LEEDS LOW EMISSION ZONE

TECHNICAL FEASIBILITY STUDY

(Summary Report)

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Contents

1 Background

Air pollution is a key determinant of health. This has been recognised within the Department of Health's Public Health Outcome Framework which contains a specific indicator related to air pollution ('fraction of mortality attributable to particulate air pollution'). Air pollution is, however a determinant of many other indicators within the framework, including low birth weight and premature mortality for cardiovascular disease, respiratory diseases and cancer.

A causal link between road pollution and poor health has been demonstrated for various road based pollutants, the most significant of which are particulate matter and nitrogen dioxide. Table 1 summarises how both long and short term exposure, can trigger hospital admissions or deaths for people with cardiovascular or respiratory disease.

Table1. Main Health Effects of Vehicle Pollutants

Pollutant	Effects
Particulate matter	Short term: Increased GP consultations, cardiopulmonary deaths hospital admissions and wheeze symptoms in asthmatics. Long term: Increased lung cancer and cardiopulmonary deaths and risk of preterm birth. Weaker evidence regarding a link between particulate matter and childhood leukaemia and childhood type II diabetes
Nitrogen oxides (NOx)	Short term: Inflammation of the airways, increased incidence of shortness of breath and wheeze symptoms. Long term: Affects the lung function, increased mortality and hospital admissions for those with respiratory disease, increased risk of low birth weight[1]
Ozone	Short term: Impact on hospital admissions, asthma attacks, breathing difficulties and COPD admissions
Carbon monoxide	Short term: Effect on hospital admission for heart attacks
Benzene and 1,3-butadiene	Exposure linked to leukaemia and lymphomas.
Polycyclic aromatic hydrocarbons (PAHs)	Linked to lung cancer.

The World Health Organisation (WHO) classifies diesel exhaust emissions as carcinogenic[2] and suggests that whilst there is no known safe exposure level of particulates, countries should work towards an annual average concentration limit of 10ug/m^3. Research by Public Health England[3] shows that $PM_{2.5}$ concentrations are estimated to cause over 1000 adult deaths a year in West Yorkshire with 350 of these occurring within Leeds. This represents 5.5% of the total mortality in Leeds and is calculated as the equivalent to 3825 life years lost.

[1] http://www.borninbradford.nhs.uk/
[2] http://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf
[3] Estimating Local Mortality Burdens associated with Particulate Air Pollution, PHE, 2014

On 6th April 2011, Full Council passed the following resolution:

> *"This Council recognises the health and environmental benefits of reduced air pollution to Leeds communities, especially those in inner city areas, and notes the success of the Low Emissions Zones in London and Oxford which prevents the most polluting vehicles from entering the city.*
>
> *Council therefore requests the Executive Board to undertake a feasibility study with a view to implementing a similar scheme in Leeds."*

Shortly afterwards, Leeds City Council secured funding from DEFRA (2011/12) to conduct a technical feasibility Study following recommendations that local authorities who will have Air Quality Management Areas beyond 2015 should examine the feasibility of Low Emission Zones (LEZ) to accelerate a reduction in road transport emissions within the District. DEFRA also awarded Bradford MDC funding to investigate and develop a Low Emission Strategy (LES) with the aim of reducing road transport emissions across the District.

An Integral element of the Bradford LES was the requirement to undertake a study regarding the feasibility of a LEZ within Bradford. Leeds CC and Bradford MDC have taken a partnership approach to their LEZ Studies by working with each other and local health professionals, including Public Health, NHS Bradford and Bradford Health Observatory, strengthening local and regional capacity and capability to evaluate the health impacts of road transport emissions.

Bradford MDC now chairs and manages the development of a Low Emission Strategy for West Yorkshire (WYLES), including a Project Board representing all the 5 West Yorkshire Local Authorities, WYCA, Local Transport Plan (LTP) Joint Officer Board and Public Health England. The intention of the WYLES is to develop a series of templates allowing each district within West Yorkshire to more easily develop and adopt their own Low Emission Strategies.

Approaches taken by the joint Bradford and Leeds LEZ Studies will soon be extrapolated across West Yorkshire through the WYLES Project.

2 Transport and Air Quality

Historically, the main air pollution problem in both developed and rapidly industrialising countries has typically been high levels of smoke and sulphur dioxide emitted following the combustion of sulphur-containing fossil fuels such as coal, used for domestic and industrial purposes. More recently, the major threat to clean air has been posed by traffic emissions. Petrol and diesel-engined motor vehicles emit a wide variety of pollutants including; oxides of nitrogen (NOx), and particulate matter (PM) and volatile organic compounds (VOC), which have an increasing impact on urban air quality. In addition, pollutants from these sources may not only prove a problem in the immediate vicinity of the sources, but can be transported long distances.

Photochemical reactions resulting from the action of sunlight on nitrogen dioxide (NO_2) and VOCs , lead to the formation of ozone. Ozone is classed as a secondary pollutant and often impacts rural areas far from the original emission site.

In all except worst-case situations, industrial and domestic pollutant sources tend to be steady or improving over time. However, traffic pollution problems are worsening world-wide.

Leeds City Council has a duty to review and assess air quality in the District and pursue the achievement of UK Air Quality Objectives, as part of the requirements of the Environment Act 1995[4]. Monitoring and modelling has shown that concentrations of NO_2 exceed Government Air Quality Objective in the vicinity of the urban road network. Table 2 outlines the target values for the pollutants most relevant to this study as set out in the UK Air Quality Regulations for England, Scotland, Wales and Northern Ireland)

Table 2 Air Quality Objectives Values for the Protection of Human Health (DEFRA, 2007)

Pollutant	UK and EU Objective	Measured as	Date to be achieved by and maintained thereafter
PM_{10}	40 µg.m3	Annual Mean	31 Dec 2004
$PM_{2.5}$ UK (except Scotland)	25 µg.m3	Annual mean	2020
$PM_{2.5}$ (urban areas)	Target of 15% reduction in concentrations at urban background	3 year mean	Between 2010 and 2020
Nitrogen dioxide (NO_2) (UK)	200µg.m-3 not to be exceeded more than 18 times per year	1 hour mean	31 Dec 2005
Nitrogen dioxide (NO_2) (UK)	40µg.m-3	Annual mean	31 Dec 2005

2.1 Nitrogen Dioxide

Both the EU and UK Government Annual Objective Level for NO_2 is 40ug/m3. UK Legislation requires Air Quality Management Areas (AQMA) to be designated where there is relevant exposure i.e. homes and schools. However, the EU Limit Value applies to any location where the public has access.

[4] http://www.legislation.gov.uk/ukpga/1995/25/contents

Therefore, the area which exceeds the EU Limit Value in Leeds is much greater than the areas designated as AQMAs.

Leeds has designated six AQMAs where public exposure is a concern and monitoring data shows that concentrations of NO_2 have not reduced in line with expectations. This is believed to be, in part, due to the increase in diesel passenger vehicle numbers over the last decade and the failure of road vehicles in general to replicate the emission standards achieved under test conditions.

Many urban zones across the UK are experiencing similar problems and Leeds is classified by DEFRA, in its reporting under the EU Air Quality Directive[5], to be part of the West Yorkshire Zone which has the 4th most significant NO_2 concentration issues after London, West Midlands and Greater Manchester. DEFRA predicts that areas of Leeds and West Yorkshire will not meet the binding EU Limit Value for NO_2 until beyond 2030[6].

On the 20th February 2014, the European Commission commenced infraction proceedings against the Government for failing to meet the EU Limit Value and significant annual fines are expected. Under the reserve powers of the Localism Act 2011[7] the Government can transfer EU fines to any public authority whose "***act or omission***" has contributed to the breach.

2.2 Particulates

Nowhere within the Leeds District is likely to exceed the EU Limit Values for coarse particles with a diameter less than 10µm (PM_{10}). However there are areas, with concentrations of fine particulates with a diameter less than 2.5µm ($PM_{2.5}$) that exceed the World Health Organisation (WHO) Target Level.

A growing body of research points towards the smaller particles in particular being more closely associated with adverse health effects than PM_{10} and that there is no recognised safe level of exposure. There is strong evidence to suggest that elevated concentrations of $PM_{2.5}$ can occur close to major roads[8]

2.3 National Pollution Source Apportionment

The concentration of a pollutant at any given location is a result of different emission sources. Depending on the location and the pollutant concerned, the most dominant source of the emission could be in close proximity to the receptor or many miles away.

