%
Islington EB	R11	32.4	16.6	99.2%	16.5	32.3	0.2%
Islington EB	R12	31.0	25.6	99.2%	25.4	30.9	0.3%
Lime Street SB	R13	27.2	6.1	93.1%	5.7	27.0	0.8%
Lime Street SB	R14	27.3	6.2	93.1%	5.8	27.0	0.8%
Lime Street NB	R15	31.3	16.4	93.1%	15.3	30.8	1.7%
Lime Street NB	R16	28.3	8.2	93.1%	7.6	28.0	1.0%
Dale Street S Side	R17	34.0	22.1	95.2%	21.0	33.5	1.4%
Dale Street N Side	R18	35.4	25.0	95.2%	23.8	34.8	1.6%
The Strand SB	R19	36.7	27.9	98.8%	27.6	36.5	0.4%
The Strand SB	R20	34.3	22.8	98.8%	22.5	34.2	0.4%
The Strand NB	R21	36.3	27.2	98.8%	26.8	36.2	0.4%
The Strand NB	R22	32.8	33.7	98.8%	33.3	32.6	0.5%

Note: Also see Table 42 for effects of bus driver training at 18508 (A5080, Bowring Park Road).

Table 44 Effects of Speed Optimisation on Annual Mean NO_2

Road	ID	2020 Annual Mean NO_2		Speed Optimisation			
		$T\text{-}NO_2$	$R\text{-}NO_X$	Emissions Change	$R\text{-}NO_X$	NO_2	NO_2 Reduction
Bowring WB	R1	27.6	20.8	Speed prioritisation not feasible			
Bowring WB	R2	27.8	21.2	Speed prioritisation not feasible			
Bowring WB	R3	36.9	40.9	Speed prioritisation not feasible			
Bowring EB	R4	36.8	40.7	Speed prioritisation not feasible			
Bowring EB	R5	38.5	44.6	Speed prioritisation not feasible			
Bowring EB	R6	30.8	27.5	Speed prioritisation not feasible			
Islington WB	R7	29.2	10.1	98.0%	9.9	29.1	0.3%
Islington WB	R8	28.7	9.0	98.0%	8.8	28.6	0.3%
Islington WB	R9	29.8	11.3	98.0%	11.1	29.7	0.4%
Islington EB	R10	30.7	13.2	98.0%	12.9	30.6	0.4%
Islington EB	R11	32.4	16.6	98.0%	16.3	32.2	0.5%
Islington EB	R12	31.0	25.6	98.0%	25.1	30.7	0.8%
Lime Street SB	R13	27.2	6.1	Further study to be undertaken			
Lime Street SB	R14	27.3	6.2	Further study to be undertaken			
Lime Street NB	R15	31.3	16.4	Further study to be undertaken			
Lime Street NB	R16	28.3	8.2	Further study to be undertaken			
Dale Street S Side	R17	34.0	22.1	95.0%	21.0	33.5	1.5%
Dale Street N Side	R18	35.4	25.0	95.0%	23.8	34.8	1.6%
The Strand SB	R19	36.7	27.9	98.0%	27.4	36.4	0.7%
The Strand SB	R20	34.3	22.8	98.0%	22.3	34.1	0.6%
The Strand NB	R21	36.3	27.2	Further study to be undertaken			

The Strand NB	R22	32.8	33.7	Further study to be undertaken

Part 5: Setting out a preferred option

The detailed modelling has indicated that the road links identified by the PCM modelling will be compliant no later than 2018, with the exception of Bowring Park Road which is projected to be compliant in 2020

However, due to potential uncertainties about future conditions, Liverpool City Council have committed to implementing the following measures that have be evidenced as beneficial for air quality:

- Bus driver training
- Speed optimisation
- Considering the viability of installing green infrastructure and screening

These measures will have specific benefits in the areas of compliance, but will also achieve wider benefits across the region, and will align with complementary policies and aspirations for development growth.

5.1 Driver Training Secondary Critical Success Factors

The secondary critical success factors for the bus driver training are as follows.

Value for money

Measuring the impact of driver training is difficult as it depends on myriad factors such as terrain, weather and engine temperature. One study estimates a reduction in emissions by eight percent and showed that drivers decreased the time spent in excessive speed and excessive engine speed by 24 percent and 38 percent respectively. A reduction in the number of events such as extreme accelerations and decelerations was also observed.

The results also indicated an average 4.8% fuel consumption decrease, and so the potential costs of additional training are likely to be recovered though efficiency savings.

Affordability

Some costs of driver training have been estimated at £50 for a 90 minute course or £100 for a day in terms of direct costs. However businesses will have to account for both the cost of the driver being on the training rather than in work as well as the cost of a vehicle for the day in some cases.

Distributional impacts

The periodic training of drivers, potentially alongside the use of telematics has been demonstrated to reduce incidents of harsh braking and acceleration, idling and access speed as well as improving road safety. All of these help to improve congestion and have a further benefit to the drivers/operators by reducing fuel usage and therefore costs. Therefore, thus intervention is likely to impact positively on all road users.

Strategic and wider air quality fit

This intervention aligns with local and regional aspirations, as it aids in reducing NOx emissions in specific problems areas (e.g. congested roads).

Supply side capacity and capability

One of the potential outcomes from this intervention is easing congestion which can aid in improving capacity on high demand roads during peak times. There are large numbers of driver training organisations able to undertake said training but engagement with businesses is required in order to get drivers signed up.

Achievability

The reference study compared a control group and an experimental group and the control group were aware they were being monitored. This may mean that the control group would naturally look to increase the standard of driving as a result of the monitoring and so real world improvements could be even greater.

Training schemes are relatively low cost and can be quickly delivered but they are most effective with the cooperation of vehicle operators freeing up both drivers and vehicles for the training to take place. However, businesses are unlikely to want to release too many staff to undertake the training at once and so his may take a number of months to get everyone through depending on the size of the workforce.

Displacement on other roads

No displacement is expected as a result of this intervention.

5.2 Speed Optimisation Secondary Critical Success Factors

The secondary critical success factors for the speed optimisation are as follows.

Value for money

We are estimating the impact of any traffic signal optimisation could achieve up to 1.6% emissions reduction on Dale Street. However, potential reduction in journey time/delay may draw an increase in demand which will have a negative impact on air quality and congestion on the road link and its feeder roads. Therefore, gating must also be implemented as part of this intervention which is assumed to prevent additional traffic from entering the road link from side roads. In the longer term changes to road design that limit capacity

We have also assumed that optimisation will smooth the flow, reducing incidents of particularly high speed and low speed, effectively narrowing the distribution towards the centre and thus reducing stop/start or accelerating/decelerating traffic, without greatly increasing the overall average speed and therefore reducing emissions as a result.

Affordability

No direct cost estimates are available at this stage for this option, although costs in the range of between £5,000 and £25,000 per intersection could be expected. Some existing signals can be electronically controlled while others will require system upgrades and additional infrastructure.

Validation is a time hungry exercise and is a specialist skill to complete to a high standard. Consultants are available to come in and carry out the validation, which could benefit as training for LCC staff to use on other links in the City. Rates for consultants vary from firm to firm and the number of sites involved, and so further specification will be required to refine these costs.

Distributional impacts

Signal optimisation will impact on all road users however local road users are likely to incur the greatest dis-benefits as a result of gating on minor roads. Active travel may be slightly discouraged if traffic flow/speeds are improved on the mainline carriageway

Strategic and wider air quality fit

The dynamic aspect of this intervention, and the way it links key junctions and routes will ensure the longevity of this intervention and allow it to be more adaptable to changing traffic demand into the future.

Supply side capacity and capability

Where road capacity is made available through successful implementation of the UTMC, it could be utilised for alternative transport such as greater levels of walking/cycling provision. However, installation/repair of the loops as well as validation of the system is critical to improve performance on the links that have been raised as non-compliant.

Issues may arise as to the condition of the road when trying to install/repair loops; the condition of the highway will have an effect on the performance/longevity of these loops, although alternative types of detection may be used to avoid this issue.

At this stage there may not be sufficient labour resources to ensure commitment to carrying out validation, fault finding, etc., and so additional resourcing will be required.

Achievability

The Council operate a UTMC, and so there is significant potential to install additional timing loops and integrate additional junctions and signals into the control model.

The main constraint to implementing this intervention is access to the funds required, though a review as well as some manual interventions could be easily completed in the extreme short term.

