MAYOR OF LONDON

CENTRAL LONDON ULTRA LOW EMISSION ZONE – SIX MONTH REPORT

October 2019

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City Hall
The Queen's Walk
More London
London SE1 2AA
www.london.gov.uk
enquiries 020 7983 4000
minicom 020 7983 4458
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Key Findings

On 8 April 2019 the Mayor of London launched the world's first Ultra Low Emission Zone (ULEZ). Six months on, data indicates the scheme is having a significant impact – although further analysis will be needed to fully assess the long-term impacts.

This report includes data from February 2017 (when the Mayor confirmed the T charge and the accelerated change in the vehicle fleet began), March 2019 (the month before the scheme was introduced) and April – September 2019 (the first six months of the scheme).

Key findings from the first six months of operation are:

- After the first six months of operation **the average compliance rate with the ULEZ standards was 77 per cent in a 24 hour period (74 per cent in congestion charging hours).** This is significantly higher than 39 per cent in February 2017 and the 61 per cent in March 2019 during congestion charging hours

- Between February 2017 and September 2019, there has been a 32 micrograms per cubic metre (ug m^{-3}) reduction in roadside concentrations of nitrogen dioxide (NO_2) in the central zone, **a reduction of 36 per cent**

- Trend analysis shows that, for the period July to September 2019, NO_2 concentrations at roadside locations in central London were on average 24 ug m^{-3} lower, **equating to a reduction of 29 per cent,** compared to a scenario where there was no ULEZ

- Preliminary estimates indicate that after six months NO_x emissions from road transport in the central zone have **reduced by 31 per cent (200 tonnes)** compared to a scenario where there was no ULEZ. This is ahead of schedule to meet the 45 per cent NO_x emissions reduction expected in the first year

- Preliminary estimates indicate that after six months CO_2 emissions from road transport in the central zone have **reduced by 4 per cent (9,800 tonnes)** compared to a scenario where there was no ULEZ. When **compared to 2016, this equates to a 13 per cent reduction,** assuming current compliance rates continue for the remainder of the first year of operation

- None of the air quality monitoring stations located on ULEZ boundary roads have measured an increase in NO_2 concentrations since the introduction of the ULEZ

- Preliminary analysis of traffic flows indicate that the introduction of the central London ULEZ has contributed to **a reduction in traffic flows in central London from May to September 2019 of between 3 – 9 per cent when compared to**

2018, though further analysis is needed to better understand long term complex changes in traffic flows as a result of ULEZ

- From March to September 2019 there was a large reduction in the number of older, more polluting, non-compliant vehicles detected in the zone: **some 13,500 fewer on an average day, a reduction of 38 per cent** in congestion charging hours**.** This is higher than the 9,400 reduction reported after one month and the 12,500 reduction reported after four months

- There was a **34 per cent decrease in the proportion of vehicles in the central zone that were non-compliant from March 2019 to September 2019** in congestion charging hours

To fully understand the impact of the scheme it is necessary to take into account pre-compliance (i.e. people and businesses preparing ahead of time for the start of the new scheme). With this in mind, the changes between February 2017 and September 2019 were as follows:

- There was a large reduction in the number of older, more polluting, non-compliant vehicles detected in the zone: **a reduction of 40,200 vehicles on an average day, equating to a 65 per cent reduction**

- There was an **89 per cent increase in the proportion of vehicles detected in the central zone that were compliant** from February 2017 to September 2019

Introduction

On 8 April 2019 the Mayor of London launched the world's first Ultra Low Emission Zone in central London. This report evaluates the impact of the scheme in its first six months of operation (to the end of September 2019). Whilst we can determine a number of different impacts within this timeframe, further ongoing analysis will be required to understand the full impacts of the scheme over a longer period of time – particularly in relation to establishing long term changes in air quality.

A number of measures are used to assess the impacts of introducing the ULEZ. In this report we evaluate the impact on air pollution concentrations, air pollution emissions, traffic flows and vehicle compliance.

What is the Ultra Low Emission Zone (ULEZ)?

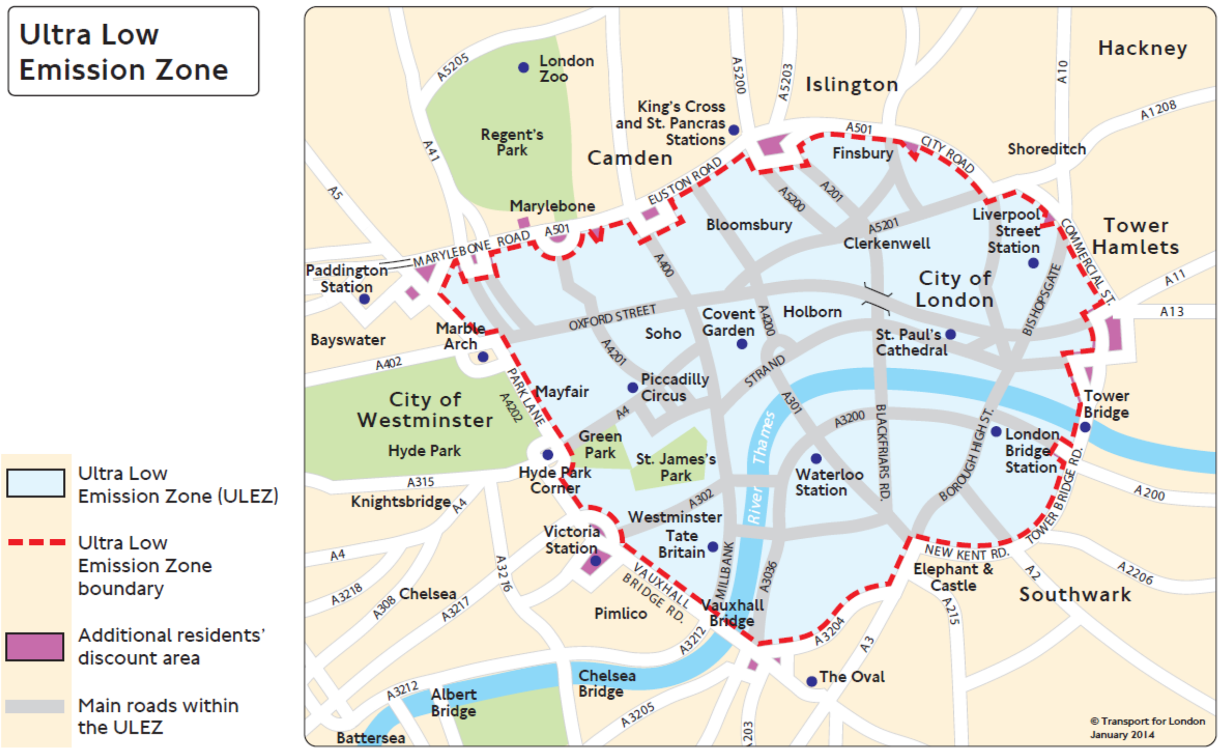

Figure 1. Map of the central London Ultra Low Emission Zone

The Central London ULEZ started on 8 April 2019 and operates in the existing central London Congestion Charge Zone. Figure 1 is a map of the area covered by the central ULEZ. Unlike the Congestion Charge (which operates Monday to Friday between 07:00 and 18:00) the ULEZ operates 24 hours a day, every day of the year. Vehicles must meet strict emission standards to drive in the ULEZ area:

- Euro 4 for petrol cars and vans (vehicles less than fourteen years old in 2019)
- Euro 6 for diesel cars (vehicles less than five years old in 2019)
- Euro 6 for diesel vans (vehicles less than four years old in 2019)
- Euro 3 for motorcycles and other L-category vehicles
- Euro VI for lorries, buses and coaches

Vehicles that do not meet these standards must pay a charge:

- £12.50 per day for cars, motorcycles and vans
- £100 per day for lorries, buses and coaches

All TfL buses operating in the zone meet the ULEZ standards. The ULEZ replaces the T-Charge in central London and is in addition to the Congestion Charge. To find out more about the ULEZ or to check if your vehicle is affected please visit: https://tfl.gov.uk/modes/driving/ultra-low-emission-zone.

Alongside the ULEZ, the Private Hire Vehicle exemption to the congestion charge was removed on 8 April 2019.

This is the third report evaluating the impact of the scheme, and the first to include an assessment of the impact on air pollutant concentrations and emissions. The first two reports are available from:

- Central London Ultra Low Emission Zone – First Month Report
- Central London Ultra Low Emission Zone – Four Month Report

An updated evaluation will be published once twelve months of data are available.

Assessing the impacts of ULEZ

The purpose of the ULEZ is to improve air quality in and around central London by reducing the number of older more polluting vehicles that enter the central zone. The impact of ULEZ can be assessed using a number of different metrics including:

- Air quality monitoring[1]
- Modelling of vehicle emissions
- Number of vehicles and compliance rates
- Traffic flow data

Air pollution concentrations are affected by many different factors including the weather and regional contributions from outside London, as well as impacts from other local schemes, therefore analysis of air quality monitoring data will need to continue over time.

At present reductions in air pollution concentrations are reported for locations that have air quality monitoring stations. In 2020 (once more data is available and the ULEZ has been in operation a full year) an air quality model of concentrations across London will be produced. This will further assess the improvement in air quality as a result of the scheme at all locations across London.

Vehicle compliance refers to the number of vehicles that “comply” or meet the ULEZ emission standards. Non-compliant vehicles do not meet the strict ULEZ emissions standards and have either:

- Paid the daily charge
- Incurred a penalty charge
- Not been required to pay the daily ULEZ charge as they are eligible for a 100% discount or exemption

Limitations of this analysis

To assess the impact of the scheme we have compared the number of vehicles detected in the zone and compliance rates from February 2017 and March – September 2019. In February 2017 the Mayor confirmed the introduction of the T-charge as a stepping-stone

[1] At this stage air quality data is from the London Air Quality Network and Air Quality England Network. This is because both provide data going back many years. The newly established Breathe London network will also be used for ULEZ evaluation in a separate report using different techniques.

for the ULEZ and this can be seen as the start of the accelerated change in the vehicle fleet as Londoners and businesses prepared for the new schemes and buses on routes in central London began to be upgraded to become ULEZ compliant. In addition, the removal of the exemption from the congestion charge for private hire vehicles also commenced on 8th April 2019. March 2019 is the month before the ULEZ was introduced and September 2019 is the latest available full month of data.