In 2008, it was estimated that across the UK, local road traffic sources contributed around 60% of the total NOx emissions at locations where the NO_2 objective levels were exceeded[9] Figure 1 illustrates how this figure can be further broken down to individual vehicle types.

Particulate concentrations can be influenced more from sources much further afield and can include sources such as sea salt and wind-blown dust. National source apportionment work published by DEFRA in 2012 (Figure 2) indicated that road transport emissions are the largest single source of fine particulates within the urban area.

[5] http://ec.europa.eu/environment/air/quality/legislation/directive.htm
[6] http://uk-air.defra.gov.uk/data/gis-mapping
[7] http://www.legislation.gov.uk/ukpga/2011/20/contents/enacted
[8]AQEG Fine Particulate Matter in the UK (2012)
[9] Air Quality Plans for the achievement of EU air quality limit values for nitrogen dioxide in the UK, (2011)

However, the UK 1km^2 background source apportionment data suggests much of this manifests itself as secondary or re-suspended sources. Approximately 50% of the emissions attributed directly to road traffic are estimated to be from tyre and brake abrasion, with the remaining 50% being from the exhaust[10] .

Figure 1 Exceeded the Annual Mean NO_2 Objective Limit Value of 40ug/m^3 in 2008

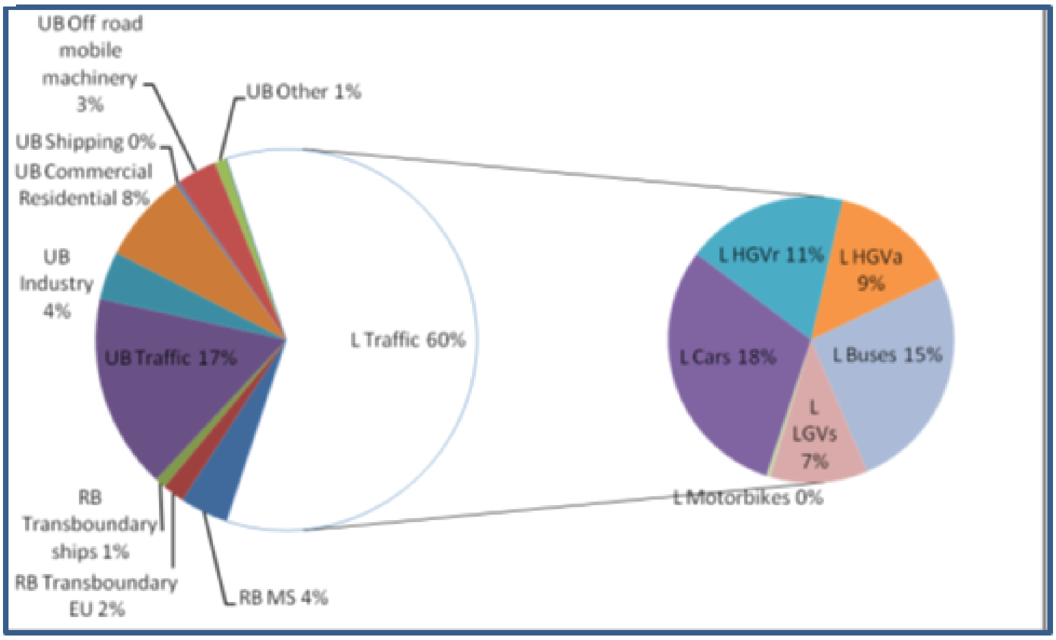
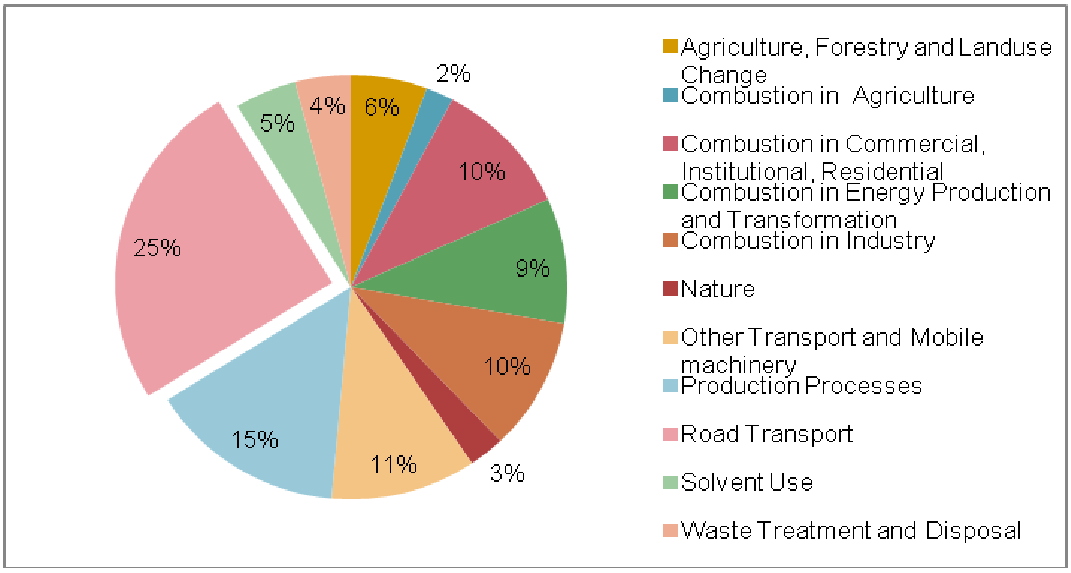


Figure 2 2012 UK Source Apportionment by Sector for PM2.5



[10] Estimated Background Air Pollution Maps (base year 2011) http://uk-air.defra.gov.uk/data/laqm-background-home

3. Low Emission Zones

A Low Emission Zone or LEZ is a pollution control scheme, where certain vehicles are forbidden to enter, or charged to enter a particular area to accelerate the uptake of cleaner vehicles. The impact of a LEZ will affect both the zone itself and the wider fleet. As the aim of an LEZ is to reduce concentrations of air-pollutants within its boundaries, generally those vehicles with the largest gross contribution to emissions are usually targeted first. A LEZ should be considered as just one specific policy measure within a wider range of pollution control measures available under a wider Low Emission Strategy (LES).

The majority of existing LEZs have been aimed solely at Euro IV or earlier HDVs to reduce particulate matter, as this was the most-cost effective way of implementation and particulates were a primary health concern. However, the improved availability of de-NO_x technologies across all vehicle sectors have enabled more recent proposals to cover both PM and NO_x.

3.1 Current European Vehicle Emission Controls

Within the European Union (EU), vehicle emissions are controlled at source through the application of the *'Euro Standards'*, which prescribe exhaust tailpipe emission limits for each pollutant by different vehicle classes over a standard 'drive cycle'. Meeting these limits is required for new vehicles sold within the EU. The initial Euro 1/I[11] standard was adopted across Europe in the early 1990s and each successive Euro standard has reduced the amount of different pollutants allowed to be emitted.

The Euro VI standard for Heavy Duty Vehicles (HDVs: rigid and articulated goods vehicles, buses and coaches) came into effect on 31st December 2014. Euro 6 standard for cars and car based vans) came in to force in September 2014, with remaining Light Duty Vans (LDVs) required to comply with Euro 6 by September2015.

Some vehicles will comply with a higher emission standard prior to the implementation date. However, vehicles which are ordered prior to the implementation date, but are not built until afterwards are often only required to meet the Euro standard in force when the order was placed.

The Euro 6 regulations for diesel LDVs mandate a 55% reduction in NOx emissions over the Euro 5 standard. There are no relevant changes to NOx limits between Euro 5 and Euro 6 for petrol vehicles. The Euro VI regulations for HDVs mandate a 75-80% reduction in NOx emissions over the Euro V standard. There is evidence suggesting that the additional technology required to meet these standards have increased vehicle prices. There is currently no statistical evidence to support or deny the concern that fuel consumption may increase with Euro 6/VI vehicles, or how well the vehicles perform in the "real world".

