MAYOR OF LONDON

LOW EMISSION BUS ZONES: EVALUATION OF THE FIRST SEVEN ZONES

November 2018

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Introduction

In August 2016 the Mayor of London announced London's first Low Emission Bus Zone programme. A total of twelve Low Emission Bus Zones are planned across London. This report reviews the progress to date now that over half of the Low Emission Bus Zones are in operation. All the remaining zones will be complete by the end of 2019.

What is a Low Emission Bus Zone?

Low Emission Bus Zones use buses with top-of-the-range engines and exhaust systems that meet or exceed the highest Euro VI emissions standards[1].

The zones have been prioritised in the worst air quality hotspots outside central London where buses contribute significantly to road transport emissions. All TfL buses operating in the central London Ultra Low Emission Zone will meet the Euro VI standard from April 2019.

The first zone was introduced along Putney High Street in March 2017 and was followed by a second Low Emission Bus Zone between Brixton Road and Streatham High Road in December 2017.

All 12 zones are set to be completed in 2019 and form a central part of the Mayor's far-reaching plans for a drastic clean-up of London's toxic air.

[1] Due to the length of the zones there are locations where non-compliant buses cross or travel for a short distance along a Low Emission Bus Zone, even though they do not serve a bus stop within the zone.

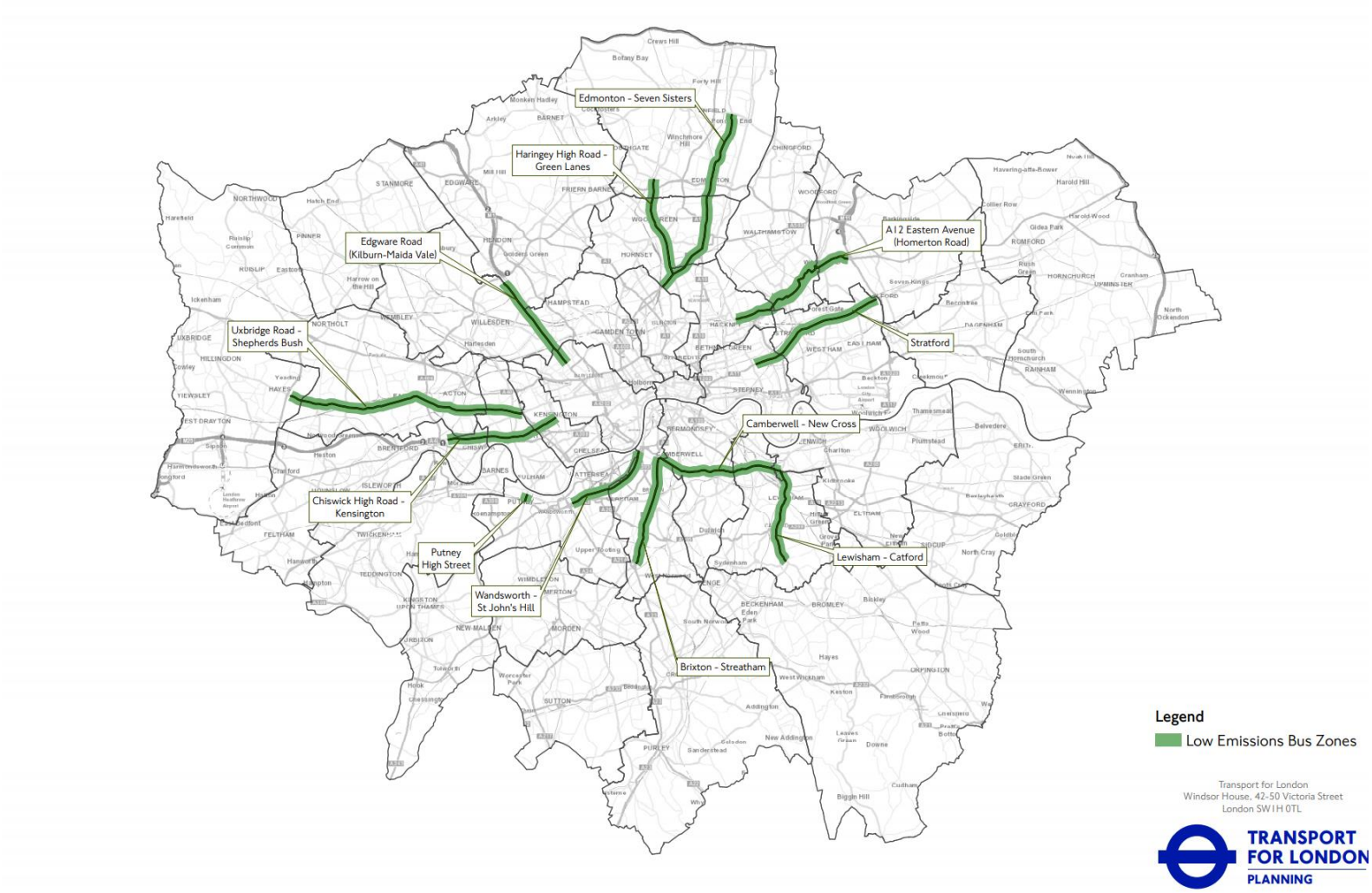

Figure 1: Map of the twelve proposed Low Emission Bus Zones in London

Low Emission Bus Zones in operation

Putney High Street from Putney Station to Putney Bridge Road – March 2017

Brixton to Streatham from Brixton Road, along Brixton Hill, Streatham Hill and Streatham High Road – December 2017

Camberwell to New Cross from Camberwell New Road, along Peckham High Street to New Cross Road – August 2018