The ULEZ is a 24 hour scheme, however, prior to the start of the scheme this April data was only collected during congestion charging (CC) hours only – 07:00 to 18:00, Monday to Friday. When assessing the impact of the first six months of ULEZ compared to historic months, comparison has been made based on CC hours to ensure the comparison is fair. 24 hour data for the months since the scheme has been in operation has also been provided.

As mentioned, the removal of the exemption from the congestion charge for private hire vehicles coincided with the launch of the ULEZ. This may also have had an effect on traffic volumes and air quality within the zone, but it is too early at this stage to separate the respective effects.

Disruptions to traffic flow in the central zone in April 2019

As explained in a previous iteration of this report, there were a number of non-typical events in central London in April 2019. These included.

- Road works (leading to signed diversions into the ULEZ)
- The Extinction Rebellion climate protests, leading to further diversions into the central zone and an unknown impact on the number of motorists choosing to drive in central London
- Easter holidays and Bank Holidays. The timing of the introduction of ULEZ was specifically chosen to target a “quiet” week when there would be fewer vehicles in the zone

As a result, only a limited number of days were used for analysis of the first month of the scheme. Data for April 2019 presented in this report is the average over “typical days” only. However, using only typical days exclusively in the month of April has little effect on the results.

As the scheme started on 8 April, the first iteration of this report covered the period from 8 April to 5 May 2019 (to provide 4 calendar weeks of “typical days” data). For consistency this report has taken the same approach.

Unique vehicles detected in zone and relation to traffic flow

Vehicle volumes within this report relate to the daily number of confirmed unique vehicles detected in central London. Unique vehicle volumes will be different in scale to changes in traffic volumes entering or within central London for a number of reasons:

- Unique vehicle volumes do not take into account how a vehicle is used. For example, a proportion of traffic is associated with a minority of vehicles that make multiple trips a day within the zone, e.g. delivery vehicles, private hire vehicles and taxis

- Trips made wholly within the zone are currently less likely to be captured by an ANPR camera than trips crossing the boundary (for which all entry and exit points are monitored). There is currently less incentive for internal trips to cease as local residents have a 100% ULEZ discount grace period until 24th October 2021

- Analysis of changes in traffic data based on automatic traffic count sites in London is compared to the same months in 2018. However, traffic exhibits seasonal variation, and further analysis will be undertaken once a full year of traffic data is available

If you want to know about estimates for changes in traffic in both central London and pan-London please see the latest Travel in London report, which looks at various sets of data for understanding traffic flow including that from TfL's automatic traffic counters: https://tfl.gov.uk/corporate/publications-and-reports/travel-in-london-reports

Further analysis is ongoing in order to understand the impacts of ULEZ including trends in changes in compliance, traffic flows, and air quality.

Air pollution concentrations

Around half of London's NO_x emissions are from road transport.[2] The purpose of the ULEZ is to improve air quality in and around central London by reducing the number of older, more polluting vehicles that enter the central zone. This will reduce the amount of NO_x emitted, which in turn will reduce nitrogen dioxide (NO_2) concentrations in the zone, Bringing London closer to compliance with the legal air quality limit values for NO_2 is a key aim of the scheme.

This section presents analysis of data from London's automatic monitoring network. This data is publicly available from the London Air Quality Network and Air Quality England websites. Full details of the methodology for this section can be found in the Appendix.

For this analysis air quality monitoring stations are grouped by site type. This analysis focuses on the two most common types of monitoring site in London; roadside and urban background.

Roadside sites are within 1 – 5m of a busy road and usually located around adult breathing height. Roadside sites enable us to track and understand changes in air pollution concentrations from traffic. These sites give the best estimate of public exposure on busy roads. Roadside sites are useful for identifying air quality hotspots due to traffic that may have potential health impacts - especially those frequented by large numbers of pedestrians.

Urban background sites are located further away from sources of emissions and are not influenced by one single nearby pollution source. In London, traffic is the main source for background sites to avoid and there are guidelines about how close background sites can be to roads. The benefit of urban background sites is they're usually representative of all the other urban background locations within an area of several square kilometres.

Air pollution concentrations are highly sensitive to the prevailing meteorology, such as wind speed, wind direction, precipitation and temperature, as well as the associated long-range transport of pollutants from outside London. Many pollutants have a seasonal cycle too. This seasonal cycle may be caused by seasonally varying emissions, such as heating in wintertime or agricultural emissions during the spring. Seasonal cycles can also be caused by other factors including sunlight that can induce chemical reactions between air pollutants. These seasonal and day-to-day variations can make is difficult to assess short term trends or the impact of interventions such as the ULEZ. One approach to minimise the impact of these variations is to consider a sufficiently long time period. Another is to

[2] London Atmospheric Emissions Inventory 2016 (LAEI 2016)

use statistics to smooth out short-term variability, this reduces the impact of weather and seasonal factors.

In this section monthly average concentrations are used to calculate trends in the period from 2010 to end of September 2019. It should be noted that measurement data from 2019 have not yet been ratified. As a result, these may be subject to change following equipment tests undertaken as part of the routine audit and servicing of air quality monitoring sites.

The ULEZ is one of the many policies to reduce air pollution in London. Other policies include the London-wide Low Emission Zone (for heavy vehicles), investment in new cleaner buses and taxis (in addition to ULEZ measures), as well as progressively tighter EU-wide exhaust controls for new vehicles. As a result, it is not straight forward to isolate the impact of the ULEZ. For this analysis the trends in outer London (largely away from the influence of the ULEZ in central London) were used as a predictor of the change in central and inner London if the ULEZ was not in place. Comparing the measured trends in central and outer London reveals the additional changes within the central zone, which provide an estimate for the impact of the ULEZ.

Detecting the additional change within the ULEZ by comparing trends in the zone to those in outer London has both strengths and weaknesses. Key amongst the strengths is the ease of analysis, allowing data to be analysed as it is produced and the large number of measurement sites involved. Another strength is the use of outer London data that also acts, to some extent, as a control for the weather and seasonal factors that can confound this type of analysis. The key weakness stems from differences in the vehicle fleets in the ULEZ area compared with outer London. Traffic in the ULEZ area has a greater proportion of certain vehicle types, such as taxis, and proportionally fewer private cars than outer London[3]. Interventions on these vehicle types from other Mayoral policies would have a different impact in the ULEZ area than outside, even in the absence of the ULEZ.

Another potential limitation to the analysis presented in this chapter is changes in the number and location of monitoring sites across London over the 10-year period. More detail on this can be found in the Appendix.

[3] London Atmospheric Emission Inventory (LAEI) 2016, Greater London Authority 2018

Trends in Nitrogen Dioxide (NO_2)

The detailed method for calculating the trends in this section can be found in the Appendix. Figure 2 shows the trends in nitrogen dioxide (NO_2) at monitoring sites in London from 2010 to 2019.The graph shows the monthly average NO_2 grouped by site type and location, statistically smoothed to reduce the impact of weather.

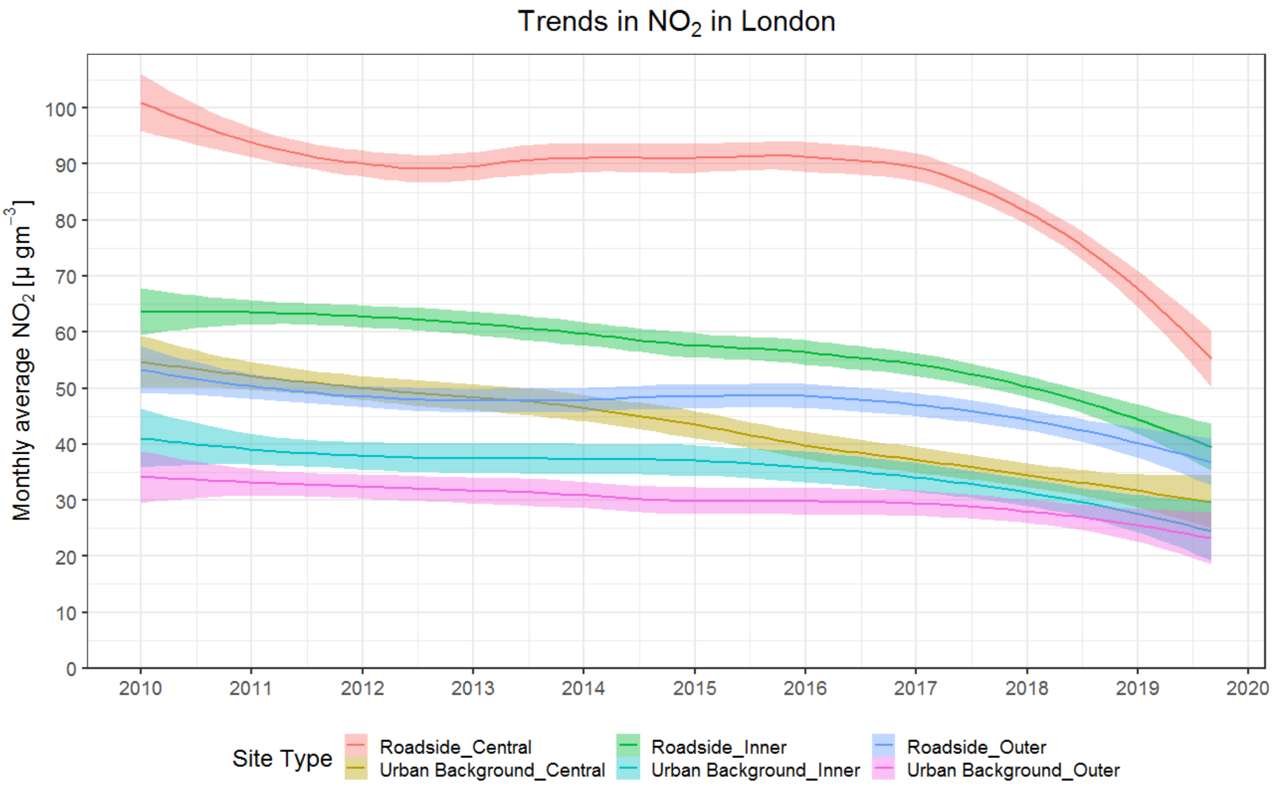

Figure 2: Monthly average NO_2 concentrations in London from 2010 to 2019

There was a slight downward trend in concentrations of NO_2 at monitoring sites across London between 2010 and 2017, most likely reflecting turnover of vehicles in the passenger fleet. At central London roadside locations (top red line), an accelerated reduction in NO_2 begins in 2017, becoming a steeper downward curve from 2018 to September 2019. A similar, though less pronounced trend also occurs in inner London roadside locations (second from top green line). This is in line with when some vehicle owners began to prepare for the ULEZ and buses on routes in central London began to be upgraded to become ULEZ compliant.