3.1.1 Particulate Reduction Technology

The most common diesel particulate filter (DPF) technology is a Continually Regenerating Trap (CRT) system where accumulated soot deposits are burnt off in an NO_2 rich atmosphere. The technology is mature and considered capable of reducing PM emissions by up to 95%. Current NAEI emission

[11] The LDV standards use Arabic numerals and define tailpipe emissions limits in terms of mass per distance (g/km), whilst Roman numerals refer to HDV standards, which are defined in mass per energy output (g/kWh)]. Different fuels and vehicle types must achieve different rates of emissions.

factors assume a 90% reduction for vehicles fitted with DPFs, consequently the scope for reducing particulates any further from diesel engines would appear to be fairly limited.

3.1.2 NOx Reduction Technologies

There are two key technologies used with diesel engines to meet current Euro 5/V and Euro 6/VI NOx limits for both light and heavy duty vehicles:-

i) Selective Catalytic Reduction (SCR) systems convert NOx into nitrogen (N_2) and water (H_2O), via introduction of a reducing agent, typically ammonia (NH_3)
ii) Exhaust Gas Recirculation (EGR) systems pass captured exhaust gases back to the intake of the engine cylinders. This reduces oxygen in the fuel/air mix which lowers the combustion temperature to reduce NOx formation

The difficulties of applying de-NOx technologies to diesel engines are compounded by the need to meet standards for particulate matter for which vehicles are fitted with DPF technology. Complex interactions between continuously regenerating traps (CRT) and other catalyst systems, such Diesel Oxidation Catalysts (DOC) may give reduction in total NOx that potentially comes at the expense of reduced engine efficiency and increased emissions of CO_2, Particulates and primary NO_2 emissions. Increased emissions of other pollutants (e.g. ammonia, NH_3) or greenhouse gases (e.g. CO_2 is produced if urea is used as the ammonia source in SCRs, or Nitrous Oxide (N_2O) may be produced from SCR chemistry). 'Ammonia slip' where low-temperatures lead to unreacted ammonia in the exhaust gas is also an issue in SCR systems.

3.2 "Real World" Emissions of NOx

There has been widespread concern in recent years that ambient NO_x and NO_2 concentrations have not reduced in proportion to the NO_x emissions standards and that previously modelled air-quality benefits have not materialised. The 'Science for Environmental Policy' bulletin of the European Commission DG Environment, recently stated *'the most recent Euro 5/V standard, adopted in 2009… did not produce the desired reduction in on-road emissions'* [12].

There is now a large amount of research suggesting that on-road NOx emissions tend to exceed emission levels established through laboratory testing. This is most likely to arise from on-road behaviour being considerably different from the New European Drive Cycle (NEDC) used for Type Approval, particularly the urban element. There is also a suggestion that vehicles are being tuned by manufacturers to produce specific, optimal emission performance over that NEDC, resulting in increased 'off cycle' emissions.

Carslaw et al [13] made the following detailed observations, based on comparison of on-street Remote Sensing Data to NOx emissions calculated using the UK emissions factors and National Atmospheric Emissions Inventory (NAEI) fleet information:

i) NOx emissions for older petrol cars are higher than expected – possibly due to under-estimation of the effect of deterioration of catalytic converters on these vehicles;
ii) For diesel cars and vans, the data suggested little change in NOx emissions for perhaps the past 20 years;

[12] http://ec.europa.eu/environment/integration/research/newsalert/pdf/312na3.pdf
[13] Evidence of an Increasing NO_2/NO_x Emissions Ratio from Road Traffic Emissions. *Atmospheric Environment* (2005)

iii) NOx emissions from HGVs appeared static over time, until introduction of Euro IV, where emissions decreased by a factor of 1/3rd. For buses, NOx emissions appeared to be either static or increasing slightly over the past 10-15 years;
iv) For modern diesel cars (EURO III+) under high engine load conditions an "increasing trend of NO_x emissions is observed that is not apparent in older vehicles"

Evidence suggests that SCR systems in HDVs may not be effective under urban driving conditions. Operating temperature plays a large role in SCR efficiency and urban operations may result in an engine never reaching the high temperatures required for optimum SCR performance. Analysis of Euro V HDVs reported that on-road emissions in urban conditions were three times higher than the standard to which the trucks supposedly conformed when fitted with SCR, whilst under motorway conditions the SCR system performed well. HDVs with EGR technology achieved better NOx reduction in urban conditions with similar benefits on motorways.

The current NAEI fleet data suggests that the Euro V fleet has a 75%:25% split in favour of SCR technology. This implies that knowledge of the technology distribution will be important in predicting future urban NO_2 levels and that interventions based on HDVs meeting Euro V standards may not achieve the desired outcome in urban areas.

3.2.1 Primary NO2

The issue of primary NO_2 (pNO_2) has also become increasingly important over recent years[14] given the trend for UK fleet-operators and consumers to purchase diesel cars on the basis of their lower fuel consumption and CO_2 emissions. The diesel car market surpassed the petrol car market in terms of new vehicle sales in 2011[15]. AQEG noted that the general assumption that the fraction of pNO_2 in vehicle exhaust emissions was of the order of 5-10%, based on 'engine out' measurements. However, with 'dieselification' of the UK fleet and exhaust treatment technologies, the actual 2009 value of pNO_2 was estimated to be in the order of 15-16% and may reach approximately 25% in the short term, before decreasing again.[16]

3.3 Existing LEZs

There are currently around 350 LEZ schemes implemented across the EU,[17,] dating back to 2002. All LEZs affect heavy duty goods vehicles over 3.5 tonnes Gross Vehicle Weight (GVW), and most buses and coaches (usually defined as over 5 tonnes GVW). Some LEZs also affect vans, cars and motorcycles. Most LEZs operate 24 hours a day, 365 days a year, although some Italian LEZs are currently an exception to this rule.

The vast majority of these controls apply to Euro 4/IV or previous vehicles, or consider implementation for particulate matter only, with any NOx/NO_2 reductions viewed as a bonus. It is therefore not easy to predict how effective a future LEZ targeting compliance for Euro 5/V and 6/VI vehicles for NOx will be.

[14] Murrells, T. (2011). Achievement of the EU Limit Value for NO2 : Why NOx is not decreasing as predicted. Presentation at the 51st IAPSC Conference, Birmingham, 6/12/11.
[15] New Car CO_2 Report 2012. The 11th Report. The Society of Motor Manufacturers and Traders Ltd. http://www.smmt.co.uk/wp-content/uploads/SMMT-New-Car-CO2-Report-2012.pdf
[16] *Trends in NOx and* NO2 *– Emissions and Ambient Measurements in the UK*. http://uk-air.defra.gov.uk/reports/cat05/1108251149_110718_AQ0724_Final_report.pdf
[17] http://urbanaccessregulations.eu

Additionally, many LEZ studies have utilised pre-implementation emissions modelling, rather than post scheme analysis of monitored air-quality data. There does appear to be some evidence that earlier LEZ feasibility studies may have been optimistic, with expected emission benefits on paper not necessarily materialising in concentration reductions in the real world. The impacts of the London LEZ (introduced in phases from 2008) estimated PM_{10} emission reductions of 6.6%, and NOx emission reductions of 7.3% by 2012[18], but also concluded that predicted changes in concentrations were "generally small... and would be difficult to detect in actual monitoring data"

3.4 Existing LEZs in the UK

Only five LEZs either exist, or are committed to be implemented in the near future, within the UK. Only the London LEZ affects general vehicles, whilst the other 4 affect only buses. However there are at least 7 other Local Authorities, including Birmingham, Sheffield, Bradford and Newcastle/Gateshead currently undertaking feasibility studies similar to Leeds.

In addition to the LEZ outlined below, London and Durham also operate Charging Schemes whereby vehicles are charged to enter the zone or use the particular road. The Schemes apply to all vehicles regardless of emission standards, other than limited exemptions, such emergency services and low emission vehicles.

3.4.1 London

The London scheme was introduced on the 4th February 2008 and was originally designed to deter the most polluting diesel-engine lorries, buses and coaches from being driven within Greater London. The LEZ covers most of Greater London and all public roads, however the M25 is not included within the LEZ even where it passes within the GLA boundary.