Displacement on other roads

An assumption that roads feeding into and out of targeted road links will be gated to avoid any increase in traffic on associated roads is part of this intervention. This could redistribute come emissions over a wider area but reduce concentration of vehicles on the link in exceedance. It may also encourage traffic to divert onto more local roads and "rat run" in order to avoid delays accessing the link, or that congestion may occur at the start or end of the link and further revisions to the UTMC may be required.

5.3 Green Infrastructure and Screening to Reduce Exposure

The secondary critical success factors for green infrastructure and screening are as follows. Based on this summary, it is proposed that screening will not be taken forwards as it does not reduce emissions, and as such it is not a sustainable approach that aligns with the LCC strategic objectives. Furthermore, it is not considered that such a precedent would represent an acceptable example in terms of local air quality management.

Value for money

The design and construction of the barriers would not provide any additional or long-term benefits, and so would provide minimal value beyond the short-term reduction of roadside exposure. The effects would need to be considered with regards to the actual health impacts and reduction in exposure, as the affected area are footpaths that are unlikely to be heavily trafficked.

Affordability

No direct cost estimates are available at this stage for this option, although it will require complex fluid dynamic modelling to ensure the design is effective as well as direct construction costs. It is therefore likely that costs would be significantly greater than £100,000.

Distributional impacts

No distribution impacts will occur.

Strategic and wider air quality fit

The barrier option would not be sustainable or support long-term strategic measure to reduce emissions and improve air quality in the region. It would also represent an example for other potential hot-spots and viewed as a viable policy option.

Supply side capacity and capability

There are a number of suppliers for the type of barrier that may potentially be installed, although it would require close liaison and design with key stakeholders to ensure it was practical, feasible and effective.

Achievability

The achievability of physical barriers would be subject to the availability of funding, and the necessary timescales to design and install the infrastructure, within the framework of the projected compliance dates and proposed junction improvements. Therefore, a significant amount of detailed work will be required to determine if this approach may be feasible.

Displacement on other roads

No displacement impacts will occur.

Liverpool City Centre Connectivity Programme

The Liverpool City Centre Connectivity Programme is due to start work on The Strand in Autumn 2018, which will also affect Dale Street, whilst work on Lime Street is due to start in 2019. This will alter the short-term projections whilst the work is ongoing, but will also enable opportunities to integrate measures into the final design to benefit air quality and reduce emissions.

Conclusions

The feasibility study has used local air quality modelling to determine that the roads identified by the Defra PCM will be compliant no later than 2018, except for A5080, Bowring Park Road (road link 18508), which will be compliant in 2020.

It was recognised that quite substantial drops in NO_2 concentrations were predicted from 2017 to 2018. The model used the relevant EFT emissions profile and Defra background concentrations, and so these changes were a result of the model outputs.

No feasible emission reduction methods have been identified that would effectively reduce emissions on Bowring Park as this is a major through-route connecting to the Strategic Road Network, and the connecting junction to the west of this link would be adversely affected by any of the potential UTMC interventions.

Physical barriers have been considered at link 18508, although there are a number of additional constraints that must be considered before determining if this may be a viable option, such as funding, timescales, political support and strategic sustainability. Therefore, it is proposed that screening will not be taken forwards as it does not reduce emissions, and as such it is not a sustainable approach that aligns with the LCC strategic objectives, and it is not considered that such a precedent would represent an acceptable example in terms of local air quality management.

The study has also screened potential interventions to further reduce NO_X emissions and reduce roadside NO_2 concentrations, and has identified measures that may be implemented. However, significant constraints were related to the timescales and investment required to implement short-term interventions, whilst potentially more significant benefits may be realised across a wider area where long-term policy and strategic interventions could be implemented.

Therefore, whilst there is a recognised need to mitigate the effects of air pollution on public health, it illustrates the case for a focus on policies that prevent the emissions in the first place rather than looking to reduce them retrospectively. Furthermore, given the immediacy of the interventions required, as well as the need to demonstrate impacts on specific links rather than over a wider region, this greatly limits the possible interventions available and discounts a lot of the work already completed, or being undertaken, by LCC and the Combined Authority to reduce emissions since the PCM model was created in 2015. The Combined Authority has recently completed a preliminary study to improve air quality across the Liverpool City Region, rather than solely on specific links. By taking this integrated approach, alternative and integrated transport become much more effective and it enables longer term, strategic interventions to be evaluated and to tie in with other initiatives. This would therefore be the logical next step to further reduce emissions.

Part 6: Further local data

In response to the Council having further local data that showed a more persistent exceedance in a number of areas in Liverpool City Council, further modelling was carried out to assess the scale of the problem. This is set out in this section of the study.

Part a: Understanding the problem

Reference is made to documentation published by Defra relating to the exceedances, Draft Air Quality Interventions Feasibility Study undertaken in 2018 on behalf of Merseytravel and the Combined Authority[11], and the Council's statutory reports compiled in fulfilment of its Local Air Quality Management (LAQM) obligations. It also draws upon traffic count information sourced from LCC's own traffic count data and the Department for Transport (DfT).

Parts 1 to 5 of the Targeted Feasibility Study above recognised there may be locations outside those identified by the PCM where the annual mean NO_2 objective may be exceeded.

Therefore, this section of the study represents a further part of the work based on model domains subjectively prioritised based on a review of local air quality monitoring in Liverpool. This study considers the projected annual mean NO_2 concentrations near the following areas:

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[11] Merseytravel (2018), Draft Air Quality Interventions Feasibility Study

- A562, Smithdown Road
- A5080, Edge Lane Drive
- A5098 Walton Vale
- A561 Speke Road

Baseline Air Quality Monitoring

The Council undertake air quality monitoring at key locations throughout the district that have previously been identified as potential areas of concern with regard to air quality.

The Air Quality monitoring is undertaken using a network of passive NO_2 diffusion tubes. The data presented in Table 46 indicates a decreasing overall trend in annual mean NO_2 concentrations since 2016, but concentrations remain above the EU Limit Value at some locations.

The Air Quality monitoring is undertaken using a network of passive NO_2 diffusion tubes. The data presented in Table 46 shows the monitored annual mean NO2 concentrations in selected areas, whilst data for monitoring undertaken across the city is presented in **Error! Reference source not found.** in Annex 2.

It is recognised that annual mean NO_2 concentrations throughout the City were substantially lower in 2017 than in previous years. The reason for this is not currently understood, although the QA/QC procedures have been reviewed and indicated that the data is correct.

Table 4545 LCC Air Quality Monitoring in Modelled Domains

ID	Location	Grid Ref		Model Domain	Annual Mean NO_2 Concentration, µg/m³					
		X	Y		2012	2013	2014	2015	2016	2017
S59	Smithdown Road Lamp outside Costcutter	338170	388629	A562, Smithdown Road	67	61	58	66	52	43
S60	Smithdown Road info sign outside Sefton Pk pharmacy	337881	388939		63	58	54	59	52	40
S62	Smithdown Road Info sign by Howard Jenkins funerals nr jct with lodge lane	337003	389459		58	55	54	60	50	48
S47	Edge Lane/Rathbone Rd Junc Lamp Post	339023	390715	A5080, Edge Lane Drive				54	56	38
S48	St Oswald St/Paraffin Oil Shop Tlight L13	339149	390762		71	70	68	68	64	46
S49	Edge Lane Drive/Mill Ln L8047 Cent Resvtn	339380	390645		72	68	66	65	63	50
N67	Middle Walton Vale-Pedestrian crossing	336375	396687	A5098 Walton Vale	77	72	68	71	67	49
N68	Lamp post J 3268 outside 324-328 Rice Lane L9	336216	396165					51	48	37
S55	Speke Rd 1st Dual Pelican Cross 2672/2673	340959	384247	A561 Speke Road	71	71	63	64	61	48

Automatic air quality monitoring is undertaken by Defra as part of the Automatic Urban and Rural Network (AURN) at one site: Liverpool Speke. This site is in proximity to an industrial area and the John Lennon Liverpool Airport, and is within approximately 50m of Speke Boulevard[12].

An AURN site at Queens Drive was closed in November 2016.

These sites are not in proximity to the model domains in this report, although the data has

[12] https://uk-air.defra.gov.uk/networks/site-info?uka_id=UKA00247

been presented in 46 to indicate the regional trends. It is important to note the lower NO2 concentration in 2017 compared with previous years, corroborating the drop measured by the diffusion tube network.