Modelling produced before the ULEZ was launched predicted the scheme would reduce concentrations of NO_2 across London, with the greatest reductions in central London and more modest reductions in inner London. The trends in Figure 2 indicate this has been the case.

Table 1 lists the quarterly average concentrations of NO_2 in London from 2017 to September 2019 grouped by site type and location. The biggest reduction in average concentrations between the beginning of 2017 and September 2019 is at central roadside sites, 32 ug m^{-3}, equating to a 36 per cent reduction. This is over double the reduction at inner roadside sites of 14 ug m^{-3}, and three times the reduction at roadside sites in outer London. The smallest improvement was recorded at urban background sites in outer London, 6 ug m^{-3}.

Table 1. Quarterly average NO_2 at roadside sites by zone

Period	Average NO_2 [µg m^{-3}]					
	Roadside Central	Background Central	Roadside Inner	Background Inner	Roadside Outer	Background Outer
Jan – March 17	89	37	54	34	47	29
April – June 17	87	36	53	33	46	29
July – Sept 17	85	36	52	33	46	29
Oct – Dec 17	83	35	51	32	45	28
Jan – March 18	81	34	50	31	44	28
April – June 18	78	34	49	30	43	27
July – Sept 18	74	33	47	29	42	27
Oct – Dec 18	70	32	46	28	41	26
Jan – March 19	66	31	44	27	40	25
April – June 19	62	31	42	26	39	24
July – Sept 19	57	30	40	25	37	24
Reduction *(Q1 2017 – Q3 2019)* [µg m^{-3}]	32	7	14	9	10	6
Reduction *(Q1 2017 – Q3 2019)* [per cent]	36%	19%	26%	27%	21%	20%

It is important to note that Table 1 presents an average across several sites of each type in each zone. Data presented in Table 1 is quarterly as opposed to annual, so not directly comparable to annual air quality limits. However, there are still many sites in 2019 in inner and outer London that continue to exceed the legal air quality limit value for annual mean NO_2 of 40 ug m^{-3}.

Reduction attributable to central London ULEZ

As mentioned previously, air pollution is influenced by many complex factors. It is therefore important to perform additional analysis to ensure the trends reported in Table 1 were not a product of weather and seasonal factors and to attribute the proportion of the recent reduction in NO_2 concentrations within the central zone which are attributable to the ULEZ.

A technique often used to isolate the proportion of pollution that relates to traffic sources is to subtract the background concentration from the roadside concentration. This is referred to as the "roadside increment"[4]. Changes in the roadside increment, or traffic contribution, in outer London were used as a predictor of the changes in a "no ULEZ" scenario for

[4]Font, A. & Fuller, G. (2016) Did policies to abate atmospheric emissions from traffic have a positive effect in London? Environmental Pollution, Volume 218, November 2016, Pages 463-474

roadside sites in central and inner London. The full methodology for calculating the "no ULEZ" trend can be found in the Appendix.

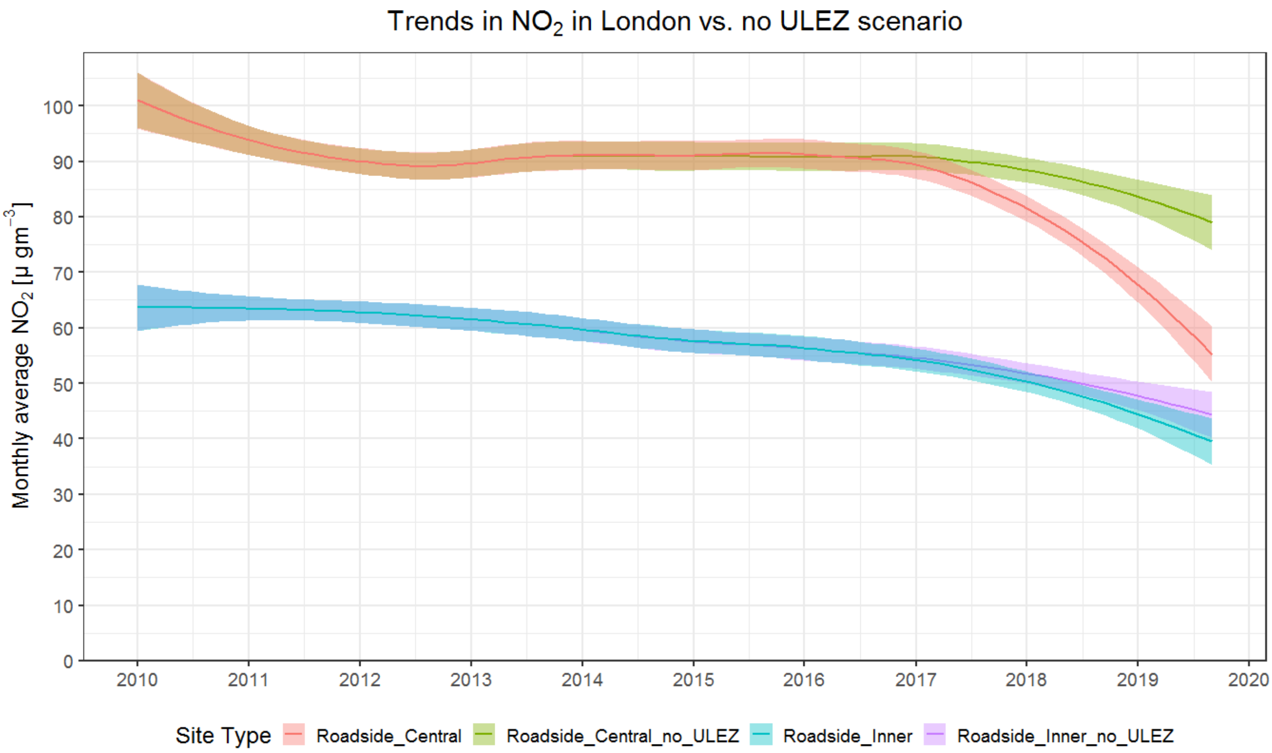

Figure 3: Monthly average NO_2 concentrations in London with and without ULEZ

Figure 3 shows the monthly average NO_2 at roadside sites in central and inner London as well as a "no ULEZ" scenario for each. The "no ULEZ" reflects changes in central and inner London were they to follow the same trend as roadside sites in outer London. The divergence between the measured concentrations and "no ULEZ" scenario is much more pronounced in central London than in inner London. This shows there was a reduction in roadside concentrations in central and inner London that was far greater than the reduction measured at outer London sites.

Table 2: Estimated reduction in NO_2 concentrations as a result of ULEZ

Period	Reduction central London compared to "no ULEZ"		Reduction inner London compared to "no ULEZ"	
	[ug m^{-3}]	[per cent]	[ug m^{-3}]	[per cent]
Jan – March 19	17	20%	3	7%
April – June 19	20	24%	4	9%
July – Sept 19	23	29%	5	10%

Table 2 presents the difference between the trend in actual roadside measurements and the scenario where there was no ULEZ over three-month periods in 2019. This can be understood as the reduction at central and inner London sites that is in addition to the changes measured at outer London roadside sites.

In July to September 2019, the most recent period for which data is available, the ULEZ reduced mean NO_2 concentrations at roadside sites by 23 ug m^{-3}, a reduction of 29 per cent compared to the scenario where "no ULEZ" is in place.

The smaller reduction of 10 per cent was measured at roadside sites in inner London. This is expected, since many vehicles driven in the ULEZ also travel in this area. This is the area that will benefit most from the expansion of the Ultra Low Emission Zone to the North and South circular roads in 2021.

Trends in Nitrogen Dioxide on boundary roads

When charging schemes, such as the ULEZ or Congestion Charge, are introduced in part of a city it is always important to measure the impact of the scheme not only in the zone itself, but also in the surrounding area.

There are four established air quality monitoring stations on the central London ULEZ boundary roads. Figure 4 shows that, similar to sites within the central zone, sites on the ULEZ boundary roads measured an increased downward trend in emissions since 2017. No sites on the boundary roads have experienced an increase in the trend of monthly average NO_2 since the scheme was introduced in April 2019. (Note, these boundary sites are not included in the analysis in the previous section).