It operates 24 hours a day, 7 days a week, 365 day of the year. It is enforced using fixed and mobile cameras. Operators of all vehicles that do not meet the LEZ emissions standards, or qualify for an exemption must pay a daily charge (£100 to £200 depending on type) or they will be liable for a Penalty Charge

From 2012 vans, 4x4s and pick-ups weighing 1.205 tonnes unladen to 3.5 tonnes GVW and minibuses weighing 5 tonnes or less GVW were included and must meet Euro 3 standard on PM_{10}. Whilst HGVs over 3.5 tonnes GVW and buses and coaches over 5 tonnes GVW have to meet Euro 4 standard on PM_{10}. Cars, motorcycles and small vans (under 1.205 tonnes u-laden weight) are not included in the LEZ.

From 2015 the LEZ will be tightened to include NOx standards for TfL controlled buses which will only be met by new Euro VI & hybrid buses together with SCR retrofitting of Euro III buses. The LEZ applies to all vehicles meeting the criteria, irrespective of whether they are used for commercial or private use.

London has also recently announced plans to introduce an Ultra Low Emission Zone (October 2014) which will differentiate between petrol and diesel vehicles, and is the first policy to do so. Due for implementation in 2020, the Zone allow Euro 4 petrol cars (up to and including on the date of implementation) and Euro 6 diesel cars (up to and including 5 years old). Older vehicles will still be

[18] Kelly et al 2011, *The LEZ Baseline Study*. Research Report (Health Effects Institute) http://pubs.healtheffects.org/getfile.php?u=669

allowed into the ULEZ but will be liable to a fine of £12.50. It is estimated that this policy, including emission reduction targets on buses and HGVs, will result in a reduction of NOx emissions by 51%.

3.4.2 Oxford

Buses with routes into the city centre had to comply with Euro V standard for NOx and PM_{10} by 1st January 2014. Retrofitting older buses is allowed but vehicles have to register. Currently through a voluntary agreement with bus companies, but will become enforced through the Traffic Commissioner if the voluntary agreement does not work

3.4.3 Brighton

From 1 January 2015 buses passing through a public transport corridor with an Air Quality Management Area which comprises approximately 98% of total local bus routes will have to comply with Euro V standard. The LEZ will be primarily through a Traffic Regulation Order and agreements between the city authority and the bus companies but potentially enforced through an existing CCTV network. Approximately 55 buses are being retrofitted as part of the scheme agreement.

3.4.4 Norwich

Since the 1st April 2010, bus companies have been required to comply with Euro III NOx standards with an increasing percentage of their fleet. 100% for operators based within the LEZ, 50% for operators based outside the LEZ. Local bus services with less than five departures per week from Castle Meadow are exempt. The LEZ is achieved through agreements with bus operators and enforced through the Traffic Commissioner.

3.4.5 Nottingham

A Statutory Quality Partnership Scheme between Nottingham City Council and local bus operators which is enforceable through the Traffic commissioner, who can also impose fines on operators who fail to ensure that their buses meet the Euro III standard. The scheme came in to force on the 2nd May 2010.

4 Methodology

The Leeds LEZ feasibility Study has been carried out in four phases:

i) Assessment of baseline road transport emissions for 2012, 2016 and 2021 for oxides of nitrogen ($NO_{x,}$) particulate matter (PM) and carbon dioxide ($CO_{2,}$) and the resulting changes from LEZ intervention scenarios applied to the areas bounded by the Inner Ring Road, Outer Ring Road and across the wider Leeds Urban District (See Map 1)

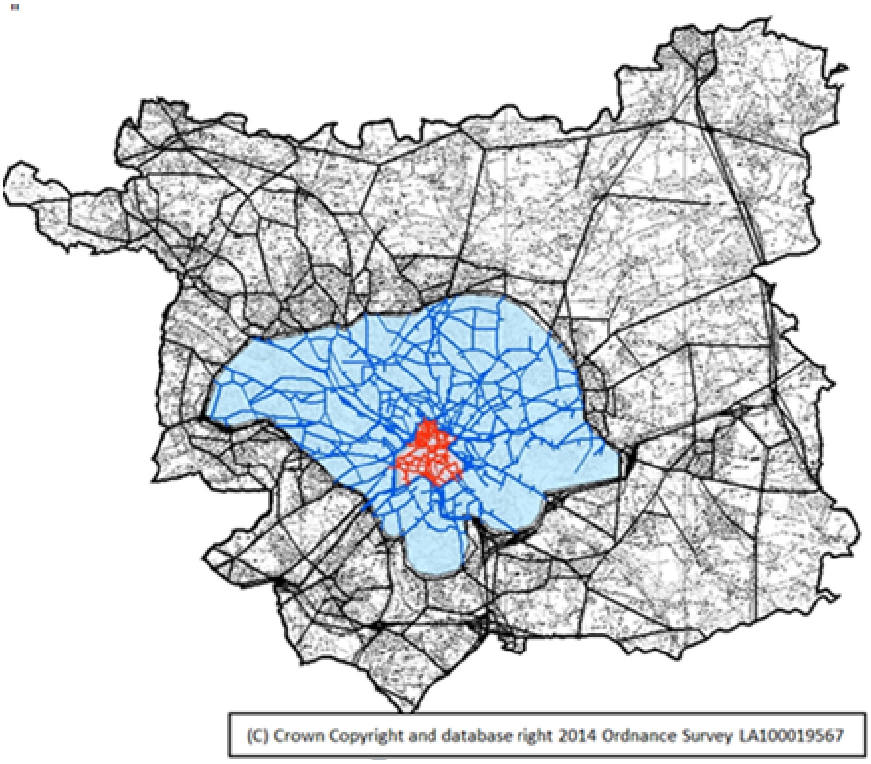
ii) Assessment of the pollution concentrations from the modelled emissions on fine particles ($PM_{2.5}$) and NOx through dispersion modelling of each scenario.

iii) Assessment of the impact of road transport emissions on health, including deprivation correlation, and the anticipated effects of introducing selected LEZ intervention scenarios

iv) Economic assessment of the costs and benefits of introducing selected LEZ intervention scenarios, including enforcement scenarios, within the Inner and Outer Ring Road

This Report draws the four elements of the study together and provides supporting information on the technical feasibility and potential impacts of implementing a LEZ to address air quality issues within the Leeds City Council District.

Map 1 Assumed LEZ Boundaries: Inner and Outer Ring Roads and Modelled Network



This Study does not represent the development of a plan to implement Low Emission Zones in Leeds. it aims to show the relative impact of several intervention scenarios beyond the 'business as usual' case and discusses the impact that these scenarios may have on projected air quality concentrations, health of the local population and the costs and benefits associated with each intervention measure. The costs of enforcing LEZ are also discussed.

It is acknowledged that further analysis of selected scenarios will be required in order to progress the concept of a LEZ in Leeds beyond this initial feasibility study

4.1 Emission and Concentration Modelling

The first and second phases of the Study have been carried out internally by Leeds City Council and consisted of the following five elements;

i) A traffic emission inventory, by vehicle type and fleet age within the proposed LEZ boundaries.
ii) A baseline assessment of existing air quality across the Leeds District for NO_2 and $PM_{2.5}$.
iii) A baseline source apportionment analysis of emissions within the proposed LEZ areas by vehicle type.
iv) The remodelling of transport emissions to show the effectiveness of the proposed LEZ scenarios if implemented in years 2016 and 2021 against the predicted business as usual position.
v) Remodelling of the potential impact of the modelled scenarios on pollution concentration levels of NOx, NO_2 and $PM_{2.5}$ for 2016 and 2021 using dispersion modelling techniques.

A separate Emission and Air Quality Modelling Report will be prepared separately to provide more technical information on the detail of data collection and modelling techniques used to complete this Study. A summary of the modelling methodology is presented in Section 5 of this report.

4.1.1 Calculating the Emissions from the Road Transport Network

The Leeds Transport Model (LTM) is a SATURN (Simulation and Assignment of Traffic to Urban Road Networks) based network of modelled road links which is incorporated within the multi-model West Yorkshire Strategic Transport Model. Modelled traffic flows were split in to users classes representing; Cars, Light Goods Vehicles (LGV), Heavy Goods Vehicles (HGV) and buses were modelled.