Table 46. Defra Air Quality Monitoring

Location	Pollutant	Grid Ref		Annual Mean NO_2 Concentration, mg/m3					
		X	Y	2012	2013	2014	2015	2016	2017
Liverpool Speke (Urban Background)	NO_2	343887	383603	25	23	25	22	23	18
	PM_{10}			13	14	14	14	15	11
	$PM_{2.5}$			8	9	8	7	7	3
	O_3			47	48	46	49	43	49
	SO_2			3	3	3	2	2	2
Liverpool Queen's Drive (Closed) (Roadside)	NO_2	336172	394896	30	34	34	22	23	-

Air Quality Modelling

Background Pollutant Sources

For any modelling exercise the ideal situation is to estimate emissions from all known sources (road, rail, industry etc.). In practice, information will only be available for those sources under the spot light. In this case it's the road traffic component. Under these circumstances all other sources are collectively considered to be a background element. The concentrations calculated by the model due to vehicle emissions are therefore added to these background concentrations to give the total concentration.

The annual mean background pollutant concentration used in this assessment were modelled estimations provided by Defra (Defra, 2018)[13], who provide values for the centre point of each 1 km by 1 km grid square in the UK, for each year between 2015 and 2030.

[13] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

Estimated average background concentrations for the Ordnance Survey grid squares containing the modelled receptors were downloaded in August 2018.

Pollutants of Concern

NO_2 and nitric oxide (NO) are both oxides of nitrogen, and are collectively referred to as NO_X. All combustion processes produce NO_X emissions, largely in the form of NO, which is then converted to NO_2, mainly as a result of its reaction with ozone in the atmosphere. Therefore the ratio of NO_2 to NO is primarily dependent on the concentration of ozone and the distance from the emission source.

The Government and the Devolved Administrations adopted two Air Quality Objectives for nitrogen dioxide (NO_2) which were to be achieved by the end of 2005. In 2010, mandatory EU air quality limit values on pollutant concentrations were to apply, although it continues to be breached in locations throughout the UK. The EU limit values for NO_2 in relation to human health are the same as the national objectives (Defra, 2007):

- An annual mean concentration of 40 µg/m^3 (micrograms per metre cubed); and
- An hourly mean concentration of 200 µg/m^3, to be exceeded no more than 18 times per year (99.79th percentile).

For the purposes of this study it is necessary to convert the NO_2 concentrations to NO_X, as the relationship between NO_2/NO_X is not linear, and also varies depending on region and year.

The emissions from road traffic are presented as R-NO_X, which excludes non-road sources, such as background emissions (see above). This is an essential calculation step to determine the required emissions reduction required for each component of the traffic.

Liverpool City Transport Model

The traffic data used in the model was from the Liverpool City Transport Model, using the local growth scenario that includes significant local developments and; approximately a 28% increase in vehicle km for the period 2012-2030 includes the predicted effects of major transport schemes in the City. The local growth scenario was considered to be most representative of the likely traffic growth in the region.

The traffic model output provided predicted traffic flows for 2015, 2020 and 2030.

The traffic flows for 2015 were used for the 2017 baseline air quality modelling, as this was the best data available, and which informed the model verification. The traffic flow data for 2020 and 2030 were used to model the respective future years, and the resultant NO2 concentrations were interpolated for the intervening years.

Converting NO_X and NO_2 Emissions to Concentrations

The modelled Road-NO_X concentrations where converted into Total-NO_2 using version 6.1 of the NO_X to NO_2 calculator.

Meterological Data

Meteorological data was obtained from the Liverpool Speke airport meteorological recording site for the year 2017.

Model Domains

A562, Smithdown Road

The A562 model domain includes two NO_2 diffusion tube sites that have recorded high annual mean concentrations; S48 and S49. This is a major east-west route linking the centre of Liverpool to the M62 motorway, and also links to the 'Rocket' junction and Bowring Park Road, which was identified as a PCM exceedance link.

The road passes through a predominantly residential area.

The required reduction of R-NO_X was calculated with reference to the nearest air quality monitoring undertaken by LCC (47), taking account of the last three years of monitoring.

Table 47. Emissions Reduction Required to Achieve Objective

	NO2			**Background NO2**			**R-NOX**			**R-NOX Required Reduction**		
ID	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**	**2015**	**2016**	**2017**
S47	54	56	38	17.6	17.1	16.1	82.57	89.19	44.65	42%	45%	-13%
S48	68	64	46	17.6	17.1	16.1	125.03	113.41	65.2	62%	57%	23%
S49	65	63	50	17.6	17.1	16.1	115.83	110.43	75.53	59%	56%	33%

A5080, Edge Lane Drive

The A5080 model domain includes one NO_2 diffusion tube sites that has recorded high annual mean concentrations; S59, S60 and S62. This is a busy road linking the Speke area to central Liverpool, and is an alternative to the southern route whilst also linking to the

A5058 ring road and the M62 to the north.

The road passes through a predominantly residential area, including parkland and commercial sites.

The road is characterised by congestion at peak hours, although it is also busy throughout the day.

The required reduction of R-NO_X was calculated with reference to the nearest air quality monitoring undertaken by LCC (48), taking account of the last three years of monitoring

Table 48. Emissions Reduction Required to Achieve Objective

ID	NO2			Background NO2			R-NOX			R-NOX Required Reduction		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
S59	66	52	43	16.3	15.8	14.9	122.08	82.1	60.31	59%	37%	12%
S60	59	52	40	16.0	15.5	14.7	101.97	82.76	53.47	50%	37%	0%
S62	60	50	48	17.3	16.8	15.9	101.58	74.41	70.8	52%	34%	28%

<u>A5098, Walton Vale</u>

The A5098 model domain includes two diffusion tube sites that has recorded high annual mean concentrations; N67 and N68. .

The road passes through a mixed residential and industrial area.

The required reduction of R-NO_X was calculated with reference to the nearest air quality monitoring undertaken by LCC (49), taking account of the last three years of monitoring.

Table 49. Emissions Reduction Required to Achieve Objective

ID	NO2			Background NO2			R-NOX			R-NOX Required Reduction		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
N67	71	67	49	15.6	15.3	14.6	139.41	126.89	76.34	63%	59%	30%
N68	51	48	38	15.6	15.3	14.6	80.97	73.02	48.53	36%	28%	-11%

<u>A561, Speke Road</u>

The A561 is the main road link from Widnes and the Mersey Gateway Bridge into the south of Liverpool.

The road passes through a mixed residential and commercial area.

The required reduction of R-NO_X was calculated with reference to the nearest air quality monitoring undertaken by LCC (50), taking account of the last three years of monitoring.

Table 50. Emissions Reduction Required to Achieve Objective

ID	NO2			Background NO2			R-NOX			R-NOX Required Reduction		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
S55	64	61	48	19.5	19.2	18.5	108.08	99.26	65.03	60%	56%	30%

Future baseline

Detailed dispersion modelling was undertaken for the compliance links using data from the LCC Transport Model, based on a 2017 baseline year, and a 2020 and 2030 future years.

The concentrations were interpolated between 2020 and 2030 to determine the compliance year.

Model Verification

The model was verified using the nearest passive diffusion tube monitoring data to each model domain. The factors applied to the model were:

- A562, Smithdown Road, verified with S59, S60a and S62, factor x6.7
- A5080, Edge Lane Drive, verified with S47, S48 and S49, factor x2.8
- A5098 Walton Vale, verified with N67 and N68, factor x4.8
- A561 Speke Road, verified with S55, factor x8.3