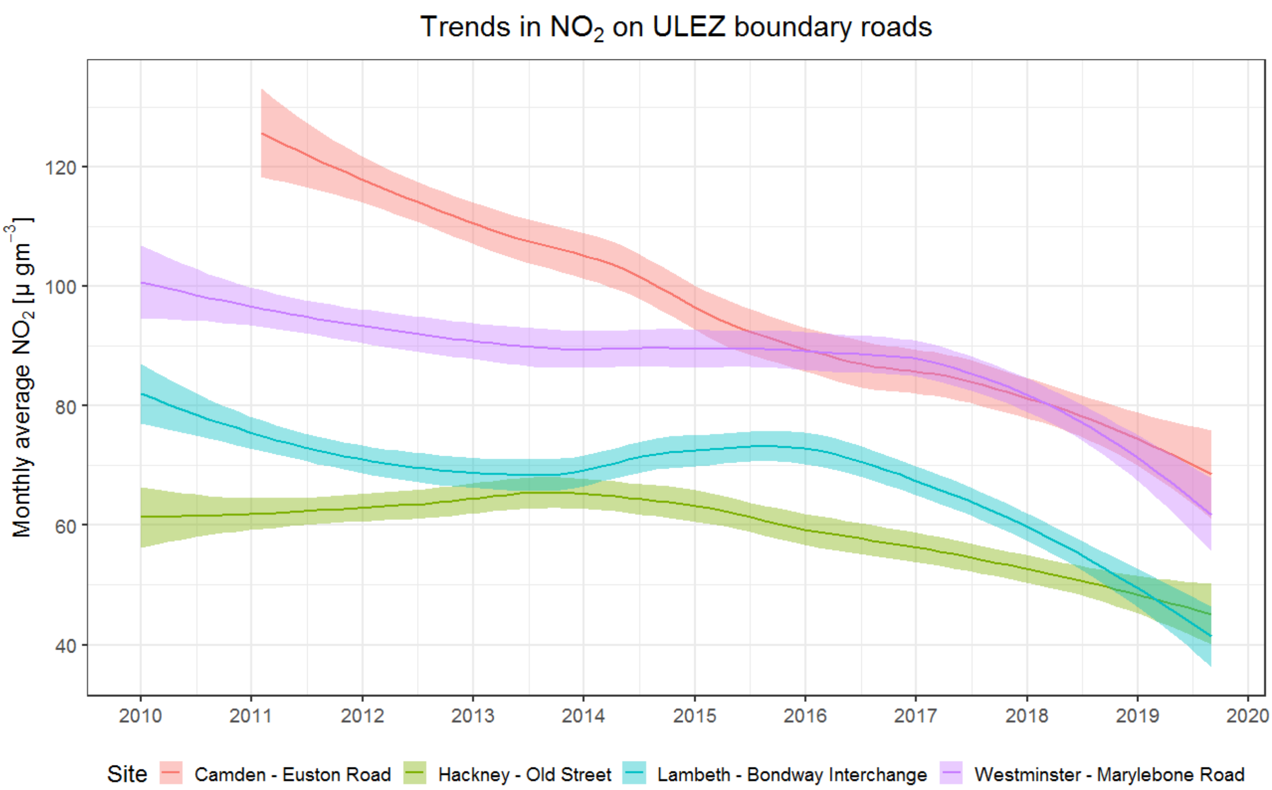

Figure 4: Monthly average NO_2 concentrations at sites on ULEZ boundary roads

This is a strong indication that there has been a positive impact on air pollution on the ULEZ boundary roads. A full picture of the impact on boundary roads will be available in 2020 (once more data is available and the ULEZ has been in operation a full year) when an air quality model of concentrations across London will be produced.

Particulate Matter ($PM_{2.5}$)

Road transport is the largest single source of particulate matter in London, accounting for around 30 per cent of emissions[5]. However, unlike NO_2, over half of London's concentrations of $PM_{2.5}$ come from regional, and often transboundary (non-UK) sources outside of London. There is also a large proportion of $PM_{2.5}$ emitted within London that the Mayor does not currently have the powers to control, for example wood burning. In addition, a growing proportion of road transport $PM_{2.5}$ emissions are now non-exhaust emissions including road wear, resuspension of road dust and tyre and brake wear.

For these reasons, the reduction in $PM_{2.5}$ emissions reported in the next section will have a less pronounced impact on concentrations than seen for NO_2, for which London-based sources are dominant. Figure 5 shows there has been a downward trend in $PM_{2.5}$ since 2010 which continued after the introduction of the ULEZ.

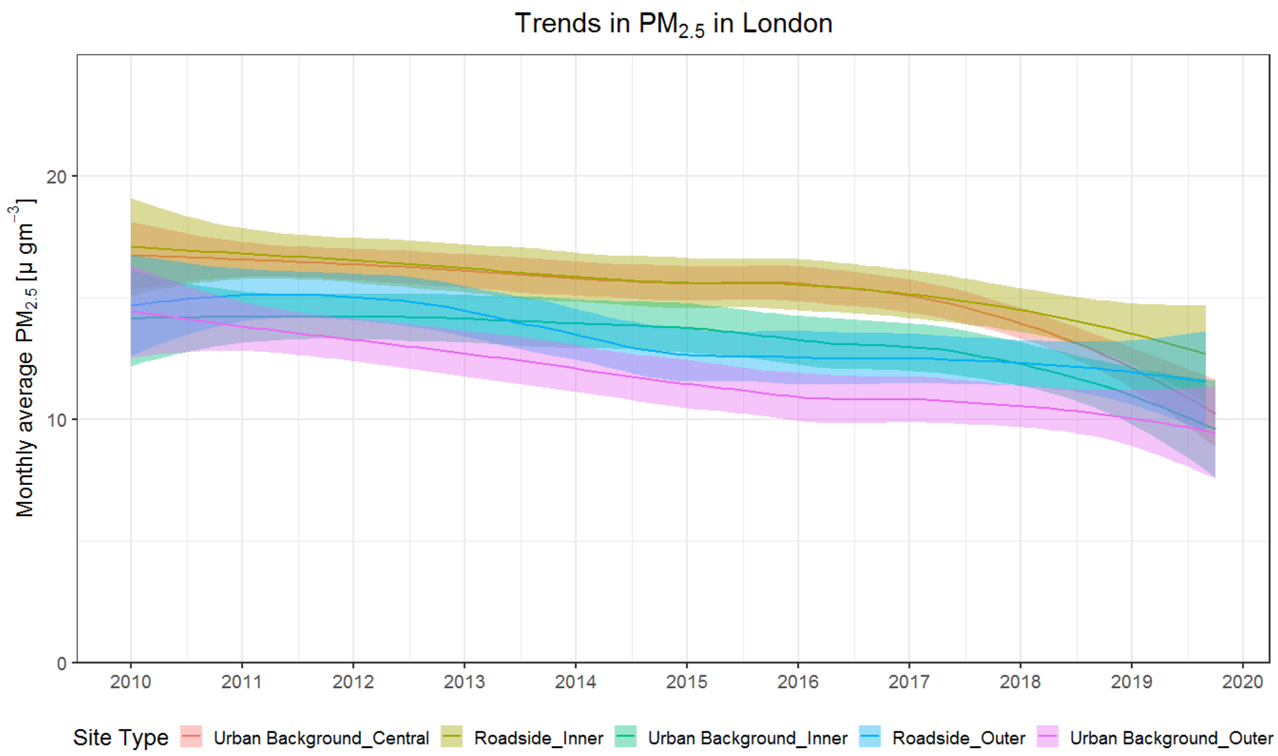

Figure 5: Monthly average $PM_{2.5}$ concentrations in London

In addition, there are far fewer $PM_{2.5}$ monitoring sites than NO_2, and there are no $PM_{2.5}$ roadside monitoring sites in central zone in the automatic network. However, the newly established Breathe London network has greatly increased $PM_{2.5}$ monitoring across London, with over 20 monitors in central London alone.

[5] London Atmospheric Emissions Inventory 2016 (LAEI 2016)

Air pollution emissions

Emissions from road transport have been modelled to estimate how NO_x emissions from vehicles has changed since the ULEZ was introduced. Full details of the methodology for this section can be found in the Appendix. Emissions reductions are calculated as the reduction in emissions using current compliance rates compared to a "no ULEZ" scenario for the period July to September 2019.

Reductions in NO_x emissions

Preliminary estimates indicate that between July and September 2019 NO_x emissions from road transport reduced by 31 per cent (or 200 tonnes of NO_x) compared to a scenario where there was no ULEZ. Modelling done by TfL as part of the ULEZ consultation process predicted that by the end of the first year of the scheme ULEZ would result in a 45 per cent reduction in NO_x emissions from road transport in the central zone. After only 6 months two thirds of the expected emissions reductions in the first year have already been delivered.

Reductions in $PM_{2.5}$ emissions

Similarly, it has been estimated that between July and September 2019 $PM_{2.5}$ emissions from road transport reduced by 5 tonnes, a reduction of 13 per cent compared to a no ULEZ scenario. As discussed, total $PM_{2.5}$ emissions are more sensitive to changes in vehicle kilometres due to the dominance of non-exhaust particles. This will be addressed by policies in the Mayor's Transport Strategy that will reduce traffic volumes by encouraging mode shift from car to walking, cycling and using public transport. As a result, the Mayor aims for 80 per cent of all trips in London to be made on foot, by cycle or using public transport by 2041.

Reductions in CO_2 emissions

CO_2 emissions in the central zone are estimated to have reduced by 9800 tonnes, a reduction of 4 per cent, compared to a scenario with no ULEZ in place. Were the current vehicle compliance rate to continue for the rest of the year, CO_2 emissions in 2019 would be reduced by 30,000 tonnes compared to those estimated in the LAEI 2016, a reduction of 13 per cent. CO_2 emissions are also more sensitive to changes in vehicle kilometres due to the dependence on fuel use.

Summary of emissions reductions

Table 3. Summary of emissions reductions in central zone

Pollutant	Comparison to “no ULEZ” scenario, July – September 2019	
	Reduction [tonnes]	Reduction [per cent]
NO_x	200	31%
$PM_{2.5}$	5	13%
CO_2	9,800	4%

Table 3 presents the summary of emissions reductions by pollutant. In future analysis, once more data is available, fleet composition estimates will be revised to take account of a full year of data and consider other changes in vehicle types, such as proportions of petrol and diesel cars, and further assessment of traffic flows. Further emissions calculations will be carried out for a one-year evaluation report including the impact of the central London ULEZ on road transport NO_x, $PM_{2.5}$ and CO_2 emissions in both inner and outer London.

Traffic flows

Transport for London uses automatic traffic count data at representative sites across London to monitor changes in traffic flows. These sites provide total traffic flows (for all vehicles) for each hour of the day. In this section the sites have been averaged over each month to allow estimates of changes in traffic flows in central, inner and outer London to be determined. Missing data for outer London flows since July will be updated in future reporting.