The traffic flows and speed data from the LTM have been entered in to a simple emission modelling framework developed by Dr. Paul Goodman whilst at Leeds University's Institute for Transport Studies. The framework now forms the front end of a more comprehensive integrated modelling package known as PITHEM (*P*latform for *I*ntegrated *T*raffic, *H*ealth and *E*mission *M*odelling), A concept developed by Dr Anil Namdeo at Newcastle University

PITHEM takes the link-based period output traffic data and calculates the traffic vehicle kilometres travelled (VKM) for each modelled user class. Suitable speed-based emissions factors and scaling factors are then applied to produce total annual emissions by each vehicle type on each modelled road link. for total NOx, pNO_2, ultimate Carbon Dioxide (uCO_2) and $PM_{2.5}$.

The vehicle emission data calculated within PITHEM was then summarised for links falling within each of the ring roads and passed on to the consultants appointed to undertake the Cost Benefit Analysis, which is available as a separate report.

4.1.2 Calculating the Predicted Changes in Pollutant Concentrations

The total annual emission networks calculated in PITHEM were post-processed to produce link based emission rates. The resulting emission rates were then imported in to the Leeds City Council air pollution dispersion modelling package, '*AIRVIRO*' to create line source emission databases representing each scenario.

AIRVIRO was set up to calculate the average hourly concentrations of both NOx and $PM_{2.5}$ over a $250m^2$ grid by applying sequential hourly meteorological data for the full 2011 calendar year using the Gaussian dispersion model. The resulting hourly average concentration data was then post processed to calculate the estimated annual average concentration for each pollutant.

The average pollutant concentrations calculated for each 250m grid were passed over to the Leeds Public Health and West Yorkshire Health Protection Teams (Public Health England), who devised a method to apply each Lower Super Output Area (LSOA) in Leeds with a suitable pollutant concentration value corresponding to the exposure experienced by the majority of the population within each LSOA.

The West Yorkshire Health Protection Team (Public Health England) then proceeded to complete the Health Impact Assessment which is available as a separate report.

4.2 Cost Benefit Assessment

The emission projections were passed over to RICARDO – AEA to study economic costs and benefits of each measure to allow assessment of the most cost-effective measure combinations. It provides estimates of the economic impact of the proposed measures, using methods prescribed by Defra's Interdepartmental Group on Cost and Benefits (IGCB)[19].

The Cost Benefit Assessment (CBA) estimates the "value" of the emissions reduced by assessing the significance of the NOx reductions in enabling the area concerned to meet the EU NO_2 Objective Level.

The CBA also provides estimates of the costs of introducing the proposed measures and compares them against the abatement costs avoided by each measure. A summary of CBA is provided in section 7. The full Report is also available separately.

4.3 Health Impact Assessment

Health Impact Assessment (HIA) is a tool for systematically assessing the potential health impacts of projects, programmes and policies. The desired outcome is to improve the quality of public policy decisions by making recommendations which enhance the predicted positive health impacts and minimise the negative impacts

A baseline assessment has been undertaken by a collaborative group from Bradford and Leeds councils, their Primary Care Trusts and the Health Protection Agency. This work included a detailed literature review of previously published studies on the health effects of pollution, provided an overview of the health and socio-economic profile of Bradford and Leeds and described current baseline levels of air quality.

19 19 https://www.gov.uk/air-quality-economic-analysis#damage-costs-approach

As part of this Study, West Yorkshire Health Protection Team (Public Health England) developed an analytical model to determine the populations most affected by projected changes in emissions and the estimated health impact. The model uses data from the LEZ source apportionment work and demographic data from the Office for National Statistics to describe the population and areas most affected by pollutants. It then adds small area health data (from Local Authorities) and research evidence about the health effects of pollutants to estimate the overall health impact of various emission scenarios. The full HIA Report is available separately. A summary of the HIA is provided in Section 6.

5 The Leeds Low Emission Zone Feasibility Study

This LEZ Study has incorporated the most up-to-date information available, applying best practice tools and techniques at each stage of assessment. It is acknowledged however that there are gaps in both local and national data, emission factors and costs. Assumptions and caveats around estimates are therefore clearly stated where necessary.

At the time the modelling work was undertaken, the speed based emission factors recommended for use by DEFRA were contained in the UK National Atmospheric Emission Inventory's (NAEI) Emission Factor Toolkit (EFT) v5.1.3. These factors were incorporated in the PITHEM model to calculate the base data for all the results used in this study, however since then the recommended emission factors have changed to EFT v5.2 (it is not yet known how much this change will impact on the results).

The NAEI UK average urban fleet hierarchy incorporated within the PITHEM model was adjusted to reflect the predicted local fleet mix for the future business as usual or the LEZ intervention scenario being assessed.

5.1 Assessment of Base Year Emissions

A key issue of this Study has been the comparison of the emission profiles of the Leeds vehicle fleet in relation to the national fleet composition. Automatic Number Plate Recognition (ANPR) camera data has been collected and examined to establish a more accurate picture of the local fleet emission profile, based on actual vehicle movements entering the central urban area. The data indicates the Leeds vehicle fleet profile is generally older with different proportions of vehicle sub-types than the national assumption.

While the Study has used ANPR data to gain an accurate picture of baseline conditions, future projections have used NAEI data regarding fleet emission profile which may prove ambitious. For example Table 3 illustrates how the projections assume that 64% of all the 28 – 34t articulated HGVs will be Euro VI in 2016 for both UK and Leeds biased fleets under business as usual. This is despite the Leeds fleet containing less than half the proportion of Euro V vehicles within the national fleet as whole in 2012.

Table 3 Comparison of Local Fleet Movements and NAEI Urban for 28t -34t Artic HGVs

Proportion of HGV ARTICs within the 28t to 34t weight class	NAEI UK 2012 percentage	Leeds Local Fleet 2012 percentage	NAEI UK Projected 2016 Percentage split	Projected Leeds 2016 percentage split	2016 scenario, All Pre-Euro 4 HGVs replaced with Euro 6
Pre-Euro	0.0%	0.0%	0.0%	0.0%	0.0%
Euro_I	0.0%	0.0%	0.0%	0.0%	0.0%
Euro_II	0.9%	15.3%	0.0%	0.0%	0.0%
Euro_III	14.4%	16.0%	1.6%	1.8%	0.0%
Euro_IV	19.9%	37.4%	3.6%	6.8%	6.8%
Euro_V_EGR	16.2%	7.8%	7.7%	6.8%	6.8%
Euro_V_SCR	48.7%	23.5%	23.1%	20.5%	20.5%
Euro_VI	0.0%	0.0%	64.0%	64.0%	65.8%

It is therefore possible that future fleet projections based on national trends could overestimate the emission benefits of the natural fleet turnover and underestimate the benefits of any intervention for the Leeds area.

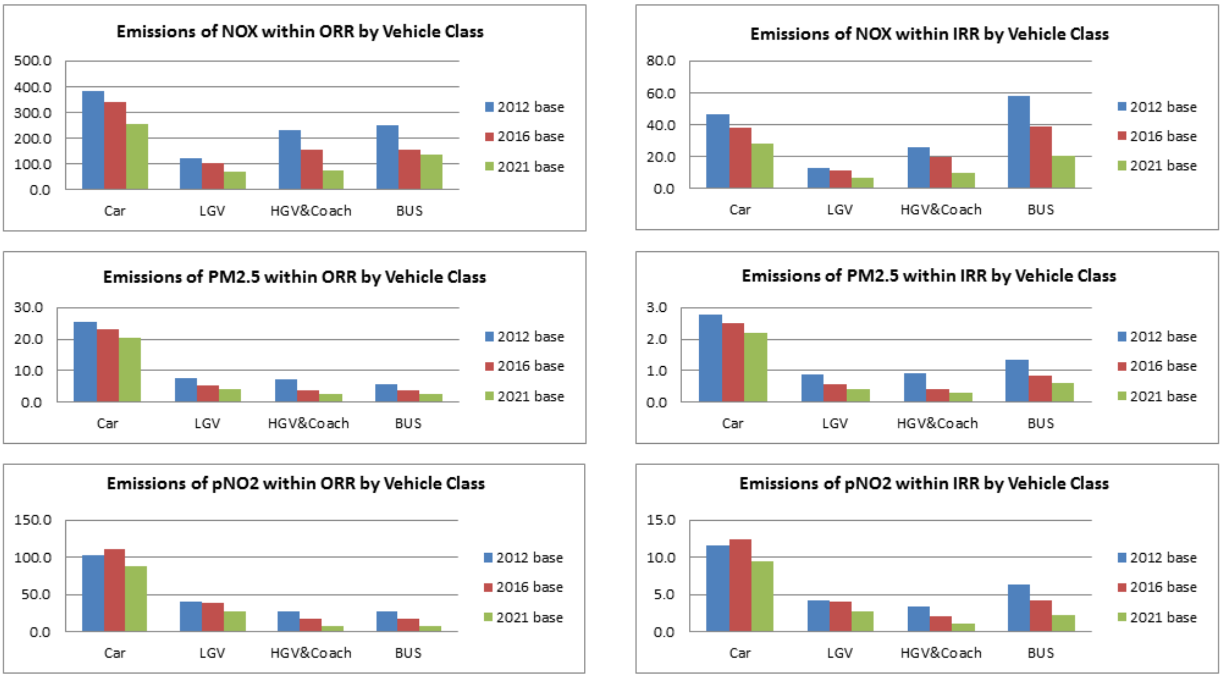
Additionally, emission factors for certain vehicle types including natural gas vehicles are not available. The modelling has therefore taken the Euro 6/VI factors to represent the impact of introducing gas vehicles as well as diesel even though test data indicates that Euro 6/VI gas vehicles will be cleaner than Euro 6/VI diesel vehicles[20].