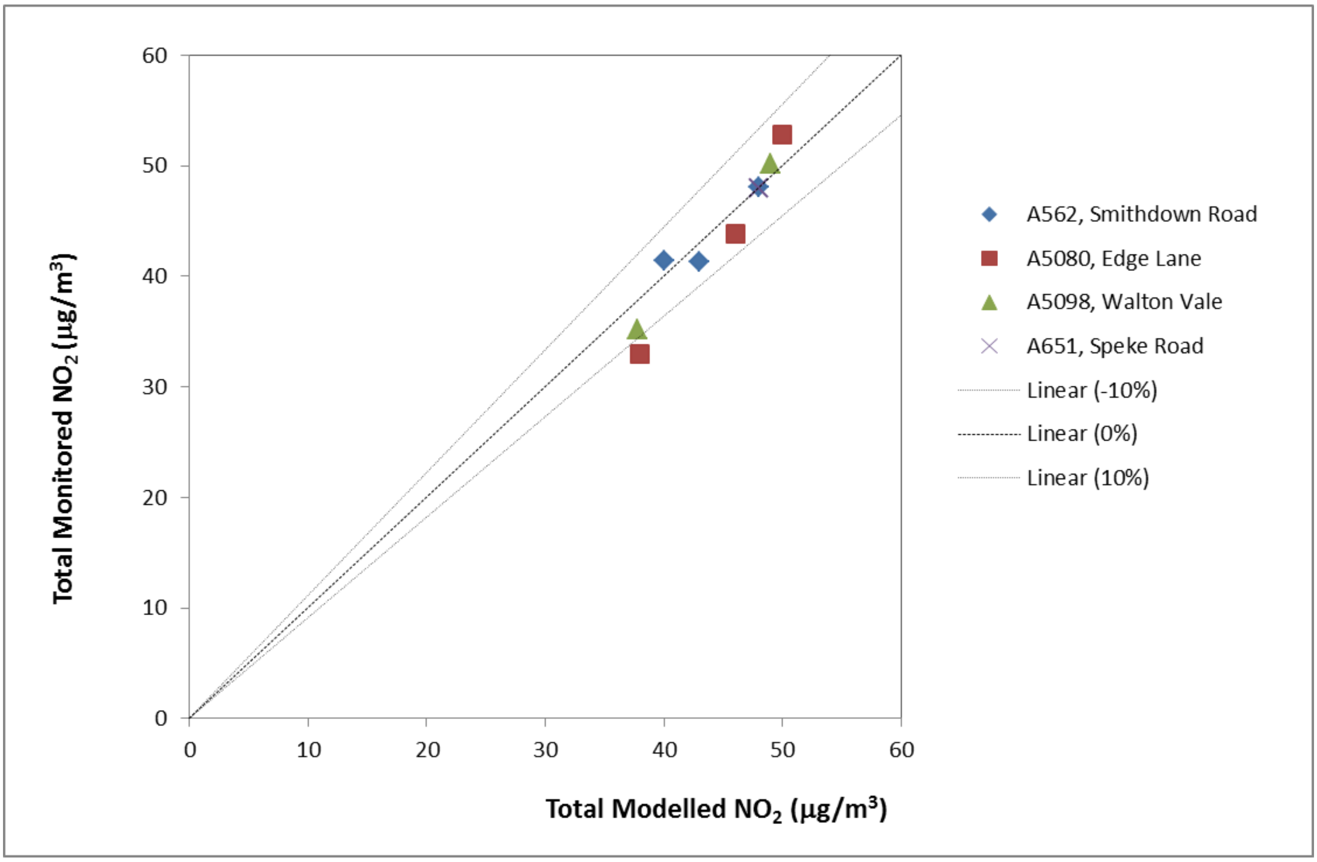
The adjusted NO_2 concentrations were within 13% of the monitored concentrations for all sites, with an overall RMSE of 2.38. The verification data are presented in Table 51 and Table 45, and indicate a reasonable correlation between the modelled and monitoring data in the baseline.

The relatively high adjustment factor (for some of the domains) is hypothesised to indicate localised hot-spots, but also discrepancy between the actual and nominal fleet composition used in the model. There is also congestion and queuing on the many of the major routes, due to high numbers of vehicles and traffic-light-controlled junctions; although due to the timescales available to undertake the modelling it was not possible to incorporate this emission component.

Table 51 Model Verification, 2017

ID	Background NO_2	Before Adjustment	Monitored		Adjusted		
		Mod R-NO_X	Meas NO_2	Meas R-NO_X	Mod NO_X	Adjustment Factor	% Mod / Meas
S59	18.4	18.4	43	52.7	48.7	6.7414	-4%
S60	17.2	17.2	40	48.1	51.6	6.7414	4%
S62	19.3	19.3	48	63.1	63.3	6.7414	0%
S47	20.9	20.9	38	35.7	24.6	2.8264	-13%
S48	20.9	20.9	46	54.7	49.5	2.8264	-5%
S49	20.9	20.9	50	64.8	72.1	2.8264	6%
N67	18.0	18.0	49	68.6	71.6	4.7777	2%
N68	18.0	18.0	38	41.3	35.3	4.7777	-7%
S55	21.4	21.4	48	58.5	58.4	8.2931	0%

Figure 17Model Verification Adjustment Plot for Model Domains



Modelled Annual Mean NO_2 Concentrations

Modelled Receptor Locations

The modelled receptor locations are shown in the appendix. The receptors were located at 10m intervals 4m from the kerb, and >25m from a major junction.

Local air quality monitoring locations were used to verify each of the model domains.

The detail shown in Annex 2 demonstrates that the receptors in some locations, namely parts of Walton Vale and Smithdown Road where the façade of the properties is closer to the carriageway than 4m. In these cases, the annual mean NO_2 concentrations will be potentially higher at the properties than predicted at the modelled receptor locations.

Projected Baseline

The maximum roadside annual mean NO_2 concentrations are provided in 52, and interpolated between 2020 to 2030 to determine the projected compliance year (concentrations beyond the compliance year are not presented).

Plot of the modelled receptor locations are provided in the Air Quality Modelling Tracking Table (AQ1).

It was recognised that quite substantial drops in NO_2 concentrations were predicted from year-on-year. The model used the nominal EFT emissions profile and Defra background concentrations for each year, and which are predicted to improve in the future at a rate exceeding the adverse effects of the growth projections of the transport model.

The maximum annual mean NO_2 concentration predicted in each model domain is provided in 52. The predicted compliance year for each model domain is:

- A562, Smithdown Road, compliance year 2025. Highest concentrations to the east of the junction with A5089, Ullet Road
- A5080, Edge Lane Drive, compliance year <2020. Highest concentrations opposite S47, to the west of the B5179 gyratory.
- A5098 Walton Vale, compliance year <2020. Highest concentrations near the N67 monitoring location, near the minor junction with Grace Road.
- A561 Speke Road, compliance year 2026. Highest concentrations to the east of the junction with B5171, Horrocks Avenue.

It should be noted that that the adjustment factor applied to the Speke Road model domain was relatively high, although this was based on a single tube location. Furthermore, this location recorded a significantly lower annual mean concentration in 2017 (the model verification year), and so the situation in this model domain is likely to be highly complex. However, the compliance year of 2026 projected in this study indicates that it is highly likely that high concentrations will occur beyond 2021 even if a lower adjustment were applied.

It should also be noted that the building facades are closer than 4m to the kerb in some locations, and so the actual annual mean NO_2 will be higher than predicted where this occurs. This is specifically significant at Smithdown Road, where high annual mean NO_2 concentrations were predicted at 4m from the kerbside. This means that higher concentrations will occur at the actual façade locations. Whereas for A5098 Walton Vale, where concentrations are lower and the compliance year is earlier than 2020, the closeness of the facades to the road suggests that compliance at the actual facades may not be achieved by 2020.

Table 52 Maximum Roadside NO_2 Concentrations in Each Domain

Model Domain	Predicted Annual Mean NO_2						
	2020	2021	2022	2023	2024	2025	2026
A5098 Walton Vale	38.1	36.5	34.9	33.4	31.9	30.4	29.0
A5080, Edge Lane Drive	33.8	32.2	30.6	29.2	27.8	26.5	25.3
A562, Smithdown Road	48.8	46.7	44.6	42.6	40.7	38.7	36.8
A561 Speke Road	48.3	46.7	45.1	43.6	42.0	40.5	39.1

Conclusions

Parts 1 to 5 above used local air quality modelling to determine that the roads identified by the Defra PCM will be compliant no later than 2018, except for A5080, Bowring Park Road (road link 18508), which will be compliant in 2020.

In part 6 of the study, further modelling was undertaken based on four domains where local air quality monitoring undertaken by LCC has indicated that annual mean NO_2 could exceed the objective beyond 2021.

The modelling confirmed that two of the modelled domains would most likely not be compliant until 2025-2026. (A562 Smithdown Road, and A561 Speke Road), but that two would most likely be compliant by 2020 (A5098 Walton Vale, and A5080, Edge Lane Drive). However, building facades are closer than 4m to the kerb in some locations, including A5098 Walton Vale, and so the actual annual mean NO_2 will be higher than predicted where this occurs.

Furthermore, it is recognised that annual mean NO_2 concentrations throughout the City were substantially lower in 2017 than in previous years, and whilst these locations were selected subjectively based on the timescales available to undertake this report, it is considered that other locations in the City may also continue to exceed the compliance thresholds beyond 2021.