Table 4: Change in average 24-hour traffic flows in London from 2018 to 2019

	All Days of week			Weekdays			Weekends		
Comparison 2019 to 2018	**Central**	**Inner**	**Outer**	**Central**	**Inner**	**Outer**	**Central**	**Inner**	**Outer**
January	0%	-1%	2%	0%	-1%	2%	-1%	-1%	2%
February	0%	-1%	2%	0%	-1%	2%	0%	-2%	2%
March	2%	2%	4%	1%	2%	3%	4%	3%	6%
April	-2%	-2%	2%	-2%	-1%	2%	-3%	-2%	1%
May	-3%	-1%	1%	-2%	-2%	1%	-6%	0%	1%
June	-5%	0%	0%	-5%	0%	0%	-6%	1%	0%
July	-5%	-1%	na	-5%	-2%	na	-5%	0%	na
August	-8%	-4%	na	-7%	-4%	na	-9%	-3%	na
September	-9%	-2%	na	-9%	-2%	na	-11%	-1%	na

Traffic flows change across the year reflecting seasonal patterns such as holiday periods. Therefore, the best way to evaluate a change in traffic flow is to compare to the same period in previous years. In Table 4 monthly data for 2019 has been compared to 2018 and the percentage change in average flows calculated.

The table shows that in early 2019 there was very little change in average traffic flows in central and inner London when compared to 2018, whilst there was around 2 per cent increase in outer London. Traffic in inner and outer London between April and July varied by up to a couple of percent compared to the same months in 2018. However, after March reductions in average traffic flows of around 3 – 9 per cent are reported in central London when compared to the previous year. Similar estimates have been seen across both weekdays and weekends.

This is an indication that the introduction of the ULEZ is contributing to a reduction in traffic flows in central London. However, it is too soon to fully attribute these changes solely to ULEZ, as more data is required for analysis over a longer period.

When comparing weekdays, a similar pattern is seen – whereby changes in central London in 2018 are greater than those for inner London. For weekends, the difference appears to be greater still. This is likely to reflect the fact that weekends are now subject to a charge for the first time, unlike congestion charging which only affects weekdays.

Analysis of changes in traffic flows across different times of the day has also been analysed. The results are similar to those seen for 24 hour data. However, the data suggests more substantial differences between 2018 and 2019 in the evening, late evening and night time hours – which are hours where charges have not been applied before.

Traffic flow changes are still preliminary, and data will continue to be collected over the coming months in order to understand if trends are sustained, and how these vary across the different times of day and weekends.

Number of vehicles and compliance rates

FIRST MONTH – changes in vehicle numbers and compliance (March 2019 – April 2019)

Table 5 compares vehicle numbers and compliance rates for the month immediately before the scheme was introduced (March 2019) and the scheme's first month of operation (April 2019). As explained earlier in this report, this excludes non-typical days.

The changes below capture the more immediate effect following the launch of the scheme and does not take into account those who changed their behaviour ahead of time in preparation for the scheme.

Table 5. Average number and proportion of compliant vehicles detected in the zone per 'typical' day during CC hours March 19 – April 19

	Number of vehicles driving in the charging zone per day during CC hours			Proportions of vehicles driving in the charging zone during CC hours	
Date	**Unique vehicles detected in zone***	**Non-compliant vehicles**	**Compliant vehicles**	**Non-compliant vehicles**	**Compliant vehicles**
Mar - 19	91,035	35,578	55,457	39.1%	60.9%
Apr – 19	89,380	26,195	63,185	29.3%	70.7%
Change	-1,655	-9,383	7,728	Decrease of 9.8 percentage points	Increase of 9.8 percentage points
% change	-1.8%	-26.4%	13.9%	-25.0%	16.1%

*not representative of traffic flow

Key impacts of the first month of the scheme compared to the previous month:

- In the first month of operation (excluding non-typical days) the compliance rate with the ULEZ standards in congestion charging hours was around 71 per cent. This is much higher than the 61 per cent in March 2019

- There was a large reduction in the number of older, more polluting, non-compliant vehicles detected in the zone: some 9,383 fewer on an average ‘typical’ day, a reduction of over a quarter

FIRST SIX MONTHS – changes in vehicle numbers and compliance (March 2019 – September 2019)

Table 6 compares vehicle numbers and compliance rates for the month immediately before the scheme was introduced (March 2019) and the scheme's first six months in operation. This excludes non-typical days for April 2019. The table below captures the more immediate effect following the launch of the scheme and does not take into account those who changed their behaviour ahead of time in preparation for the scheme, this is captured in the pre-compliance data presented later in this report.

Table 6. Average number and proportion of unique compliant vehicles detected in the zone during CC hours March 19 – September 19

	Number of vehicles driving in the charging zone per day during CC hours			Proportions of vehicles driving in the charging zone during CC hours	
Date	**Unique vehicles detected in zone***	**Non-compliant vehicles**	**Compliant vehicles**	**Non-compliant vehicles**	**Compliant vehicles**
March 19	91,035	35,578	55,457	39.1%	60.9%
April 19	89,380	26,195	63,185	29.3%	70.7%
May 19	88,796	25,610	63,186	28.8%	71.2%
June 19	87,113	24,549	62,564	28.2%	71.8%
July 19	83,899	23,054	60,844	27.5%	72.5%
August 19	80,128	21,133	58,994	26.4%	73.6%
Sept 19	85,854	22,133	63,721	25.8%	74.2%
Change March – Sept 19	-5,181	-13,445	8,264	Decrease of 13.3 percentage points	Increase of 13.3 percentage points
% change	-5.7%	-37.8%	14.9%	-34.0%	21.8%

*not representative of traffic flow

Key impacts of the first six months of the scheme compared to March 2019 (the month before the scheme was implemented):

- In September 2019 the compliance rate with the ULEZ standards was 74 per cent. This is much higher than the 61 per cent in March 2019.
- From March – September 2019 there was a large reduction in the number of older, more polluting, non-compliant vehicles detected in the zone: some 13,445 fewer on an average day, a reduction of around 38 per cent.
- There was around a 34 per cent decrease in the proportion of vehicles in the central zone that were non-compliant between March and September 2019.

PRE- COMPLIANCE – changes in vehicle numbers and compliance (February 2017 – March 2019)

Table 7 below shows the change in the number of vehicles detected in the zone and the compliance level between February 2017 and March 2019. This data was released in April 2019 to coincide with the launch of the scheme.[6]

Table 7. Average number and proportion of unique compliant vehicles detected in the zone per day during CC hours February 17 – March 19

	Number of vehicles driving in the charging zone per day during CC hours			Proportions of vehicles driving in the charging zone during CC hours	
Date	**Unique vehicles detected in zone***	**Non-compliant vehicles**	**Compliant vehicles**	**Non-compliant vehicles**	**Compliant vehicles**
Feb 17	102,493	62,310	40,184	60.8%	39.2%
March 19	91,035	35,578	55,457	39.1%	60.9%
Change Feb 17 – March 19	-11,458	-26,732	+15,273	Decrease of 21.7 percentage points	Increase of 21.7 percentage points
% change	-11%	-43%	+38%	-35.7%	55.4%

*not representative of traffic flow

As Table 7 indicates, the proportion of compliant vehicles detected in the Central London ULEZ zone rose from 39 per cent in February 2017 (when the Mayor confirmed the introduction of the T-charge) to 61 per cent in March 2019. This represents a 55 per cent increase in the proportion of compliant vehicles detected in the zone.

The proportion of vehicles that are compliant is the best way of comparing changes in the vehicle fleet, given the number of unique vehicles detected in the zone also changed over this period.

[6] https://www.london.gov.uk/press-releases/mayoral/ulez-launches-in-central-london

PRE- COMPLIANCE and LATEST MONTH – changes in vehicle numbers and compliance (February 2017 – September 2019)

Table 8 shows the change in vehicle compliance from February 2017 to September 2019. This is presented as an absolute change in the number of vehicles detected, the change in the percentage of vehicles that are compliant, and also the change in the proportion of vehicles that are compliant.

Table 8. Average number and proportion of unique compliant vehicles detected in the zone during CC hours February 17 – September 19

	Number of vehicles driving in the charging zone per day during CC hours			Proportions of vehicles driving in the charging zone during CC hours	
Date	**Unique vehicles detected in zone***	**Non-compliant vehicles**	**Compliant vehicles**	**Non-compliant vehicles**	**Compliant vehicles**
Feb 17	102,493	62,310	40,184	60.8%	39.2%
Sept 19	85,854	22,133	63,721	25.8%	74.2%
Change Feb 17 – Sept 19	-16,639	-40,177	23,537	Decrease of 35.0 percentage points	Increase of 35.0 percentage points
% change	-16.2%	-64.5%	58.6%	-57.6%	89.3%

*not representative of traffic flow

Key findings for the first six months of the scheme compared to February 2017, taking pre-compliance into account:

- From February 2017 to September 2019 there was a large reduction in the number of older, more polluting, non-compliant vehicles detected in the zone: some 40,177 fewer on an average day, a reduction of 65 per cent.

- There was an 89 per cent increase in the proportion of vehicles detected in the zone that met the ULEZ standards between February 2017 and September 2019. As mentioned previously, the proportion of vehicles that are compliant is the best way of comparing changes in the vehicle fleet, given the number of unique vehicles detected in the zone also changed over this period.

Comparison between congestion charge hours and 24 hour data

To ensure a fair comparison with historic data the previous section compares data for CC hours only. Table 9 below includes vehicle numbers and compliance rates for CC hours and 24 hour average daily vehicles detected in the zone for September 2019.

Table 9. Comparison of average unique daily vehicles for September 2019 for CC hours and 24 hour data

Time	Number of vehicles driving in the charging zone per day			Proportions of vehicles driving in the charging zone	
	Unique vehicles detected in zone*	Non-compliant vehicles	Compliant vehicles	Non-compliant vehicles	Compliant vehicles
CC hours	85,854	22,133	63,721	25.8%	74.2%
24 hour	116,601	27,044	89,557	23.2%	76.8%

*not representative of traffic flow

As was the case in the preceding months, the majority of unique vehicles detected in the zone (around three quarters) were detected during CC hours. There was a slight increase in compliance rate between CC hours and 24-hour data, this indicates that vehicles entering the zone in the evening and on weekends were less likely to be older more polluting vehicles.