Wandsworth to St John's Hill from Lavender Hill to Wandsworth Road – August 2018

Haringey from High Road to Green Lanes – August 2018

A12 Eastern Avenue from Homerton High Street along Homerton Road, Warren Road, Gainsborough Road, Cambridge Park Road to Eastern Avenue – October 2018

Edgware Road (Kilburn to Maida Vale) from Cricklewood Broadway via Shoot-Up Hill to Kilburn High Road – November 2018

Low Emission Bus Zones to be delivered by end of 2019

Lewisham to Catford from Bromley Road, along Lewisham High Street to Lewisham Road

Stratford from Mile End Road to Romford Road

Edmonton to Seven Sisters from Hertford Road High Street via Fore Street to Seven Sisters Road

Uxbridge Road to Shepherds Bush from Uxbridge Road via Ealing Broadway, The Vale to Uxbridge Road

Chiswick High Road to Kensington from Chiswick High Road via Hammersmith Broadway to Kensington High Street

Summary of data

Estimated annual NO_x emissions reductions from the buses operating on the completed Low Emission Bus Zones

Table 1. Reduction in NOx emissions as a result of the Low Emission Bus Zone

	Emissions before LEBZ (tonnes) (2016)	Emissions after LEBZ (tonnes) (2018)	Savings (tonnes)	Reduction
Putney High Street	20	3	17	87%
Brixton - Streatham	82	9	73	89%
Camberwell - New Cross	104	11	93	90%
Wandsworth - St. John's Hill	53	5	48	91%
High Road (Haringey) – Green Lanes	86	7	79	92%
A12 Eastern Avenue (Homerton Rd)	59	5	54	91%
Edgware Road (Kilburn to Maida Vale)	43	5	39	90%
Total	447	44	403*	90%

*For context, in 2013 the entire London bus fleet emitted 4841 tonnes of NO_x

NO_2 concentrations – where monitoring data available

Table 2 and **Table 3** show the reductions in annual and hourly NO_2 concentrations reported at monitoring stations in the Low Emission Bus Zone. We are only able to include data from a Low Emission Bus Zone where a monitoring station is located nearby. Low Emission Bus Zones with a monitoring station are listed below. The London boroughs are responsible for installing, maintaining and operating these monitoring stations.

It should be remembered that buses will only be one part of the traffic contributing to local pollution concentrations. Therefore, the resulting scope for any reductions in pollution concentrations as a result of the introduction of a Low Emission Bus Zone will vary by location.

Table 2. Reduction in annual average NO_2 concentrations at monitoring sites in Low Emission Bus Zones

	Annual average in 2016 [µg m^{-3}]	Annual average in 2018* [µg m^{-3}]	Reduction
Putney High Street (Façade)	110	58	47%
Putney High Street (Kerbside)	No data	66	N/A
Brixton - Streatham	118	98	17%
Camberwell - New Cross ǂ	46	43	11%
Wandsworth - St. John's Hill^ǂ	45	43	4%

* To November 2018 except for Brixton where data to August 2018 has been used (the monitoring station on Brixton Road suffered considerable damage from flooding and is being repaired).

ǂ The conversion to cleaner buses has only recently been completed on these routes, it will take more time for the annual average to be reduced.

^ The monitoring station at Wandsworth, Lavender Hill (part way down the Wandsworth to St John's Hill LEBZ) is set quite far back from the kerb and on an adjacent road. As a result, this monitor is not best placed to record roadside exposure on the LEBZ itself and results are less distinct than at the previously mentioned sites

Numbers of hours exceeding NO_2 hourly limit [200 µg m^{-3}] – where monitoring data available

Table 3. Reduction in annual average NO_2 concentrations at monitoring sites in Low Emission Bus Zones

	Hours in 2016	Hours in 2018*	Reduction
Putney High Street (Façade)^	403[2]	2	99%
Putney High Street (Kerbside)	1272	25	98%
Brixton - Streatham	539	83	85%
Camberwell - New Cross	0	0	-
Wandsworth - St. John's Hill	23	0	100%

* To November 2018 except for Brixton where data to August 2018 has been used (the monitoring station on Brixton Road suffered considerable damage from flooding and is being repaired).

^ There are two monitoring stations on Putney High Street. We primarily use the Putney High Street Façade monitoring station to calculate the benefits of the LEBZ as this is more representative of conditions that pedestrians will experience.

[2] Corrected April 2019 to reflect ratification.

Detailed analysis of the first seven Low Emission Bus Zones

Putney High Street

Putney High Street was the first Low Emission Bus Zone completed in March 2017.

Reduction in emissions from buses

Our modelling indicates that since becoming a Low Emission Bus Zone, the buses on Putney High Street emit on average 87 per cent less NO_x than previously, with some routes having reduced emissions by 92 percent.

As a result of cleaning up the buses on Putney High Street, these buses now emit 17 tonnes less NO_x per year than they did previously.