5.1.1 Vehicle Emission Apportionment

Figure 3 illustrates the source apportionment of vehicle emissions for the chosen base years within the Leeds Inner and Outer Ring Roads under the business as usual forecast. Total transport based emissions of NOx, $PM_{2.5}$ and pNO_2 are forecast to reduce from all vehicle classes between 2012 and 2021. However emissions of $pNO_2$from cars are forecast to increase between 2012 than 2016, before reducing to below the existing levels by 2021.

Figure 4 illustrates the proportion of emission attributable to each vehicle type against their contribution towards the total VKM driven inside both Ring Roads for each base year

Figure 3 **Projected Changes to Emission for Business as Usual Within the Outer Ring Road (ORR) and Inner Ring Roads (IRR) using NAEI Projections (Tonnes/Year).**



5.1.2 Vehicle Emission Apportionment within Leeds Outer Ring Road

In 2012, buses were estimated to contribute over 25% of the total NOx emissions and 13% of total $PM_{2.5}$ emissions inside the Outer Road, despite only contributing to 2.5% of the total VKM driven. This compares with cars contributing 39% of the total NOx emissions and 55% of the total $PM_{2.5}$. However cars did account for 83% of the VKM driven.

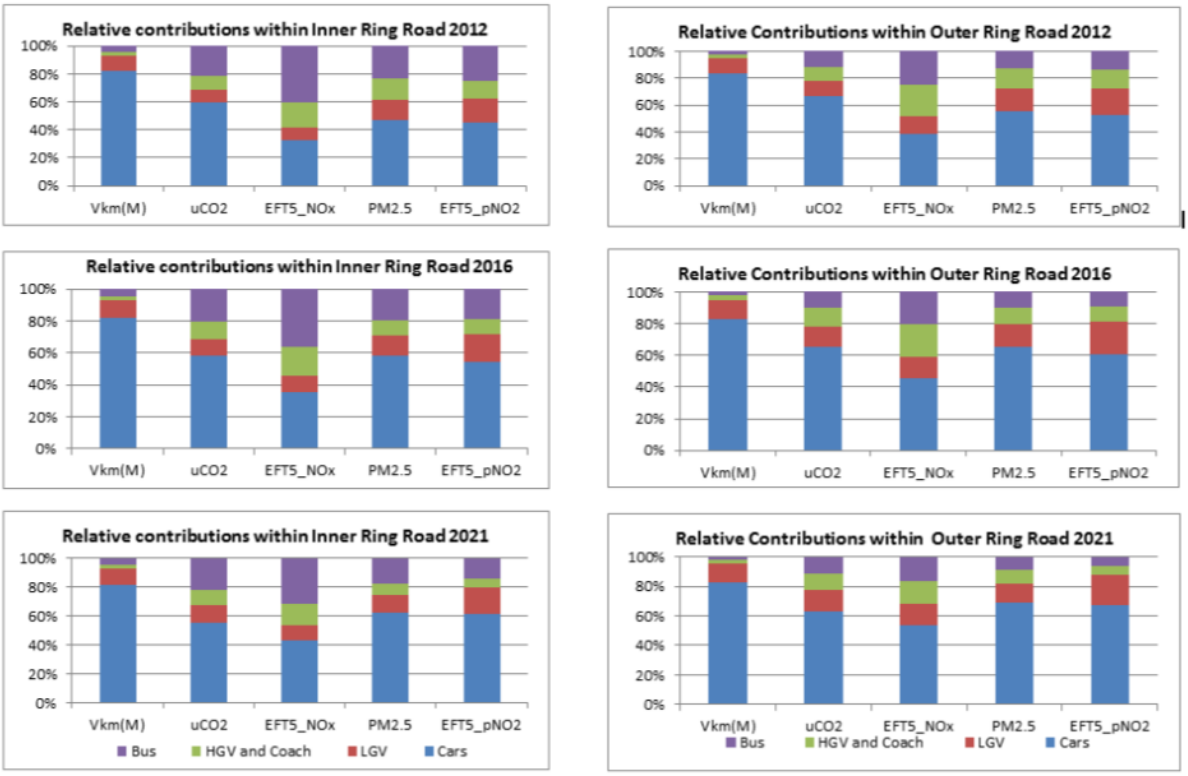
The predicted business as usual vehicle replacement projections indicate the relative contribution of NOx emissions between buses and cars are expected change by 2021. Bus contributions are forecast to fall to 16% of total contributions whilst car emissions will increase to over 54%. However

[20] Scania 2014, VTT (Finland), TNO (Netherlands)

emissions of NOx from all road sources are predicted to reduce in absolute terms of 255 tonnes per year.

The contribution towards the total $PM_{2.5}$ from buses within the Outer Ring Road is forecast to reduce to 9% whilst the relative contribution from cars will increase to 69% of total vehicle emissions. This is mainly due to the predicted success of Euro VI exhaust treatment for HDVs and a continuing increase in the proportion of diesel vehicles in the LDV fleet.

Figure 4 Comparison of Emissions Against VKMs Driven by Vehicle Class Under Business as Usual Within the Modelled LEZ Boundaries 2012, 2016 and 2021



The modelling indicates that the total emissions contributing to poor air quality from buses will reduce by 53% ($PM_{2.5}$) and 69% (NOx) compared to an improvement from cars of only 18% ($PM_{2.5}$) and 34% (NOx).However buses and HGVs will remain the two vehicle classes contributing a higher proportion of the emissions compared to their share of total VKMs travelled.

5.1.3 Vehicle Emission Apportionment within Leeds Inner Ring Road

Buses only accounted for 5% of the total vehicle VKM driven inside the Inner Road in 2012, although they contributed over 40% of the total NOx emissions and 23% of total $PM_{2.5}$ emissions. This compares with cars contributing 33% of the total NOx emissions and nearly 50% of the total $PM_{2.5}$. However, cars do account for over 80% of the total VKM driven.

The relative contribution of total NOx emissions between buses and cars are expected to reverse by 2021. The overall contribution from buses is forecast to reduce to just over 30% of total transport emissions whilst the contribution attributable to cars is expected to increase more than 40%, despite reducing to 28t. Emissions of $PM_{2.5}$ are forecast to reduce from all vehicle classes between 2012 and

2021. However, the relative contribution from buses is forecast to reduce to 17% whilst the contribution from cars is expected to increase to a 62% share of the total emissions.

The modelling indicates that emissions contributing to poor air quality from buses will reduce by nearly 60% ($PM_{2.5}$) and 65% (NOx) compared to the forecast reduction from cars of approximately 20% ($PM_{2.5}$) and 40% (NOx). Despite the greater relative improvements from buses and HGVs compared to cars, they will remain the two vehicle classes which contribute a higher proportion of the emissions compared to their relative VKMs travelled.