Table 10. Average number and proportion of unique compliant vehicles detected in the zone over a 24 hour period from April – September 2019

Time	Number of vehicles driving in the charging zone per day			Proportions of vehicles driving in the charging zone	
	Unique vehicles detected in zone*	Non-compliant vehicles	Compliant vehicles	Non-compliant vehicles	Compliant vehicles
April 19	121,664	32,137	89,527	26.4%	73.6%
May 19	117,289	30,146	87,144	25.7%	74.3%
June 19	118,021	29,434	88,588	24.9%	75.1%
July 19	116,082	28,562	87,520	24.6%	75.4%
August 19	108,932	25,802	83,130	23.7%	76.3%
Sept 19	116,601	27,044	89,557	23.2%	76.8%

*not representative of traffic flow

Table 10 above shows the number of unique vehicles detected in the zone and compliance rate for an average day (24 hours) from April to September 2019. For all months the 24 hour compliance rate was higher than the CC hours compliance rate.

As discussed, data before April 2019 was collected during congestion charging (CC) hours only and we are therefore unable to compare 24 hour data to a time before the ULEZ was introduced.

Charge payments and penalty charges

On an average day in September 2019 around 27,044 non-compliant, unique vehicles were detected in the zone. Of these:

- Around 14,026 (52%) paid the charge (3,488 ULEZ web or call centre payments, 6,787 Auto Pay payments and 3,751 ULEZ Fleet charge payments)
- Around 2,611 (10%) were in contravention of the scheme and incurred a penalty charge
- Around 10,407 (38%) were not required to pay the daily ULEZ charge as they are eligible for a 100% discount or exemption

Appendix 1: Methodology

We are grateful to Dr Gary Fuller, King's College London who kindly provided peer review support and comments on this methodology.

Air quality concentrations

All air quality data analysis was performed using the open source statistical software R.[7] Air pollutant concentration monitoring data across London is publicly available from the London Air Quality Network and Air Quality England websites. In order to present the full context for any changes in air pollutant concentrations, the period from 1 January 2010 to 1 October 2019 has been analysed.

Air quality monitoring stations are funded and maintained by the London boroughs, Defra, Transport for London and Business Improvement Districts. Over the period 2010 to 2019 many monitoring stations have opened, moved or closed. Figure 6 shows how the number of sites in each zone has changed over this period.

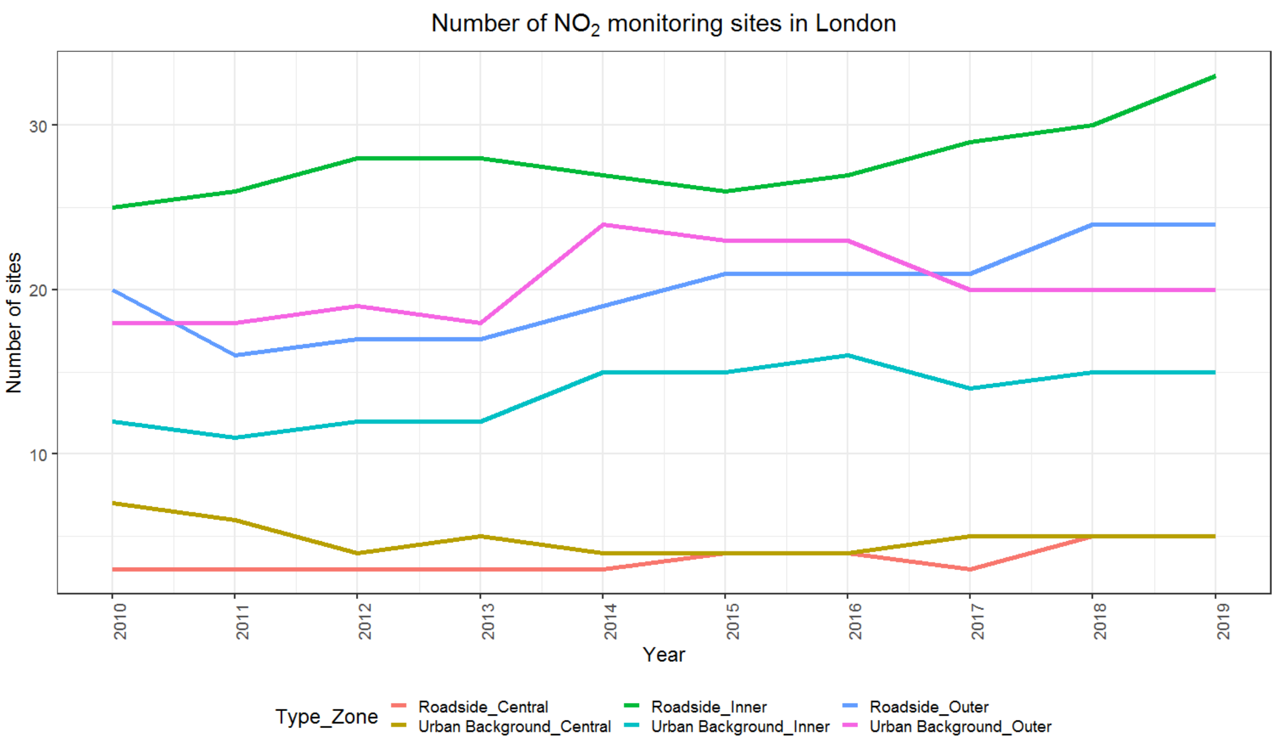

Figure 6. Number of NO_2 monitoring sites in London by zone and site type

[7] https://www.r-project.org/

This analysis includes all historic monitoring sites in London categorised as “Roadside” or “Urban Background”. For this analysis “Suburban” and “Urban Centre” sites have been treated as “Urban Background”. “Industrial”, “Airport” and “Kerbside” sites have not been included as they are fewer in number and not typical of population exposure. The table below includes a list of all 140 sites that recorded NO_2 concentrations in London between 2010 and 2019 and were included in the NO_2 trend analysis presented in this report

Table 11. Sites included in NO_2 trend analysis

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
BG1	Barking and Dagenham - Rush Green	Urban Background	Barking and Dagenham	King's College London	Outer
BG2	Barking and Dagenham - Scrattons Farm	Urban Background	Barking and Dagenham	King's College London	Outer
BL0	Camden - Bloomsbury	Urban Background	Camden	Defra	Central
BN2	Barnet - Chalgrove School	Urban Background	Barnet	Ricardo-AEA	Outer
BQ7	Bexley - Belvedere West	Urban Background	Bexley	King's College London	Outer
BT1	Brent - Kingsbury	Urban Background	Brent	King's College London	Outer
BT4	Brent - Ikea	Roadside	Brent	King's College London	Outer
BT6	Brent - John Keble Primary School	Roadside	Brent	King's College London	Inner
BT7	Brent - St Marys Primary School	Urban Background	Brent	King's College London	Inner
BT8	Brent - ARK Franklin Primary Academy	Roadside	Brent	King's College London	Inner
BX1	Bexley - Slade Green	Urban Background	Bexley	King's College London	Outer
BX2	Bexley - Belvedere	Urban Background	Bexley	King's College London	Outer
BX7	Bexley - Thames Road North	Roadside	Bexley	King's College London	Outer
BX8	Bexley - Thames Road South	Roadside	Bexley	King's College London	Outer
BY7	Bromley - Harwood Avenue	Roadside	Bromley	King's College London	Outer
CD3	Camden - Shaftesbury Avenue	Roadside	Camden	King's College London	Central
CD4	Camden - St Martins College (NOX 1)	Urban Background	Camden	King's College London	Central
CD5	Camden - St Martins College (NOX 2)	Urban Background	Camden	King's College London	Central
CD9	Camden - Euston Road	Roadside	Camden	King's College London	Inner
CR2	Croydon - Purley Way	Roadside	Croydon	King's College London	Outer
CR4	Croydon - George Street	Roadside	Croydon	King's College London	Outer
CR7	Croydon - Purley Way A23	Roadside	Croydon	King's College London	Outer

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
CR9	Croydon - Park Lane	Roadside	Croydon	King's College London	Outer
CT1	City of London - Senator House	Urban Background	City of London	King's College London	Central
CT3	City of London - Sir John Cass School	Urban Background	City of London	King's College London	Central
CT4	City of London - Beech Street	Roadside	City of London	King's College London	Central
CT6	City of London - Walbrook Wharf	Roadside	City of London	King's College London	Central
CY1	Croydon - Crystal Palace Parade	Roadside	Croydon	King's College London	Outer
EA1	Ealing - Ealing Town Hall	Urban Background	Ealing	King's College London	Outer
EA2	Ealing - Acton Town Hall	Roadside	Ealing	King's College London	Inner
EA6	Ealing - Hanger Lane Gyratory	Roadside	Ealing	King's College London	Outer
EA7	Ealing - Southall	Urban Background	Ealing	King's College London	Outer
EI1	Ealing - Western Avenue	Roadside	Ealing	King's College London	Inner
EI2	Ealing - Southall Railway	Roadside	Ealing	King's College London	Outer
EI3	Ealing - Acton Vale	Urban Background	Ealing	King's College London	Inner
EN1	Enfield - Bush Hill Park	Urban Background	Enfield	King's College London	Outer
EN4	Enfield - Derby Road	Roadside	Enfield	King's College London	Outer
EN5	Enfield - Bowes Primary School	Roadside	Enfield	King's College London	Inner
EN7	Enfield - Prince of Wales School	Urban Background	Enfield	King's College London	Outer
GB6	Greenwich - Falconwood	Roadside	Greenwich	King's College London	Outer
GN0	Greenwich - A206 Burrage Grove	Roadside	Greenwich	King's College London	Outer
GN3	Greenwich - Plumstead High Street	Roadside	Greenwich	King's College London	Outer
GN4	Greenwich - Fiveways Sidcup Rd A20	Roadside	Greenwich	King's College London	Outer
GN5	Greenwich - Trafalgar Road (Hoskins St)	Roadside	Greenwich	King's College London	Inner
GN6	Greenwich - John Harrison Way	Roadside	Greenwich	King's College London	Inner
GR4	Greenwich - Eltham	Urban Background	Greenwich	King's College London	Outer
GR5	Greenwich - Trafalgar Road	Roadside	Greenwich	King's College London	Inner
GR7	Greenwich - Blackheath	Roadside	Greenwich	King's College London	Inner
GR8	Greenwich - Woolwich Flyover	Roadside	Greenwich	King's College London	Inner