Annual average concentrations

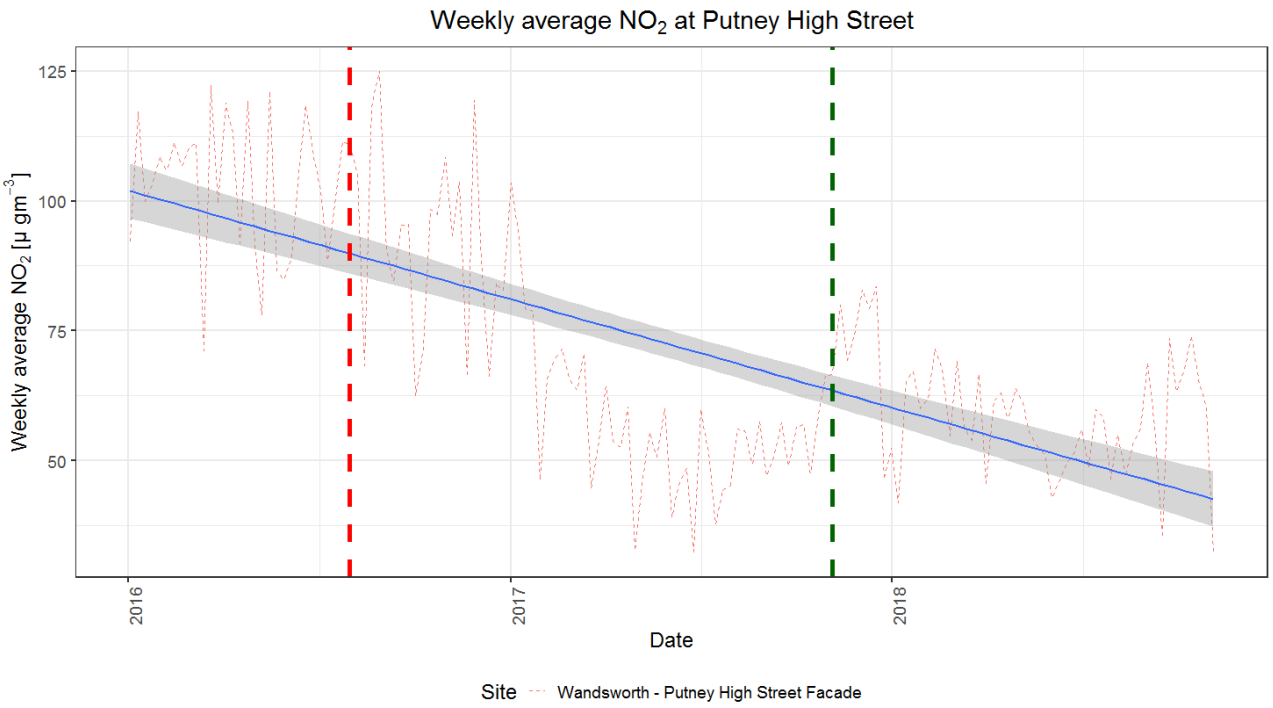

Figure 2: Weekly average concentrations of NO_2 at Putney High Street (Façade)

In **Figure 2** above the vertical red dashed line indicates the date when delivery of the Low Emission Bus Zone began. After this, non-Euro VI buses/non-compliant buses on this route were retrofitted or replaced with new buses.

The green vertical dashed line in **Figure 2** indicates the date when the Low Emission Bus Zone was complete.

There are two monitoring stations on Putney High Street. We have used the Putney High Street Façade monitoring station to calculate the benefits of the Low Emission Bus Zone as this is more representative of conditions that pedestrians will experience.

There is a legal limit set for the annual average of NO_2 of 40 µg m^{-3}.

In Putney High Street in 2016 annual average NO_2 was 110 µg m^{-3}.

In 2018 to November the annual average has been 58 µg m^{-3}. Whilst there is still work to be done in order to meet the legal limit this is a reduction of 47% in less than two years.

Hourly average concentrations

There is a legal limit set at 18 for the number of times the hourly average of NO_2 is allowed to exceed 200 µg m^{-3} per year.

In Putney High Street in 2016 there were 807 hours that exceeded the hourly limit.

In 2018 to November there have only been two hours of exceedance. Whilst there is still work to be done to meet the legal limit this is a reduction of 99% per cent in less than two years.

Brixton Road

Brixton Road was the second Low Emission Bus Zone completed in December 2017.

Reduction in emissions from buses

Our modelling indicates that since becoming a Low Emission Bus Zone, the buses on Brixton Road emit on average 89 per cent less NO_x than previously, with some routes having reduced emissions by 93 percent.

As a result of cleaning up the buses on Brixton Road, these buses now emit 73 tonnes less NO_x per year than they did previously.