Therefore, LCC has committed to undertaking a detailed review of air quality throughout the city in order to identify all locations that may exceed the annual mean objective now and in the future. This study will be used to inform appropriate measures to improve air quality that may be implemented on a regional, strategic level, and on a local, targeted level.

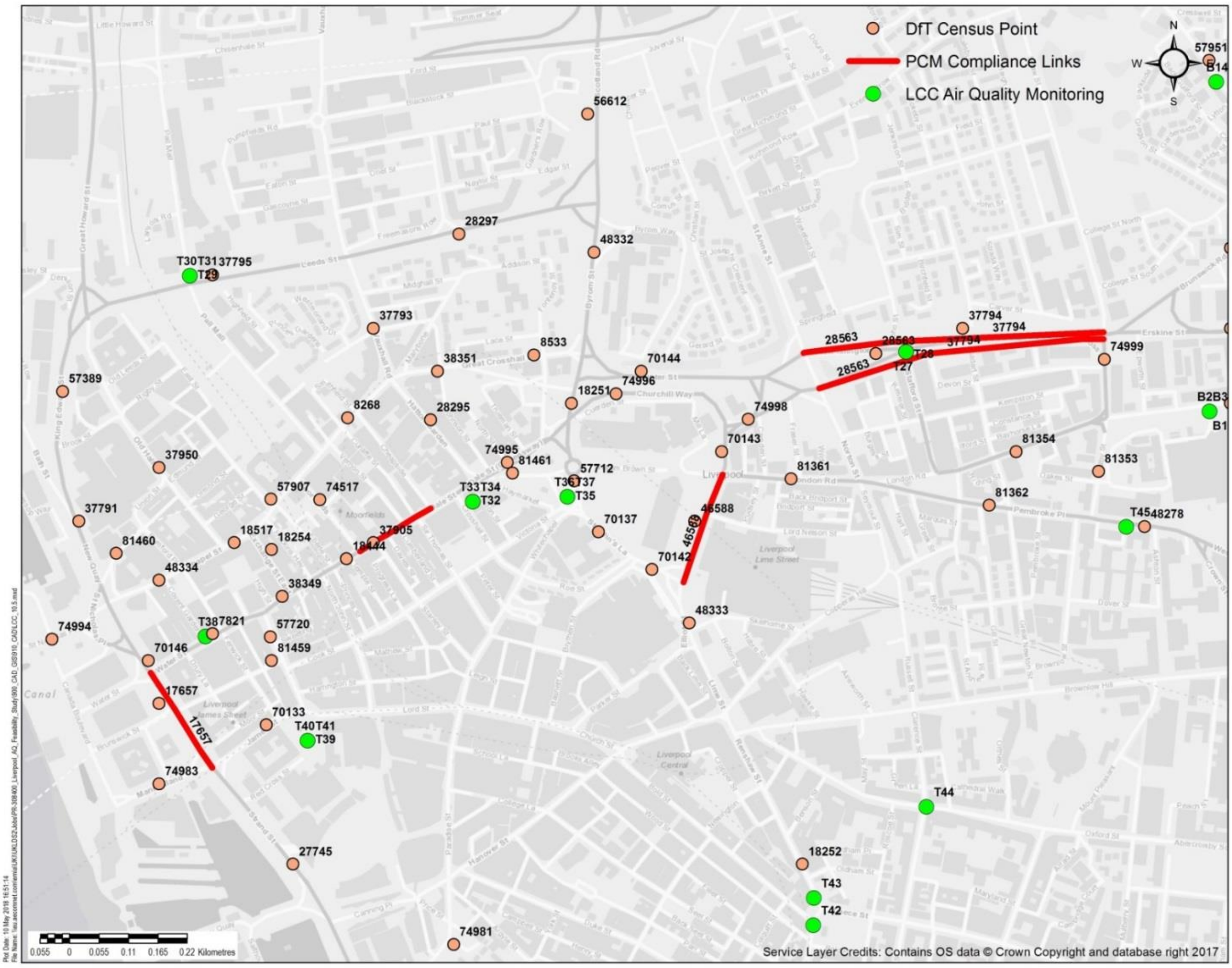
Annex 1: Air quality monitoring data used for calibration in parts 1 to 5 of the study

LCC Air Quality Monitoring Near Exceedance Links

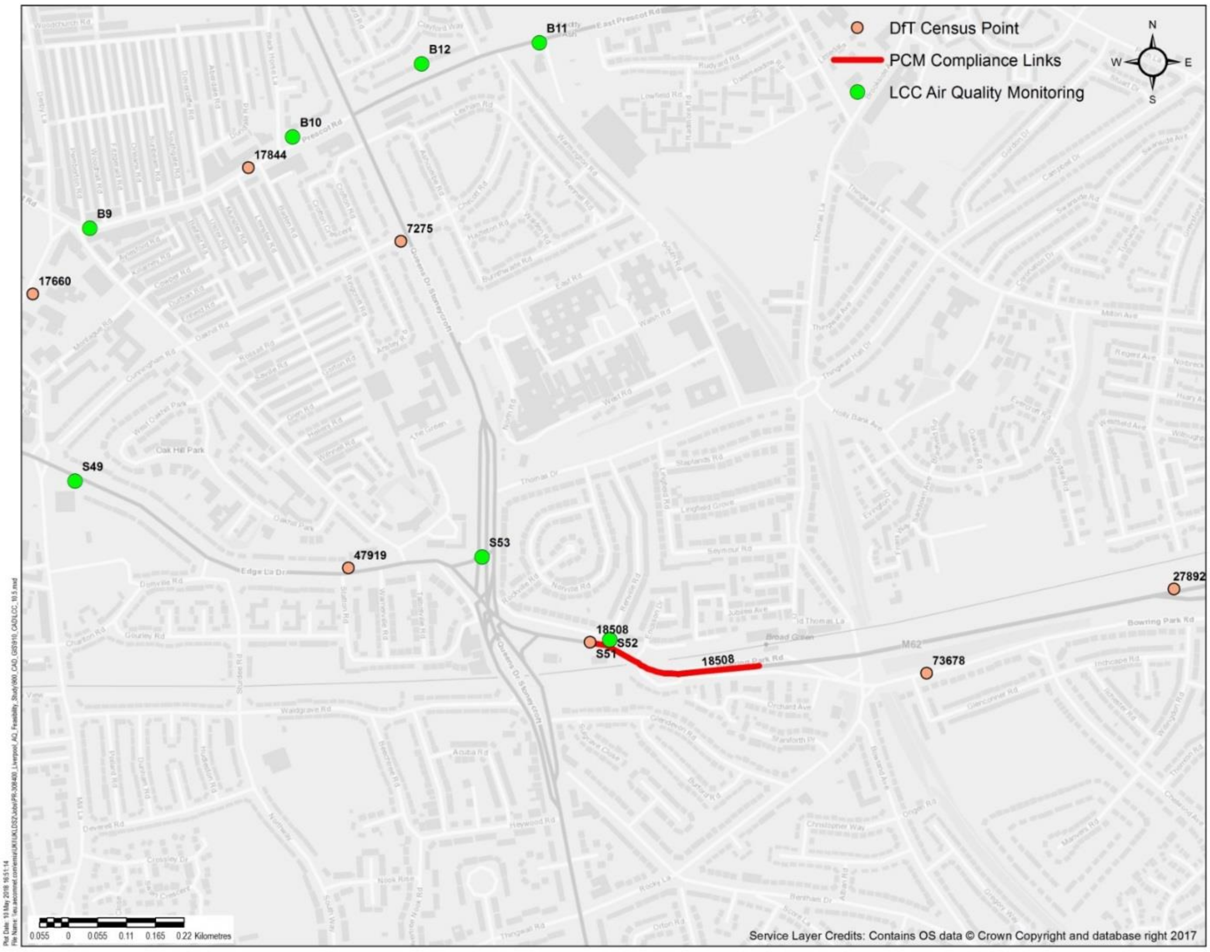
ID	Location	Grid Ref		Compliance Link	Annual Mean NO_2 Concentration, µg/m^3				
		X	Y		2012	2013	2014	2015	2016
T26	Islington AQ Station Traffic Lights	335394	390956	New Islington	49	45	46	50	42
T27	Islington AQ Station Traffic Lights	335394	390956	New Islington	48	47	46	46	41
T28	Islington AQ Station Traffic Lights	335394	390956	New Islington	48	45	47	50	42
T32	Crosshall Street Downpipe 2nd Along from Dale St.	334585	390677	Dale St	66	72	69	70	63
T33	Crosshall Street Downpipe 2nd Along from Dale St.	334585	390677	Dale St	69	72	69	73	65
T34	Crosshall Street Downpipe 2nd Along from Dale St.	334585	390677	Dale St	68	69	67	80	66
T35	Liverpool Centre Old Haymarket	334762	390686	Dale St	63	61	56	59	52
T36	Liverpool Centre Old Haymarket	334762	390686	Dale St	60	62	59	56	50
T37	Liverpool Centre Old Haymarket	334762	390686	Dale St	59	61	55	58	53
T38	Covent Garden/Dale St Lamp Post RH side	334086	390425	The Strand	52	50	46	48	44
T39	Strand Street/Water Street Junction - Road sign L2	334277	390231	The Strand	69	71	68	67	67