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
GR9	Greenwich - Westhorne Avenue	Roadside	Greenwich	King's College London	Inner
GV1	Westminster - Ebury Street (Grosvenor)	Roadside	Westminster	King's College London	Inner
GV2	Westminster - Duke Street (Grosvenor)	Roadside	Westminster	King's College London	Central
HF4	Hammersmith and Fulham - Shepherd's Bush	Roadside	Hammersmith and Fulham	Ricardo-AEA	Inner
HF5	Hammersmith and Fulham - Hammersmith Town Centre	Roadside	Hammersmith and Fulham	Ricardo-AEA	Inner
HG1	Haringey - Haringey Town Hall	Roadside	Haringey	King's College London	Inner
HG2	Haringey - Priory Park	Urban Background	Haringey	King's College London	Inner
HG4	Haringey - Priory Park South	Urban Background	Haringey	King's College London	Inner
HI0	Hillingdon - Keats Way	Urban Background	Hillingdon	Defra	Outer
HI1	Hillingdon - South Ruislip	Roadside	Hillingdon	Ricardo-AEA	Outer
HI2	Hillingdon - Hillingdon Hospital	Roadside	Hillingdon	King's College London	Outer
HI3	Hillingdon - Oxford Avenue	Urban Background	Hillingdon	Ricardo-AEA	Outer
HIL1	Hillingdon - Harmondsworth	Urban Background	Hillingdon	Ricardo-AEA	Outer
HIL5	Hillingdon - Hayes	Roadside	Hillingdon	Ricardo-AEA	Outer
HK4	Hackney - Clapton	Urban Background	Hackney	King's College London	Inner
HK6	Hackney - Old Street	Roadside	Hackney	King's College London	Inner
HP1	Lewisham - Honor Oak Park	Urban Background	Lewisham	King's College London	Inner
HR1	Harrow - Stanmore	Urban Background	Harrow	King's College London	Outer
HR2	Harrow - Pinner Road	Roadside	Harrow	King's College London	Outer
HS010	Hounslow - Boston Manor Park	Roadside	Hounslow	Ricardo-AEA	Outer
HS2	Hounslow - Cranford	Urban Background	Hounslow	Ricardo-AEA	Outer
HS4	Hounslow - Chiswick	Urban Background	Hounslow	Ricardo-AEA	Inner
HS5	Hounslow - Brentford	Roadside	Hounslow	Ricardo-AEA	Outer
HS6	Hounslow - Heston	Roadside	Hounslow	Ricardo-AEA	Outer
HS7	Hounslow - Hatton Cross	Urban Background	Hounslow	Ricardo-AEA	Outer
HS8	Hounslow - Gunnersbury	Roadside	Hounslow	Ricardo-AEA	Outer
HS9	Hounslow - Feltham	Urban Background	Hounslow	Ricardo-AEA	Outer
HV1	Havering - Rainham	Roadside	Havering	King's College London	Outer
HV3	Havering - Romford	Roadside	Havering	King's College London	Outer

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
IS2	Islington - Holloway Road	Roadside	Islington	King's College London	Inner
IS6	Islington - Arsel	Urban Background	Islington	King's College London	Inner
KC1	Kensington and Chelsea - North Ken	Urban Background	Kensington and Chelsea	King's College London	Inner
KC2	Kensington and Chelsea - Cromwell Road	Roadside	Kensington and Chelsea	Ricardo-AEA	Inner
KC3	Kensington and Chelsea - Knightsbridge	Roadside	Kensington and Chelsea	Ricardo-AEA	Inner
KC4	Kensington and Chelsea - Chelsea	Roadside	Kensington and Chelsea	Ricardo-AEA	Inner
KC5	Kensington and Chelsea - Earls Court Road	Roadside	Kensington and Chelsea	Ricardo-AEA	Inner
KG1	Kensington and Chelsea - Green Screen RS	Roadside	Kensington and Chelsea	King's College London	Inner
KG2	Kensington and Chelsea - Green Screen BG	Urban Background	Kensington and Chelsea	King's College London	Inner
KT3	Kingston - Sopwith Way	Roadside	Kingston	King's College London	Outer
KT4	Kingston - Tolworth Broadway	Roadside	Kingston	King's College London	Outer
KT5	Kingston - Cromwell Road	Roadside	Kingston	King's College London	Outer
KT6	Kingston - Kingston Vale	Roadside	Kingston	King's College London	Outer
LB1	Lambeth - Christchurch Road	Roadside	Lambeth	King's College London	Inner
LB3	Lambeth - Loughborough Junct	Urban Background	Lambeth	King's College London	Inner
LB6	Lambeth - Streatham Green	Urban Background	Lambeth	King's College London	Outer
LH0	Hillingdon - Harlington	Urban Background	Hillingdon	King's College London	Outer
LW1	Lewisham - Catford	Urban Background	Lewisham	King's College London	Inner
LW2	Lewisham - New Cross	Roadside	Lewisham	King's College London	Inner
LW4	Lewisham - Loampit Vale	Roadside	Lewisham	King's College London	Inner
ME1	Merton - Morden Civic Centre	Roadside	Merton	King's College London	Outer
ME9	Merton - Morden Civic Centre 2	Roadside	Merton	King's College London	Outer
NB1	Westminster - Strand (Northbank BID)	Roadside	Westminster	King's College London	Central
NEW2	Newham - Cam Road	Roadside	Newham	Ricardo-AEA	Inner
NEW3	Newham - Wren Close	Urban Background	Newham	Ricardo-AEA	Inner
NM2	Newham - Cam Road	Roadside	Newham	King's College London	Inner
NM3	Newham - Wren Close	Urban Background	Newham	King's College London	Inner

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
RB1	Redbridge - Perth Terrace	Urban Background	Redbridge	King's College London	Outer
RB4	Redbridge - Gardner Close	Roadside	Redbridge	King's College London	Inner
RB5	Redbridge - South Woodford	Roadside	Redbridge	King's College London	Outer
RB7	Redbridge - Ley Street	Urban Background	Redbridge	King's College London	Outer
RHG	Richmond - Chertsey Road	Roadside	Richmond	King's College London	Outer
RI1	Richmond - Castelu	Roadside	Richmond	King's College London	Inner
RI2	Richmond - Barnes Wetlands	Urban Background	Richmond	King's College London	Inner
SIPS	Hillingdon - Sipson	Urban Background	Hillingdon	Ricardo-AEA	Outer
SK5	Southwark - A2 Old Kent Road	Roadside	Southwark	King's College London	Inner
SK6	Southwark - Elephant and Castle	Urban Background	Southwark	King's College London	Central
SK7	Southwark - Heygate	Urban Background	Southwark	King's College London	Inner
SK8	Southwark - Tower Bridge Road	Roadside	Southwark	King's College London	Inner
ST3	Sutton - Carshalton	Urban Background	Sutton	King's College London	Outer
TD0	Richmond - National Physical Laboratory	Urban Background	Richmond	King's College London	Outer
TH001	Tower Hamlets - Millwall Park	Urban Background	Tower Hamlets	Ricardo-AEA	Inner
TH002	Tower Hamlets - Victoria Park	Urban Background	Tower Hamlets	Ricardo-AEA	Inner
TH1	Tower Hamlets - Poplar	Urban Background	Tower Hamlets	King's College London	Inner
TH2	Tower Hamlets - Mile End Road	Roadside	Tower Hamlets	King's College London	Inner
TH4	Tower Hamlets - Blackwall	Roadside	Tower Hamlets	King's College London	Inner
TH5	Tower Hamlets - Victoria Park	Urban Background	Tower Hamlets	King's College London	Inner
TH6	Tower Hamlets - Millwall Park	Urban Background	Tower Hamlets	King's College London	Inner
WA2	Wandsworth - Wandsworth Town Hall	Urban Background	Wandsworth	King's College London	Inner
WA8	Wandsworth - Putney High Street Facade	Roadside	Wandsworth	King's College London	Inner
WA9	Wandsworth - Putney	Urban Background	Wandsworth	King's College London	Inner
WAA	Wandsworth - Battersea	Roadside	Wandsworth	King's College London	Inner
WAB	Wandsworth - Tooting High Street	Roadside	Wandsworth	King's College London	Outer
WAC	Wandsworth - Lavender Hill (Clapham Jct)	Roadside	Wandsworth	King's College London	Inner

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
WL1	Waltham Forest - Dawlish Road	Urban Background	Waltham Forest	Ricardo-AEA	Inner
WL5	Waltham Forest - Leyton	Urban Background	Waltham Forest	Ricardo-AEA	Inner
WM0	Westminster - Horseferry Road	Urban Background	Westminster	Defra	Central
WM4	Westminster - Charing Cross Library	Roadside	Westminster	King's College London	Central
WM5	Westminster - Covent Garden	Urban Background	Westminster	King's College London	Central
WM8	Westminster - Victoria	Urban Background	Westminster	King's College London	Inner
WM9	Westminster - Victoria (Victoria BID)	Roadside	Westminster	King's College London	Inner
WMA	Westminster - Buckingham Palace Road	Roadside	Westminster	King's College London	Inner
WMB	Westminster - Oxford Street East	Roadside	Westminster	King's College London	Central
WMC	Westminster - Cavendish Square	Roadside	Westminster	King's College London	Central

Monthly average concentration trends for NO_2 and $PM_{2.5}$

In order to assess long term trends, monthly average concentrations grouped by site type and London zone (Central/Inner/Outer) were calculated for NO_2 and $PM_{2.5}$. This is an update to the trend analysis carried out by King's College London for the London Environment Strategy.[8]

Sites with less than 75% data capture in a given month were excluded and missing monthly data was interpolated. This data capture threshold is consistent with that used for EU reporting when calculating daily mean concentrations. This was calculated using openair — an R package for air quality data analysis. Trends were then created using the LOESS smoothing function which "de-seasonalized" the data.[9]

Reductions from early February 2017 (when changes associated with the ULEZ began) to September 2019 (the most recent period for which data is available) have then be calculated using three-month averages (referred to as quarters).