Annual average concentrations

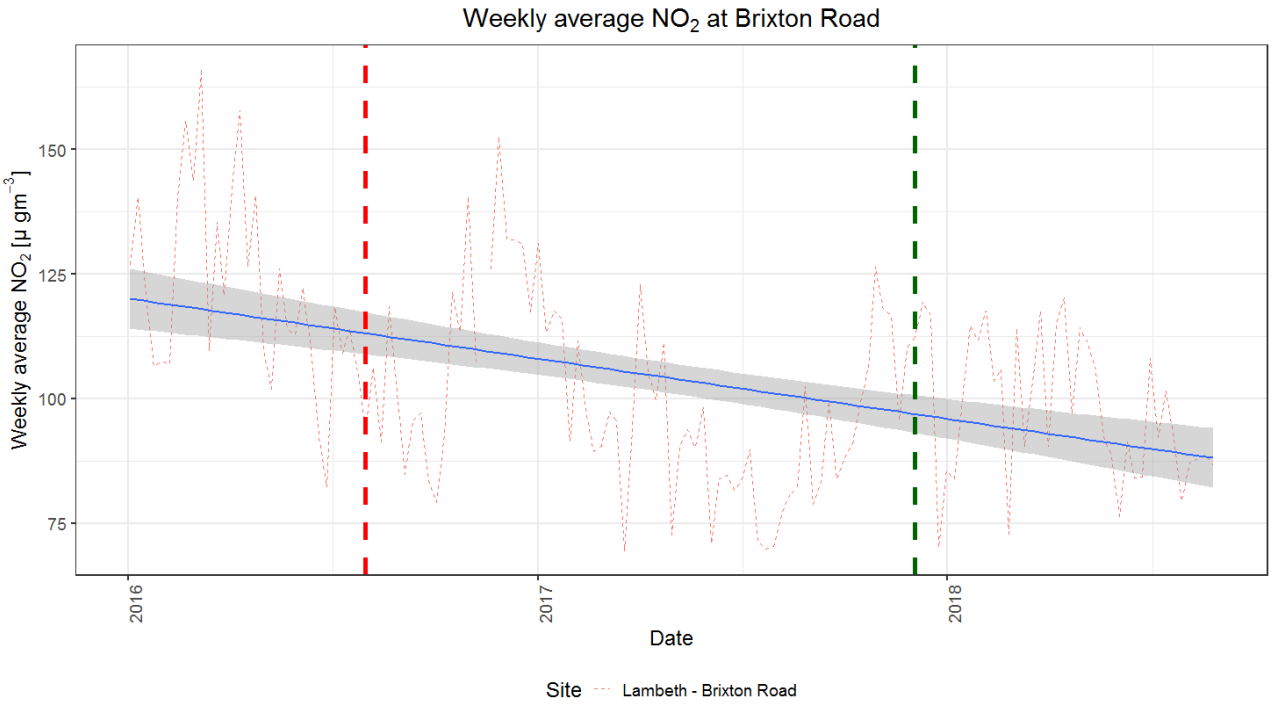

Figure 3: Weekly average concentrations of NO_2 at Brixton High Street

In **Figure 3** above the vertical red dashed line indicates the date when delivery of the Low Emission Bus Zone began. After this, non-Euro VI buses/non-compliant buses on this route were retrofitted or replaced with new buses.

The green vertical dashed line in **Figure 3** indicates the date when the Low Emission Bus Zone was completed.

There is a legal limit set for the annual average of NO_2 of 40 µg m^{-3}.

On Brixton Road in 2016 annual average NO_2 was 118 µg m^{-3}.

In 2018 to August the annual average has been 98 µg m^{-3}. Whilst there is still work to be done in order to meet the legal limit this is a reduction of 17% in less than two years.

Hourly average concentrations

There is a legal limit set at 18 for the number of times the hourly average of NO_2 is allowed to exceed 200 µg m^{-3} per year.

On Brixton High Street in 2016 there were 539 hours that exceeded the hourly limit.

In 2018 to August there have only been 83. Whilst there is still work to be done in order to meet the legal limit this is a reduction of 85% in less than two years.

Increase in hourly exceedances on Brixton Road from 2017 – 2018

There have been significant improvements in concentrations at the Brixton Road monitoring station between 2016 and 2018. However, there have been more exceedances of the hourly limit in 2018 to end August than there were in 2017.

In 2018 (to August), the hourly exceedances at Brixton Road exceeded those observed in 2017, with a total to end August of 83.

The number of NO_2 hourly exceedances at Brixton Road was lowest in 2017, with a total of 75 hours reading higher than 200 µg m^{-3}. The number of exceedances in 2016 were 539 (with previous years' data showing over 2000 exceedances).

Table 4. NO_2 concentrations at Brixton Road monitoring station

Year	# hourly exceedances	Annual mean NO_2 [µg m^{-3}]
2016	539	118
2017	75	95
2018 to end August	83	98

In light of this change, the Mayor commissioned King's College London to investigate the cause of this increase. It was initially thought that the slight increase between 2017 and 2018 was due to less favourable weather conditions and wind directions in 2018.

However, when King's College London used a statistical technique to "de-weather" the data (to remove variations in pollution levels caused by changes in the weather so that the data from different years can be better compared) they found weather conditions could not explain the differences in hourly exceedances, however, there was some natural inter-annual variability which was also seen at other sites in London (eg Marylebone Road). Overall, however, the changes in meteorology between 2017 and the first eight months in 2018 masked the slight increase in NO_2 concentrations.

Further investigation of activities at Brixton Road found that gas works had commenced one mile north of the monitoring station in August 2017, which coincided with the slight increase in NO_2 concentrations. In addition, an issue with how the bus retrofit technology was initially maintained was also identified on some buses.

Figure 4 shows the monthly average concentration on Brixton Road once the data has been "de-weathered". The period of increase coincides with the gas works. Vertical lines indicate the start of new bus contracts (green dotted lines) and the number of retrofitted buses each month (blue dotted lines). The period of the gas works is indicated with a black dotted line.

Bus data from TfL confirmed the average speed of buses passing the Brixton Road monitoring station was reduced during the period that coincided with the gas works, which temporarily reduced the effectiveness of the retrofit technology.