5.2 Assessment of Base Year Pollution Concentrations

The total amount of annual road traffic emissions calculated for $PM_{2.5}$ and NOx from the LTM network (illustrated in Map 1) were converted to time period emission rates and entered in to Leeds City Council's air quality dispersion model 'AIRVIRO'.

The dispersion modelling process applies sequential hourly meteorological data to the emissions and calculates the spatial distribution of the pollution. The resulting hourly pollution concentrations were then processed to estimate the annual average concentration at each location. Due to computer processing requirements (and degree of assumptions contained within the data), a dispersion grid of 250m^2 considered a suitable resolution to cover the entire Leeds District.

All the dispersion calculations were completed using 2011 meteorological data. Although there has been no detailed validation exercise completed, the predicted concentrations for the 2012 base year was compared against the concentrations monitored in 2011 for both the specific receptor points and the average value for the appropriate grid square. In both cases the modelled and monitored concentrations were found to be in close correlation. In any event, the scenarios are compared against each other on a like for like basis and so will under or over estimate at a consistent rate.

Map 2 below illustrates the annual average NOx concentrations predicted for 2016 attributable only to the road sources included within the LTM; whilst Map 3 shows how this is likely to convert to annual average NO_2 concentrations using the DEFRA approved conversion factors[21] and 1km^2 background values[22] to account for the sources not included within the LTM.

Maps 4 to 7 illustrate the relative contribution to the predicted 2016 NOx concentrations by each vehicle class. The maps are presented with different scales to help make identifying the relative impacts easier.

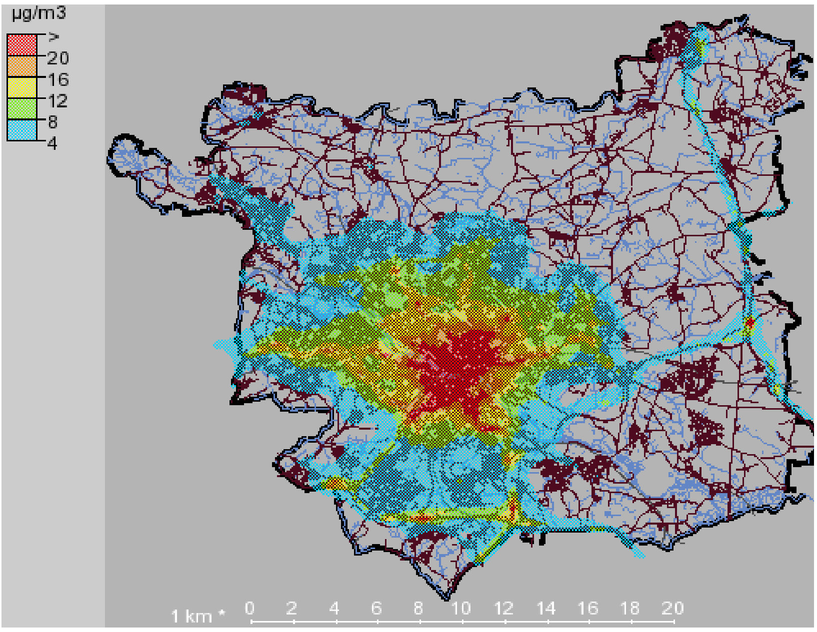
Because the concentrations are mapped as the average values over a 250m^2 grid, there will be areas within each grid which will have higher concentrations than indicated on the maps. This will most often occur for locations closer to the roads which are the source of majority of the local emissions.

The modelling shows that although emissions are expected to improve over time as older, more polluting vehicles are replaced with newer, cleaner models. However, natural replacement does not appear to be sufficient on its own to meet the EU Limit Value for NO_2.at all locations. Previous studies[23] have also forecast significant improvements predicted in air quality over time which have

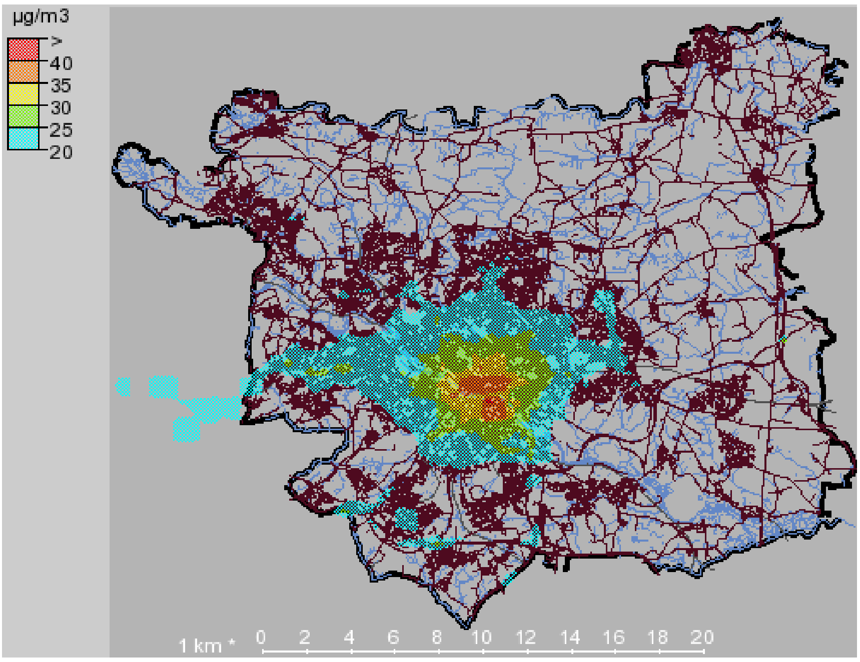
[21] LAQM NOx to NO2 conversion calculator v3.2, 2012
[22] Estimated Background Air Pollution Maps (base year 2011) http://uk-air.defra.gov.uk/data/laqm-background-home

not materialised. This is, partly due to the failure of the European Emission Standards to deliver emission benefits in real-world driving and also due to the anticipated increased take up of diesel passenger vehicles due to their greater fuel efficiency.

Map 2 Estimated 2016 Annual Average NOx Concentrations Modelled Road Transport Sources