ID	Location	Grid Ref		Compliance Link	Annual Mean NO_2 Concentration, $\mu g/m^3$				
		X	Y		2012	2013	2014	2015	2016
T40	Street/Water Street Junction - Road sign L2	334277	390231		69	71	67	64	60
T41	Strand Street/Water Street Junction - Road sign L2	334277	390231		71	72	68	67	63
S50	Renville Rd/Bowring Park Rd	340397	390344	Bowring	62	57	58	56	55
S51	Renville Rd/Bowring Park Rd	340397	390344		68	58	60	57	55
S52	Renville Rd/Bowring Park Rd	340397	390344		56	56	59	59	56
S53	Bowring Park Road Slip Rd on Give Way sign	340154	390501		52	51	47	46	47

Road Links 17657, 28563, 37794, 37905 and 46588, and Nearby LCC Monitoring Locations



Road Link 18508 and Nearby LCC Monitoring Locations, Bowring Park



Annex 2: Further information to support part 6 of this study

Table 46 Annual Mean Monitored NO_2 in Model Domains

ID	Location			Annual Mean Monitored NO_2					
	X	Y	Model Domain	2012	2013	2014	2015	2016	2017
S59	338170	388629	A562, Smithdown Road	67	61	58	66	52	43
S60	337881	388939		63	58	54	59	52	40
S62	337003	389459		58	55	54	60	50	48
S47	339023	390715	A5080, Edge Lane Drive				54	56	38
S48	339149	390762		71	70	68	68	64	46
S49	339380	390645		72	68	66	65	63	50
N67	336375	396687	A5098 Walton Vale	77	72	68	71	67	49
N68	336216	396165					51	48	38
S55	340959	384247	A561 Speke Road	71	71	63	64	61	48