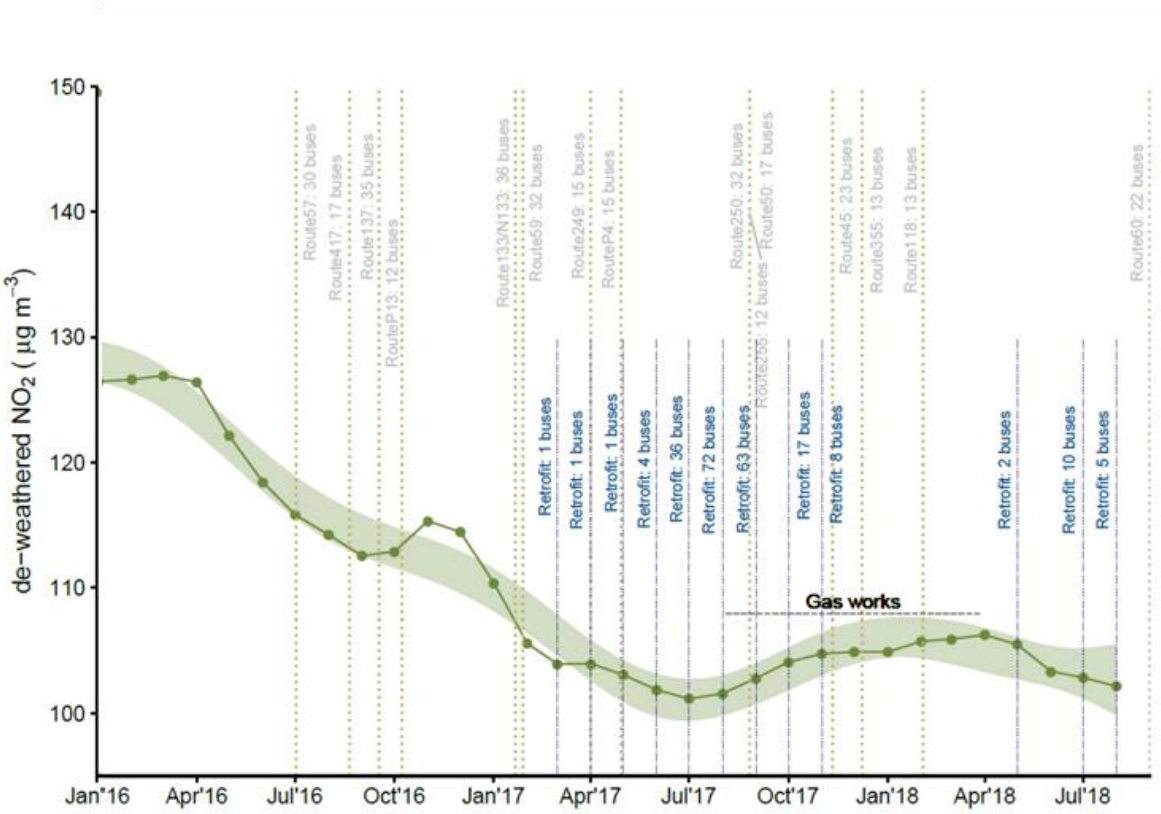

Figure 4. "De-weathered" NO_2 trends at Brixton Road

Selective Catalytic Reduction

Low Emission Bus Zones use engines and exhaust systems that meet or exceed the highest Euro VI emissions standards. In practice this is a combination of Euro VI buses and buses retrofitted with Selective Catalytic Reduction (SCR) systems, to meet the Euro VI standards.

SCR systems are most efficient when the engine is working hard (ie by moving at speed or driving a heavy bus full with passengers). If buses are sitting in stationary traffic for long periods of time the catalyst cools down and the NO_2 is not efficiently removed. This is particularly the case for retrofit buses as they rely solely on SCR for NO_x reduction.

There is also potential for the SCR to be less efficient if it is not properly maintained and there is crystallisation. When the SCR is not operating efficiently tailpipe emissions of NO_2 increase considerably.

TfL contacted the main operator of the bus route who informed them that in December 2017 they discovered crystallisation in some of their SCR systems. This would increase the emissions of NO_2 from these buses. The issue has since been rectified by the installation of an improved "Adblue mixer" by the SCR supplier.

It is likely that a combination of the usual heavy congestion around the Brixton Road monitoring station and a slowdown in traffic during the period of the gas works contributed to the SCR on the retrofit buses performing less efficiently. This will most likely have contributed to the slight increases in NO_2 concentrations.

The experiences at Brixton Road have provided useful lessons in the roll out of subsequent Low Emission Bus Zone.

Missing data since August 2018

The increase in NO_2 peaks in April 2018, after which concentrations begin to decrease again (**Figure 4**).

Unfortunately, we do not have any data from Brixton Road after August 2018. During a heavy rainstorm the station flooded, and all the equipment was damaged. The equipment has since been repaired. The London Borough of Lambeth, who are responsible for the monitoring site, have ordered a new waterproof enclosure and once this arrives the station will be reporting data again in early December 2018.

Camberwell to New Cross

The New Cross Low Emission Bus Zone was completed in August 2018.

Reduction in emissions from buses

Our modelling indicates that since becoming a Low Emission Bus Zone, the buses in New Cross emit on average 90 per cent less NO_x than previously, with some routes having reduced emissions by 93 percent.

As a result of cleaning up the buses between Camberwell and New Cross, these buses now emit 93 tonnes less NO_x per year than they did previously.