NO_2 roadside increment (R_{inc})

To analyse the changes in pollution concentrations from local road traffic emissions (i.e. changes attributable to the ULEZ), trends in NO_2 roadside increments were assessed. The roadside increment isolates the changes in concentration at the roadside from changes in background concentrations, using the equation below:

$$R_{inc} = roadside\ concentration - urban\ background\ concentration$$

[8] London Environment Strategy (pg 46), Greater London Authority, 2018
[9] Cleveland et al, STL: a seasonal-trend decomposition procedure based on loess, 1990

This removes the impact of changes over time due to processes at the regional scale (such a meteorological conditions, boundary layer dynamics, policies outside the city, etc.) as described in more detail by Lenschow et al[10] and Font and Fuller[11] in a London context.

For this analysis a R_{inc} was derived from hourly data. A single hourly roadside increment was calculated per site by averaging concentrations across all outer London urban background sites. This approach was adopted for three reasons (following similar methodology to Font and Fuller 2016).

- The use of a single background hourly value allows R_{inc} to be directly compared between different roadside locations
- Averaging across outer urban background sites creates a complete time series for the period being assessed (2010 – 2019) without interpolation
- Averaging across outer urban background sites ensures R_{inc} follows general trends across a number of sites, although bias can be induced from changes to site availability

In addition, the outer London R_{inc} has been used as a predictor for “business as usual” or in other words the change in R_{inc} that would have happened irrespective of the Ultra Low Emission Zone.

The average concentrations across the outer London urban background sites was subtracted from the average central roadside, inner roadside and outer roadside concentrations. This was done on an hourly basis. Monthly averages were calculated excluding sites with less than 75 per cent data capture, values were then linearly interpolating for missing months. This was then aggregated by zone (Central / Inner / Outer London).

[10] Lenschow et al, Some ideas about the sources of PM10, 2001
[11] Font and Fuller, Did policies to abate atmospheric emissions from traffic have a positive effect in London? 2016

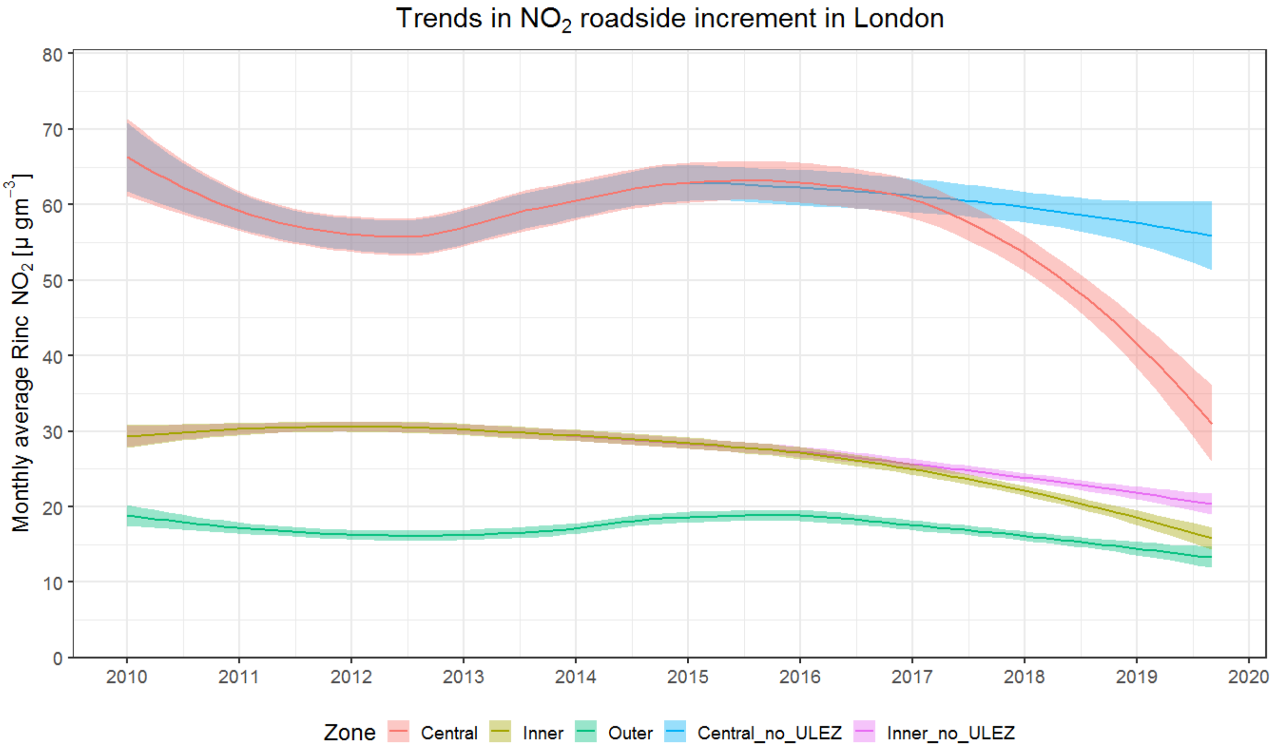

Figure 7. Monthly average NO_2 roadside increment by zone

The curves in Figure 7 are the LOESS trends of monthly average NO_2 roadside increment in central, inner and outer London as well as the central and inner “no ULEZ” scenario roadside increments.

Changes associated with the ULEZ were expected to begin in central London at the beginning of 2017. However, there is also some reduction in the NO_2 roadside increment concentrations in outer London. Independent of schemes such as the ULEZ, a certain proportion of older vehicles are replaced each month. As newer vehicles produce less NO_x emissions, fleet turnover will slowly clean up the vehicle fleet. This means that, in general, if traffic volumes were to remain constant, the roadside increment concentration R_{inc} would be expected to gradually decrease as newer vehicles enter the fleet. The reductions in outer London R_{inc} reflect turnover of the fleet as well as changes at a regional level. This can be seen as the reduction that would have occurred London-wide, regardless of the introduction of the ULEZ.

The blue and purple “no ULEZ” curves in Figure 7 are a prediction of central and inner London roadside increments if there was no ULEZ (assuming reductions at central and inner London roadside sites would follow the trend measured at outer London sites). The difference between the red curve and blue curve in Figure 7 represents the reduction in traffic contribution to NO_2 above that expected from “no ULEZ” scenario. This is an estimate for the impact of the preparation and introduction of the ULEZ, including upgrading the bus fleet in central London.

The no ULEZ scenario was calculated by subtracting the reduction in R_{inc} in outer London compared to January 2017 from the R_{inc} in central/ inner London in January 2017.

$$R_{inc}^{cenral\ no\ ulez}{}_{i} = R_{inc}^{central}{}_{Jan17} - \left(R_{inc}^{outer}{}_{Jan17} - R_{inc}^{outer}{}_{i} \right)$$

It is therefore important to remove these “no ULEZ” concentrations to isolate the NO_2 reduction in central and inner London that can be attributed to the ULEZ. This has been done using the equation below:

$$ULEZ\ impact = R_{inc}^{no\ ULEZ} - R_{inc}^{central}$$

Impact of ULEZ on monthly average NO_2

The equation above produces an estimate of the impact (in ug m^{-3}) of the ULEZ at central and inner London roadside locations. This has been used to estimate “no ULEZ” monthly average NO_2 concentrations, as in Figure 3 in the report. This was done by adding the estimated ULEZ impact concentration (in ug m^{-3}) to the actual monthly average measurements.

Emissions estimate methodology

The emissions estimates were calculated using the proportion of the vehicle fleet made up of each Euro standard. The Euro standards are European regulations that a vehicle must comply with to be sold in the European Union. The Euro standards set emissions limits for pollutants such as nitrogen oxide (NO_x), particulate matter (PM) and carbon monoxide (CO).

London has a network of Automatic Number Plate Recognition (ANPR) cameras which are used to enforce the congestion charge and Ultra Low Emission Zone. Data from these cameras has been used to determine what proportion of the vehicle fleet is made up of each Euro standard.

The daily observations of vehicles by year of manufacture, Euro standard and type of vehicle (petrol car, diesel car, van) data has been averaged by quarter (8 April – June 2019, and July – 15 September 2019) in order to estimate how vehicles within the zone are changing over time.

This observed fleet has been compared to TfL’s estimate of the composition of the vehicle fleet in 2019 without the ULEZ in place, or “no ULEZ” scenario. This “no ULEZ” scenario includes assumptions on natural turnover of vehicles – reflecting that some cleaner vehicles will be coming into the central zone irrespective of introduction of the ULEZ, as owners and operators would have continued to buy new or newer vehicles even without ULEZ.

COPERT (Computer Program to calculate Emissions from Road Transport) emission factors have been used to estimate total emissions from the observed vehicle fleet. COPERT is an air quality transport model developed by the European Environment

Agency. The European Monitoring and Evaluation Program (EMEP) recommends COPERT as the preferred tool in the calculation of vehicle emissions, COPERT is widely used in modelling studies. The COPERT speed dependent emissions factors reflect the average real-world emissions of vehicles grouped by vehicle type, fuel and Euro standard. These are known to be higher than the type approval values. The version of COPERT used for this analysis is COPERT5.

COPERT5 emissions factors were used to determine the overall changes in road traffic vehicle emissions as a function of estimated vehicle speed, fleet composition (engine type and Euro standard), and average traffic flow on all road links in Central London, based on new fleet mix and "no ULEZ" scenario. For the updated fleet emissions estimates, a subsequent reduction in vehicle-kilometres (VKM) of 5 per cent has been applied to total VKM in order to reflect the recent changes in traffic flows within the ULEZ zone.

For CO_2 the new fleet estimate has also been compared to a similar set of data for 2016 (as used within the London Atmospheric Emissions Inventory) to estimate the emissions reduction the current fleet mix has delivered in comparison to 2016.

Further emissions estimates will be undertaken based on ANPR data and longer term traffic flow estimates, including observed changes in proportions of vehicle types and speeds.

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