Figure 17 Modelled Receptor Locations, A5098, Walton Vale

Figure 18 Modelled Receptor Locations, A5080, Edge Lane Drive

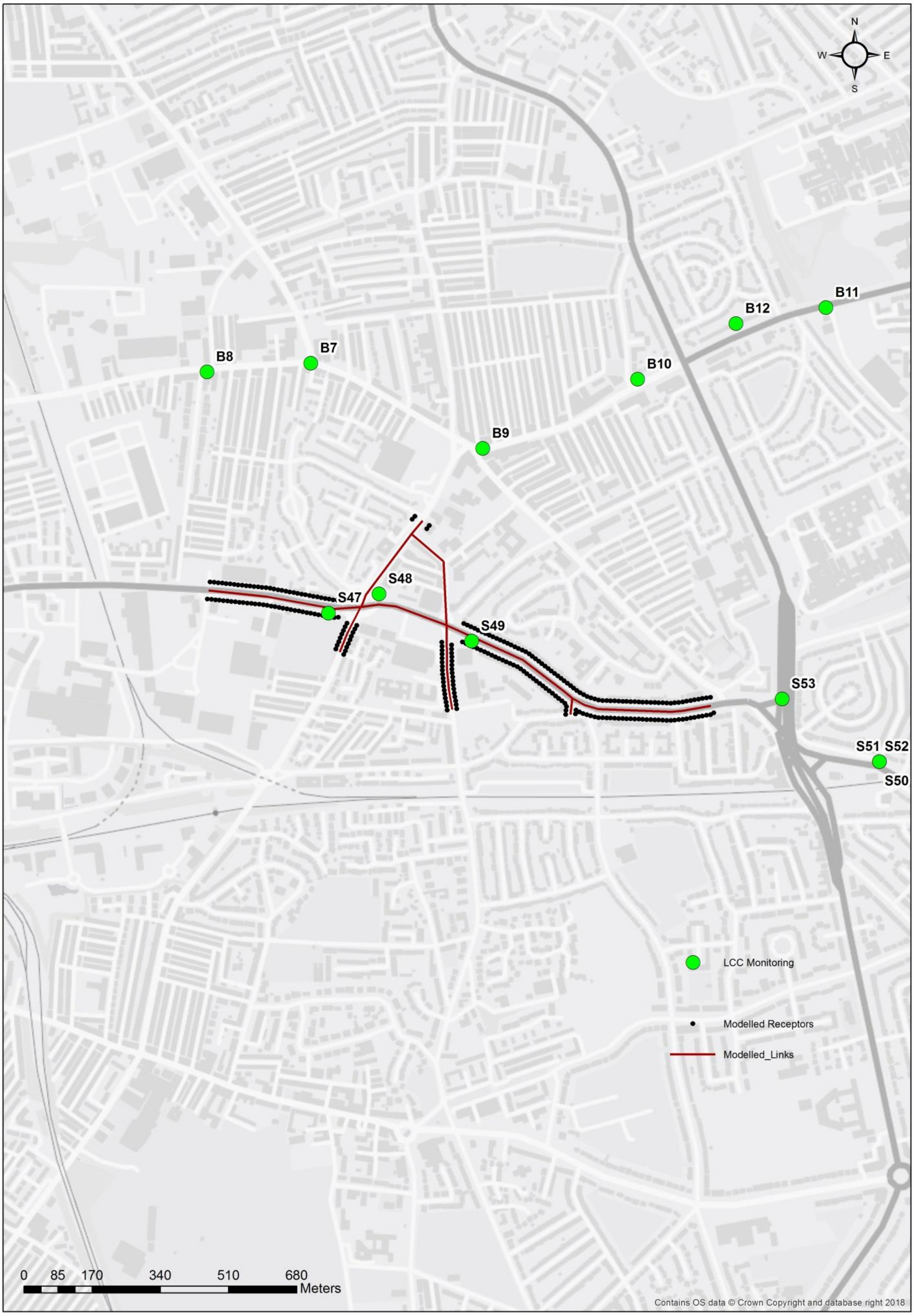


Figure 19 Modelled Receptor Locations, A562, Smithdown Road

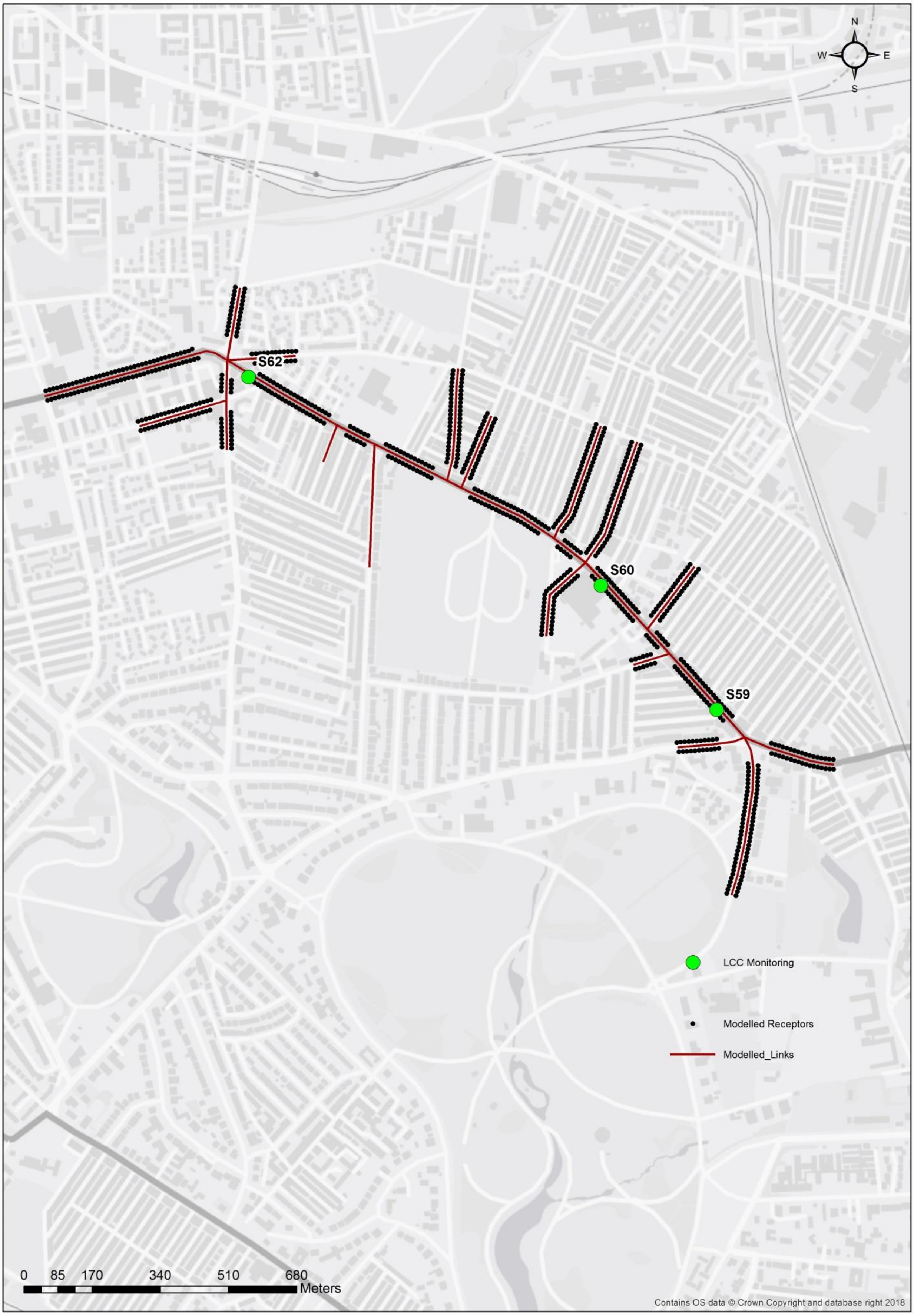


Figure 20 Modelled Receptor Locations, A561, Speke Road

Figure 21 Modelled Receptor Detail Showing Properties, A5098, Walton Vale

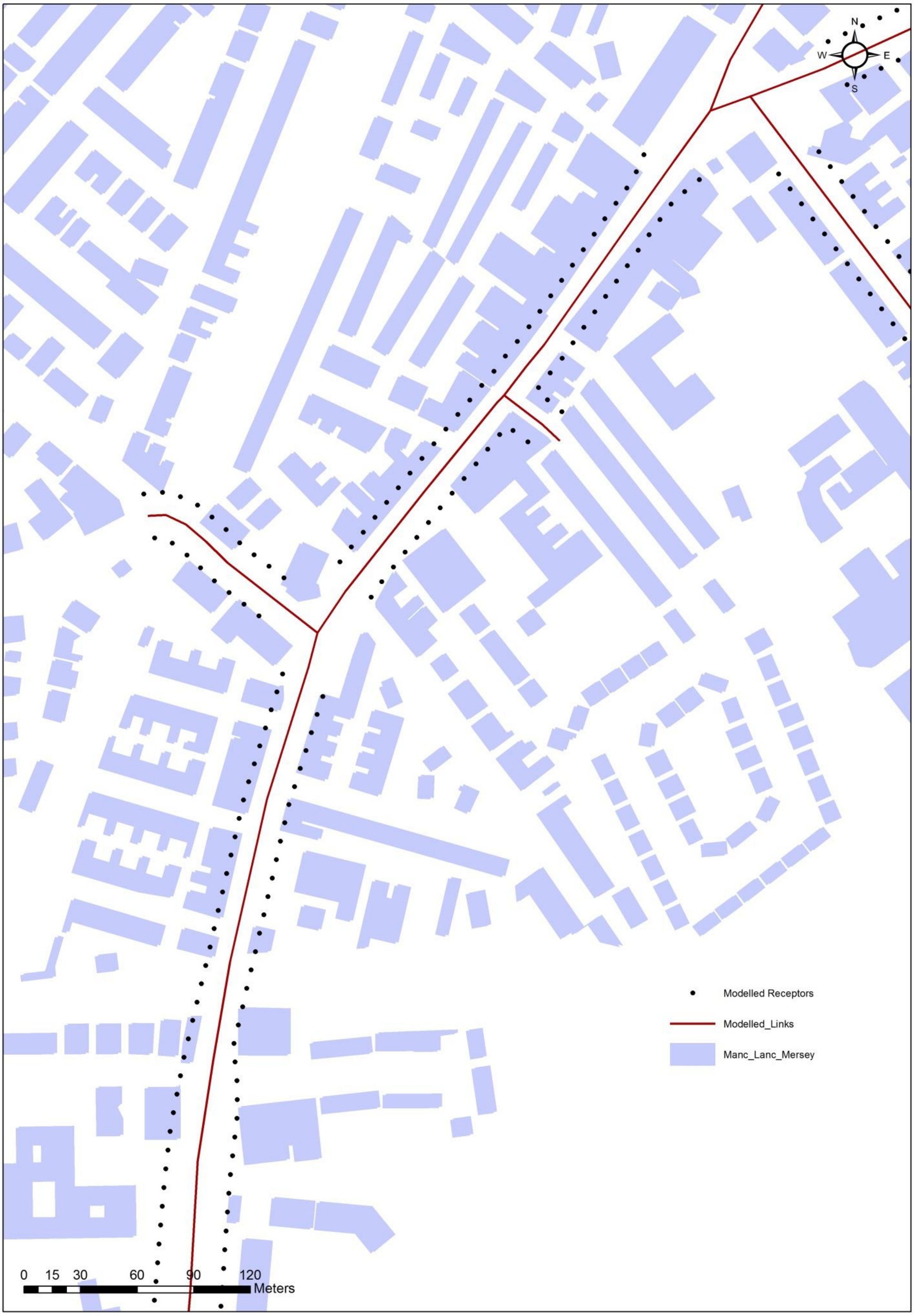


Figure 22 Modelled Receptor Detail Showing Properties, A562, Smithdown Road

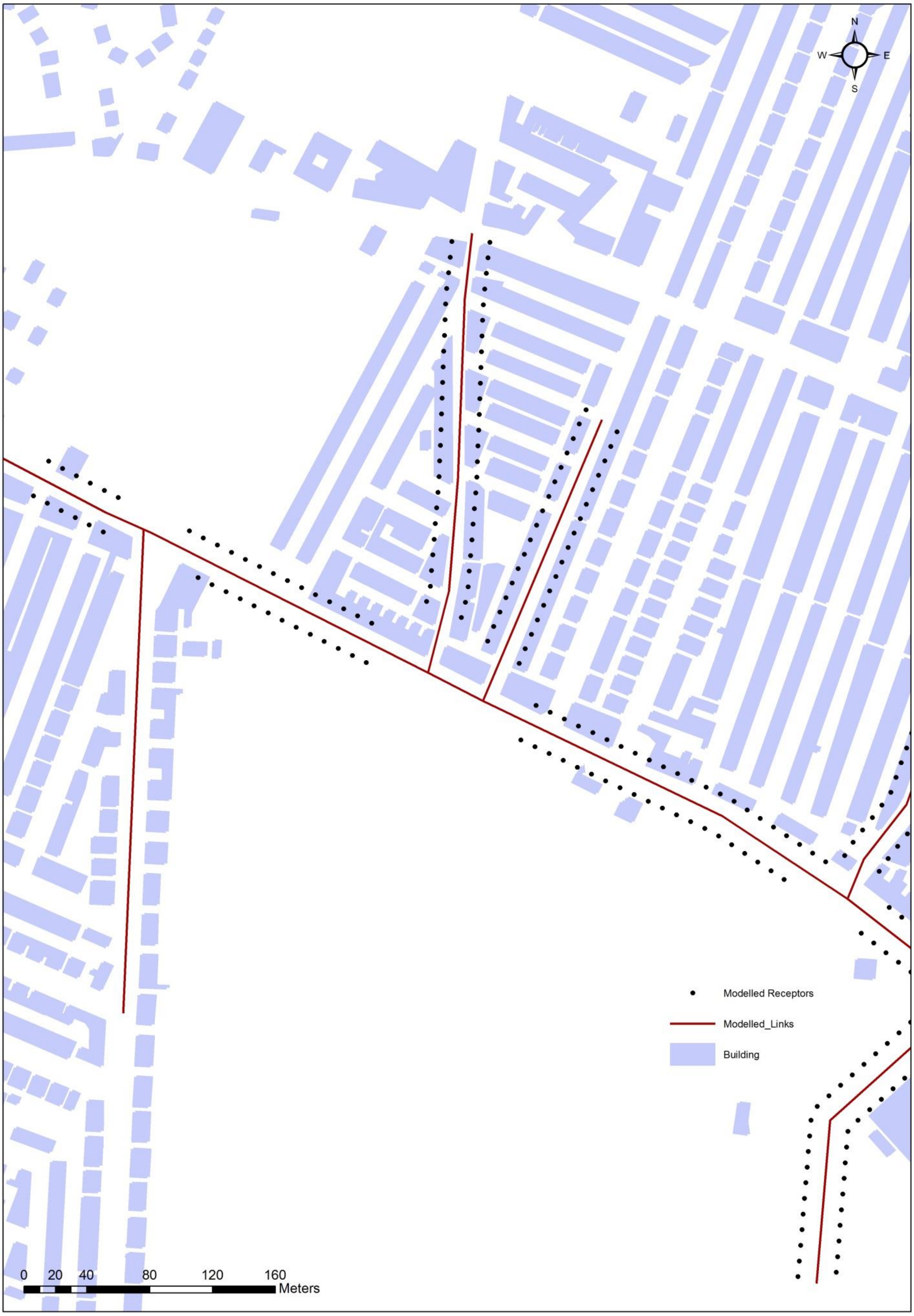


Table 47 Annual Mean Monitored NO_2

ID	Location	Annual Mean NO2, mg/m3		
		2015	2016	2017
B1	Prescot St/ RLUH Taxi Rank Lamp L7	61.32	56.65	44.18
B2	Prescot St/ RLUH Taxi Rank Lamp L7	62.20	55.67	43.23
B3	Prescot St/ RLUH Taxi Rank Lamp L7	61.83	55.80	44.17
B4	Kensington/Farnworth St Junct	54.53	50.27	42.68
B5	Outside Riverside Hsg Kensington/Sheil Rd	53.81	48.95	41.20
B6	Opposite old Aldi store Prescot Road	55.04	48.57	42.21
B7	Prescot Rd/Green Ln Junction Lamp Post	58.07	51.46	44.25
B8	Lamp post outside Salvation Army Prescot Road	49.52	48.47	40.24
B9	Prescot Rd/St Oswalds St Junc Cent L Post	64.05	64.68	50.17
B10	Lamp Post by bus stop Blackhorse Lane / Prescot Road	35.62	34.03	26.90
B11	Cental Reservation Prescot Road at jct of light by Sainsburys	48.29	44.92	36.63
B12	Corner Finch Lane / East Prescot Road	49.50	42.25	36.80
B13	Midland Chambers (Everton Road / West Derby Rd) No 14 bus stop	52.43	44.37	35.47
B14	Lamp post outside No 55 Everton Road	46.97	44.80	35.14
B15	Lamp at jct of Everton Rd / Breck Road	44.72	41.15	30.90
B16	Lamp Breck Road (opposite Lance Close)	36.16	33.77	24.06
B17	Lamp outside Green Cross Pharmacy	35.76	34.84	25.60
B18	Lamp outside Quality Fireplaces Breck Road	43.77	40.53	31.93
B19	Lamp at side of Georgeosons car (Priory Road)	44.33	41.44	31.20
B20	Lamp outside No 93 Townsend Lane	42.39	37.73	27.76
B21	Telegraph pole outside Clubmoor community centre	33.61	32.23	24.30
B22	Lamp in central res. opposite 51 Townsend Ave	41.53	39.29	30.69
B23	Lamp on central reserve opposite Surestart Utting Ave East	43.02	40.27	32.58
B24	Lamp centrl reserve opp. St Theresas schl Utting Ave East	35.42	32.73	26.94
B25	Traffic Lt in cntrl reserve jct of Lowerhouse / Utting Ave East	35.78	33.51	27.26
T26	Islington AQ Station Traffic Lights	49.96	42.40	35.05
T27	Islington AQ Station Traffic Lights	46.16	40.88	34.34
T28	Islington AQ Station Traffic Lights	50.38	41.72	34.80
T29	Leeds Street/Pall Mall Road Sign	43.32	38.85	30.38
T30	Leeds Street/Pall Mall Road Sign	41.37	40.03	30.73
T31	Leeds Street/Pall Mall Road Sign	42.70	38.43	30.41
T32	Crosshall Street Downpipe 2nd Alng from Dale St.	69.94	62.85	46.81