Annual average concentrations

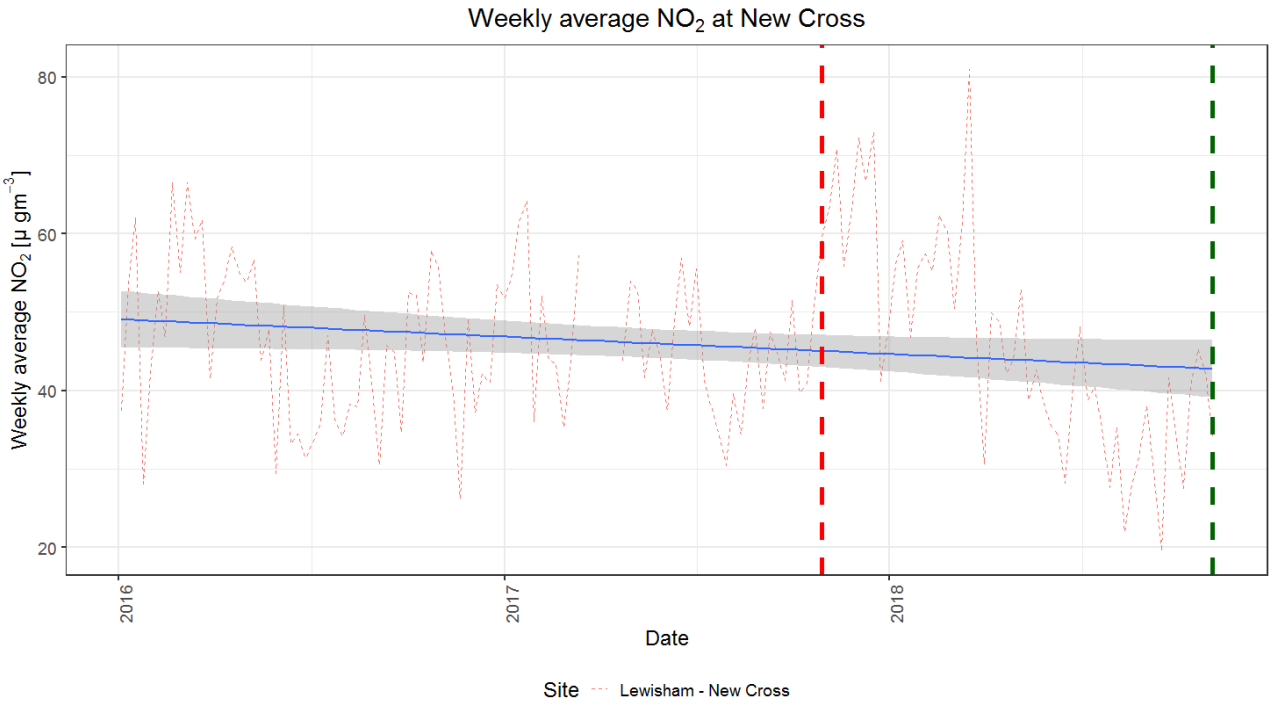

Figure 5: Weekly average concentrations of NO_2 at New Cross

In **Figure 5** above the vertical red dashed line indicates the date when delivery of the Low Emission Bus Zone began. After this, non-Euro VI buses/non-compliant buses on this route were retrofitted or replaced with new buses.

The green vertical dashed line in **Figure 5** indicates the date when the Low Emission Bus Zone was complete.

There is a legal limit set for the annual average of NO_2 of 40 µg m^{-3}.

In New Cross in 2016 annual average NO_2 was 46 µg m^{-3}.

In 2018 to November the annual average has been 43 µg m^{-3}, showing a current reduction of 11%. The conversion to cleaner buses has only recently been completed on this route, so it will take more time for the annual average to be reduced.

Hourly average concentrations

There is a legal limit set at 18 for the number of times the hourly average of NO_2 is allowed to exceed 200 µg m^{-3} per year.

In New Cross in 2016 there were 0 hours that exceeded the hourly limit.

In 2018 to November there have been 0 hours exceeding.

Wandsworth to St John's Hill

The Wandsworth Low Emission Bus Zone was completed in August 2018. The monitoring station at Wandsworth, Lavender Hill (part way down the Wandsworth to St John's Hill LEBZ) is set quite far back from the kerb and on an adjacent road. As a result, this monitor is not best placed to record roadside exposure on the LEBZ itself and results are less distinct than at the previously mentioned sites.

Reduction in emissions from buses

Our modelling indicates that since becoming a Low Emission Bus Zone, the buses in Wandsworth emit on average 91 per cent less NOx than previously, with some routes having reduced emissions by 93 percent.

As a result of cleaning up the buses in Wandsworth, these buses now emit 48 tonnes less NO_x per year than they did previously.

Annual average concentrations

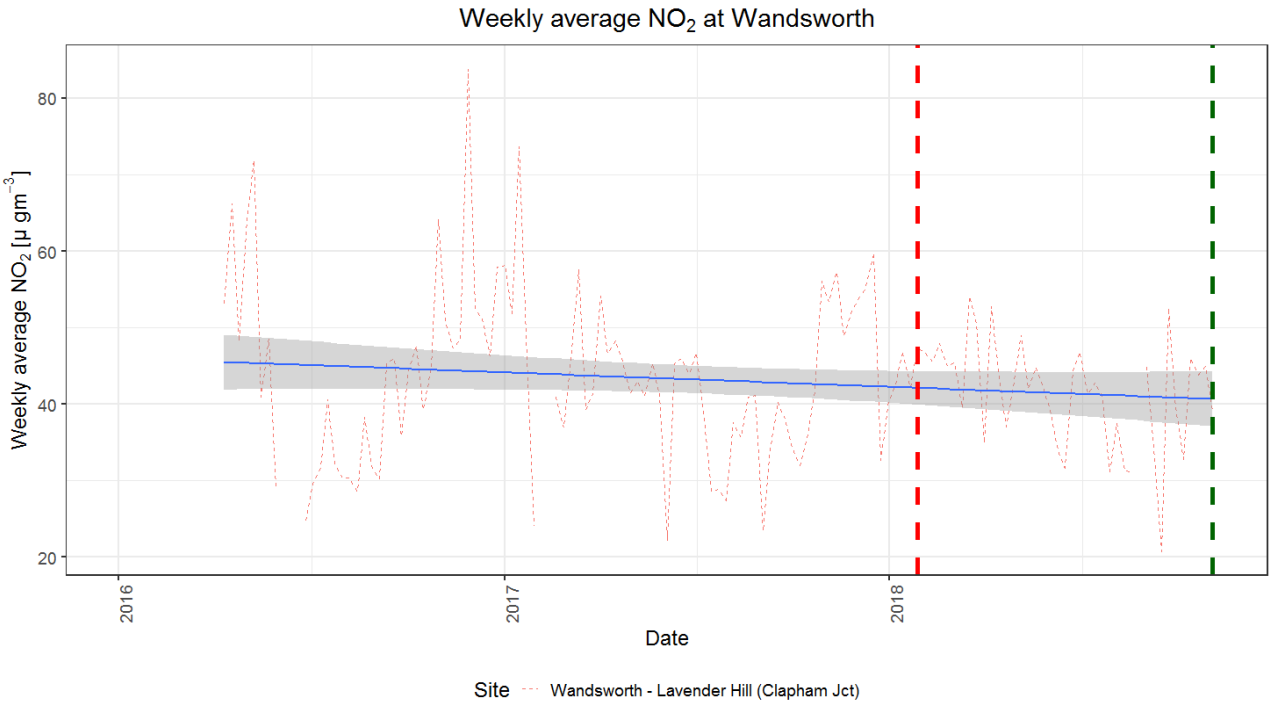

Figure 6: Weekly average concentrations of NO_2 at Wandsworth

In **Figure 6** above the vertical red dashed line indicates the date when delivery of the Low Emission Bus Zone began. After this, non-Euro VI buses/non-compliant buses on this route were retrofitted or replaced with new buses.

The green vertical dashed line in **Figure 6** indicates the date when the Low Emission Bus Zone was complete.

There is a legal limit set for the annual average of NO_2 of 40 µg m^{-3}.

In Wandsworth in 2016 the annual average NO_2 was 43 µg m^{-3}.

In 2018 to November the annual average has been 43 µg m^{-3}. This is a smaller reduction of 4%. The conversion to cleaner buses has only recently been completed on this route, it will take more time for the annual average to be reduced.

Hourly average concentrations

There is a legal limit set at 18 for the number of times the hourly average of NO_2 is allowed to exceed 200 µg m^{-3} per year.

In Wandsworth in 2016 there were 23 hours that exceeded the hourly limit.

In 2018 to November there have been 0 hours exceeding. This is a reduction of 100%.

A12 Eastern Avenue from Homerton High Street

Our modelling indicates that since becoming a Low Emission Bus Zone, the buses on A12 Eastern Avenue from Homerton High Street emit on average 91 per cent less NO_x than previously, with some routes having reduced emissions by 93 percent.

As a result of cleaning up the buses in Homerton, these buses now emit 54 tonnes less NO_x per year than they did previously.

We do not have a monitoring station at the roadside on the A12 in Homerton so we are unable to report concentrations reductions. However, the Mayor is currently trialling a hyperlocal air quality monitoring system that will be used to analyse harmful pollution at air quality hotspots and to support future evaluation of the Low Emission Bus Zones.

Haringey Green Lanes

Our modelling indicates that since becoming a Low Emission Bus Zone, the buses on Haringey Green Lanes emit on average 92 per cent less NO_x than previously, with some routes having reduced emissions by 93 percent.

As a result of cleaning up the buses in Haringey, these buses now emit 79 tonnes less NO_x per year than they did previously.

There is no monitoring station on the Haringey Low Emission Bus Zone so we are unable to report concentrations reductions. However, the Mayor is currently trialling a hyperlocal air quality monitoring system that will be used to analyse harmful pollution at air quality hotspots and to support future evaluation of the Low Emission Bus Zones.

A5 Edgware Road (Kilburn - Maida Vale)

Our modelling indicates that since becoming a Low Emission Bus Zone, the buses on A5 Edgware Road (Kilburn - Maida Vale) emit on average 90 per cent less NO_x than previously, with some routes having reduced emissions by 93 percent

As a result of cleaning up the buses on Edgware Road, these buses now emit 39 tonnes less NO_x per year than they did previously.

There is no monitoring station on the Haringey Low Emission Bus Zone so we are unable to report concentrations reductions. However, the Mayor is currently trialling a hyperlocal air quality monitoring system that will be used to analyse harmful pollution at air quality hotspots and to support future evaluation of the Low Emission Bus Zones.

Wider benefits

The benefits of the emissions reductions by the Low Emission Bus Zones will be seen on a wider scale than the zones themselves, as these cleaner buses will provide benefits beyond the Low Emission Bus Zone areas but across entire bus routes.

In **Figure 7** the orange lines show the full route of all buses that are part of a Low Emission Bus Zone. This demonstrates how cleaning up all routes passing through the Low Emission Bus Zones has a London wide benefit, as once passing through the Low Emission Bus Zones these routes go on to cover much wider areas.

The same is true for the bus routes being upgraded to meet the new requirements of the Ultra Low Emission Zone in central London. These are indicated by the blue lines in **Figure 7**. All buses operating in central London will meet the Euro VI standard by April 2019.