T33	Crosshall Street Downpipe 2nd Alng from Dale St.	72.61	65.02	45.87
T34	Crosshall Street Downpipe 2nd Alng from Dale St.	79.79	65.53	43.57
T35	Lpool Centre Old Haymarket	58.82	51.70	41.46
T36	Lpool Centre Old Haymarket	55.81	50.27	41.82
T37	Lpool Centre Old Haymarket	57.87	53.10	40.84
T38	Covent Garden/Dale St Lamp Post RH side	48.08	43.70	36.27
T39	Strand Street/Water Street Jct-Roadsign L2	66.87	66.75	49.57
T40	Strand Street/Water Street Jct-Roadsign L2	64.17	60.09	45.19
T41	Strand Street/Water Street Jct-Roadsign L2	67.17	63.46	48.74
T42	Berry St o/s St Lukes Ch Pedestrian Lights	50.91	49.12	37.80
T43	Renshaw St/Bold St J cor Lamp Post Rapid	63.85	56.59	46.10
T44	Clarence St/Mount Pleasant J LP o/s JMU	48.40	46.76	36.96

T45	Pembroke Pl LP o/s main ent Dental Hospital	51.20	49.14	36.10
S46	Edge Lane/Jubilee Dr LHS Junct nr C2414	54.15	50.04	37.95
S47	Edge Lane/Rathbone Rd Junc Lamp Post	53.53	55.63	37.52
S48	St Oswald St/Paraffin Oil Shop Tlight L13	68.06	64.25	46.48
S49	Edge Lane Drive/Mill Ln L8047 Cent Resvtn	65.03	63.20	49.81
S50	Renville Rd/Bowring Park Rd 30MPH sign AQMA2 L14	56.20	55.11	45.40
S51	Renville Rd/Bowring Park Rd 30MPH sign AQMA2 L14	57.41	55.17	43.81
S52	Renville Rd/Bowring Park Rd 30MPH sign AQMA2 L14	58.75	56.49	45.74
S53	Bowring Park Road Slip Rd on Give Way sign	45.70	46.82	34.14
S54	Hillfoot Rd/Allerton Rd J Lamp LH p J C2507	55.98	53.69	42.34
S55	Speke Rd 1st Dual Pelican Cross 2672/2673	64.02	61.36	47.82
S56	Speke DEFRA Site Tarbock Rd L24	22.51	22.63	17.11
S57	Speke DEFRA Site Tarbock Rd L24	22.36	21.77	17.12
S58	Speke DEFRA Site Tarbock Rd L24	22.17	22.65	17.14
S59	Smithdown Road Lamp outside Costcutter	65.65	52.20	43.48
S60	Smithdown Road info sign outside Sefton Pk pharmacy (by Asda)	59.28	52.00	39.59
S61	Smithdown Road Lamp in centr. Res opp. Budget exhausts	41.21	45.87	34.33
S62	Smithdown Road Info sign by Howard Jenkins funerals nr jct with lodge lane	59.53	50.38	47.90
N63	Millbank/Queens Dr - Junction Lamp Post	74.15	64.36	51.81
N64	Muirhead Ave/Queens Dr central res traffic Lights (by dentist)	62.87	59.40	47.73
N65	Storrington Ave/Stonebridge Ln (on lamp post by traf.lights)	44.64	43.43	34.29
N66	Longmoor Ln/Seeds Ln J L Traffic C2607	42.32	42.53	35.19
N67	Middle Walton Vale-Pedestrian crossing	71.28	67.25	49.32
N68	Lamp post J 3268 outside 324-328 Rice Lane L9	51.28	48.16	37.81
N69	Queens Drive Monitoring Station	42.32	40.76	38.30
N70	Queens Drive Monitoring Station	42.43	38.52	38.07
N71	Queens Drive Monitoring Station	40.69	38.85	37.07
N72	County Rd/Spellow Ln-Lp nr Traffic C2222	53.05	50.25	39.17
N73	Blackstone St./Gt. Howard St. L3 LTS 2202	52.97	47.48	37.40