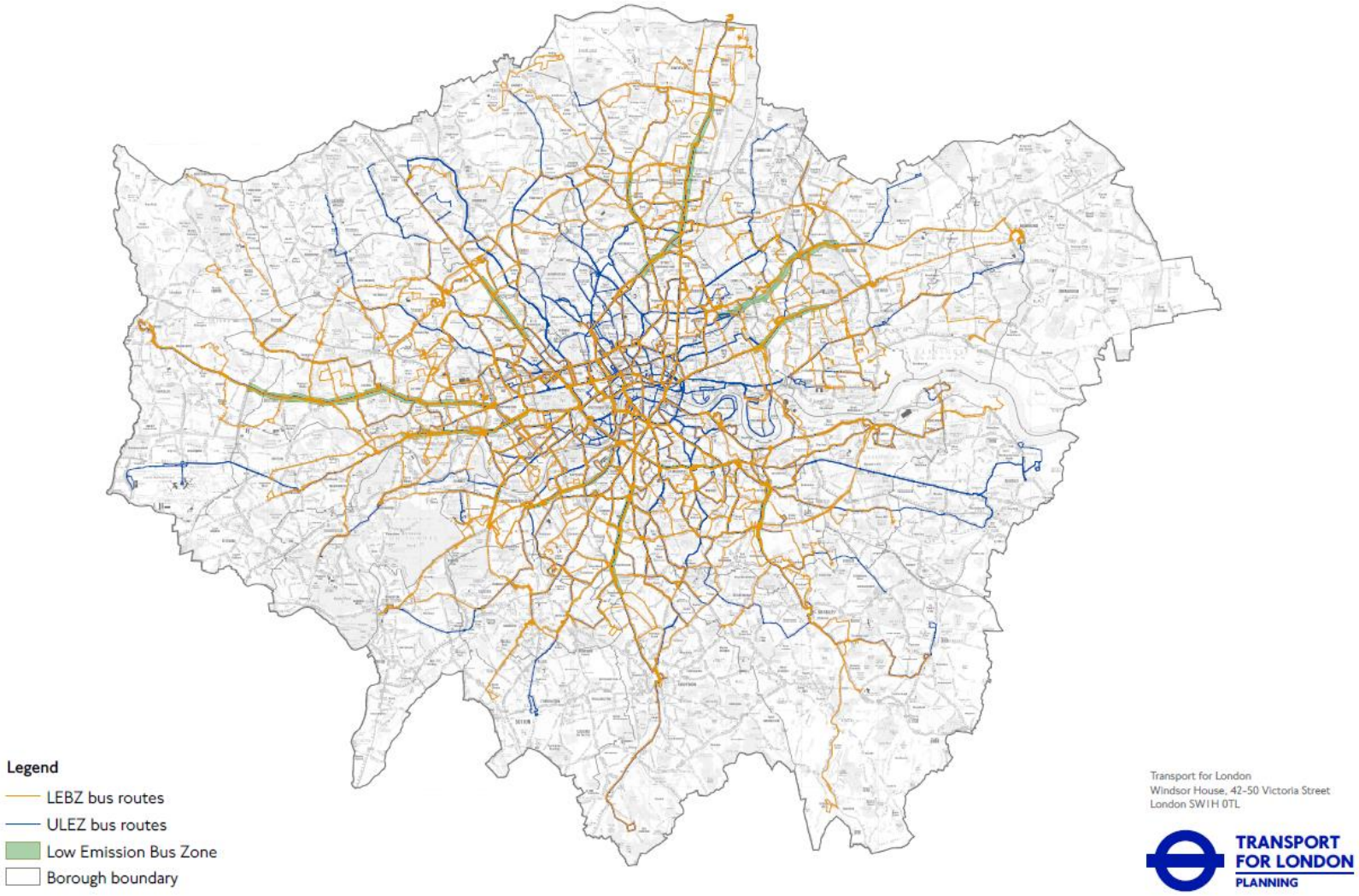

Figure 1: Map of the routes covered by cleaner buses passing through the Low Emission Bus Zones

Complementary measures

Low Emission Bus Zones have been rolled out as a targeted measure to significantly reduce the emissions from buses in specific areas with analysis showing emissions have reduced on average between 77 to 91 per cent.

However, buses are only one of the contributors to poor air quality in London. It is essential to continue to reduce emissions from all forms or road transport. This is being done through a number of measures including:

- An emissions surcharge (dubbed the ‘T-Charge) on top of the Congestion Charge, to deter older polluting vehicles from central London;
- Introducing the world’s first Ultra Low Emission Zone (ULEZ) in April 2019
- Expanding the Ultra Low Emission Zone in 2021 to the North and South Circulars for all vehicles and London-wide for lorries, coaches and buses from 2020;
- Transforming the whole of London’s bus fleet by phasing out of pure diesel buses and purchasing only hybrid or zero-emission double decker buses from 2018, with the entire fleet becoming ‘zero emission’ by 2037;
- No longer licensing new diesel taxis from 2018 and supporting the trade to upgrade to much cleaner ‘zero emission capable’ vehicles;
- Reducing traffic volumes by encouraging mode shift from travelling by car to walking, cycling and using public transport so that 80 per cent of all trips in London to be made on foot, by cycle or using public transport by 2041.

Conclusions

- Seven of the twelve Low Emission Bus Zones have now been delivered.
- Modelling shows that Low Emission Bus Zones have reduced bus NO_x emissions by an average of 90 per cent.
- Introduction of the first seven Low Emission Bus Zones has reduced NO_x emissions from those buses by 403 tonnes. This equates to an 8 per cent reduction in Londonwide bus fleet emissions.
- There is good monitoring data available from the first two Low Emission Bus Zones announced towards the end of 2017, Putney High Street and Brixton Road.
- At Putney High Street, annual mean NO_2 concentrations have reduced by 47 per cent and exceedances of the hourly mean limit have reduced by 99 per cent since 2016.
- At Brixton Road annual mean NO_2 concentrations have reduced by 17 per cent and exceedances of the hourly mean limit have reduced by 85 per cent since 2016.
- Despite a significant decrease to date in the number of hourly NO_2 exceedances at Brixton Road from 2016, there has been a slight increase from 2017 to 2018. Research by King's College London found this was most likely due to:
    - Increased congestion as a result of gas works reducing efficiency of SCR on retrofit buses;
    - Normal inter annual variability (we have also seen a slight increase in hourly exceedances at other sites including Marylebone Road); and
    - Initial issues on the maintenance of some retrofit bus systems (which have now been addressed).
- Where available, preliminary data from subsequent Low Emission Bus Zones shows downward trends in weekly average NO_2. However, these zones have not been in operation long enough to draw firm conclusions at this time.

- The benefits of the emissions reductions by the Low Emission Bus Zones will be seen on a wider scale than the zones themselves, as these cleaner buses will continue to provide benefits across their entire route.

- Low Emission Bus Zones are an important part of a series of measures, being delivered in parallel to improve air quality across London.

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