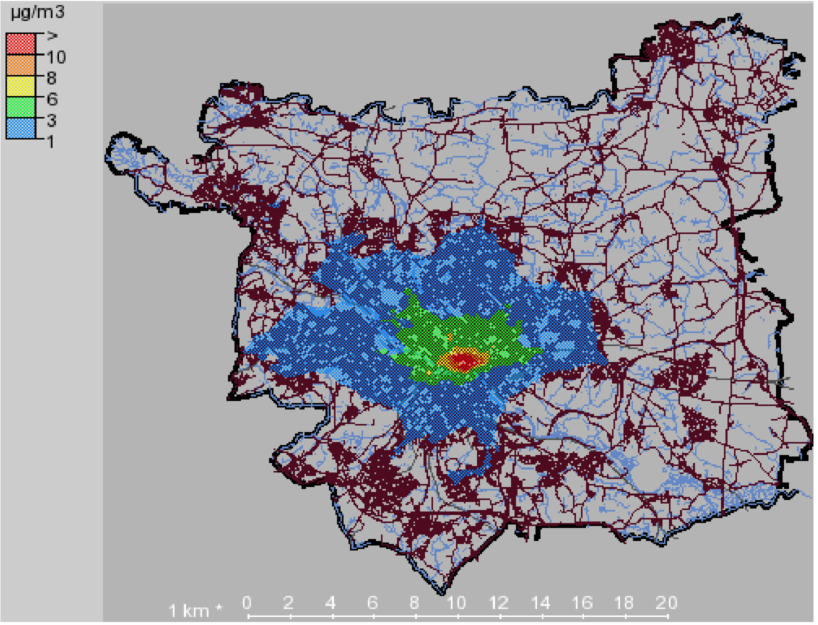


Map 3 Estimated 2016 Annual Average NO2 Concentrations All Sources

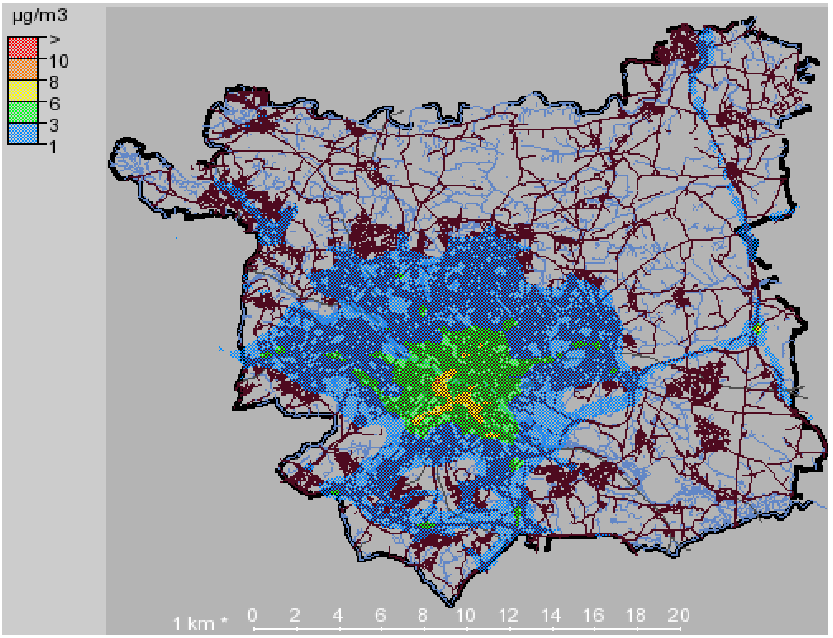


[23] Leeds City Council LAQM Review and Assessment

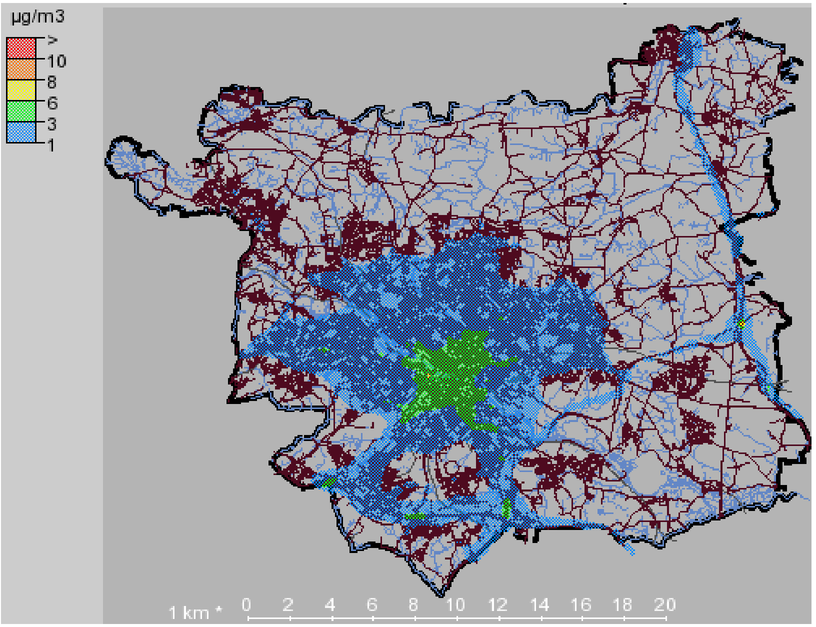
Map 4 2016 Annual Average NOx Contribution from Buses



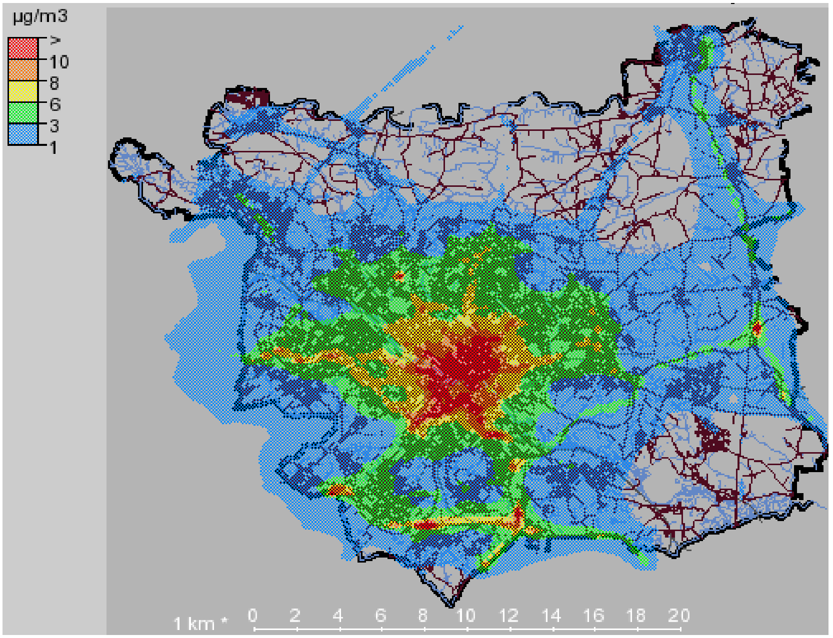
Map 5 2016 Annual Average NOx Contribution from HGVs



Map 6 2016 Annual Average NOx Contribution from LGVs



Map 7 2016 Annual Average NOx Contribution from Cars



5.3 Low Emissions Zone Interventions

In addition to the baseline assessments, the full list of potential LEZ intervention scenarios assessed within this Study are shown in Table 4. DEFRA guidance[24] on LEZs recommended that LEZs implemented from 2010 and 2012 should consider higher standards than Euro 3/III as a minimum, although local source apportionment should be used to identify target vehicles.

DEFRA suggested that their own national scale modelling indicated compliance with EU NO_2 objectives within the West Yorkshire Agglomeration might be achieved if all buses and HGVs were to meet a minimum Euro 4 standard. This is one of the scenarios modelled for the 2016 horizon.

Table 4 Modelled LEZ Scenarios

Scenario name	Description
2012 base	Existing fleet mix
2016 base	Projected fleet mix do minimum
2016 fuel split	Projected fleet but with the petrol/diesel mix for cars and N1 vans returned to Year 2000 ratios
2016 all buses Euro VI	Projected fleet but all buses (including Euro IV and Euro V) become Euro VI buses
2016 all HGV Euro VI	Projected fleet but all HGV (including Euro IV and Euro V) become Euro VI
2016 all bus and HGVs Euro VI	Projected fleet but all buses and HGVs (including Euro IV and Euro V) become Euro VI
2016 All vans Euro 6	Projected fleet but all vans replaced with Euro 6
2016 E2&E3 retrofit	Projected fleet but with Euro II and Euro III buses retrofitted with "non TFL DPF and SCR" technology
2016 all Pre Euro IV buses Euro VI	Projected fleet but all buses older than Euro IV are replaced with an Euro VI
2016 all Pre Euro IV HGV Euro VI	Projected fleet but all HGV older than Euro IV are replaced with an Euro VI
2016 Pre Euro IV bus and HGVs to Euro VI	Projected fleet but all buses and HGVs older than Euro 4 are replaced with Euro VI
2016 10% reduction in car use	Projected fleet with 10 % reduction in car use resulting from measures to promote walking and cycling
2021 base	Projected fleet mix do minimum
2021 fuel split	Projected fleet but with the petrol/diesel mix for cars and N1 vans returned to year 2000 ratios
2021 All buses to Euro VI	Projected fleet but with all buses (including Euro IV and Euro V) become Euro VI buses
2021 All HGVs to Euro VI	Projected fleet but with all HGVs (including Euro IV and Euro V) become Euro VI
2021 All bus and HGVs to Euro VI	Projected fleet but with all buses and HGVs (including Euro V) become Euro VI
2021 All vans to Euro 6	Projected fleet but all vans replaced with Euro 6
2021 All pre Euro V buses to Euro VI	Projected fleet but with all buses older than Euro V are replaced with Euro VI buses
2021 All pre Euro V HGV to Euro VI	Projected fleet but all HGVs older than Euro V are replaced with Euro VI
2021 All pre Euro V bus and HGVs to Euro VI	Projected Leeds fleet but All Pre Euro V buses and HGVs become Euro VI
2021 10% reduction in car use	Projected fleet with 10 % reduction in car use resulting from measures to promote walking and cycling

[24] Defra: *Practical Guidance to Local Authorities on Low Emission Zones*. February 2009

A number of different LEZ scenarios to reduce emissions of both PM and NOx through imposing different minimum emission standards for different vehicle types have been modelled. In addition, the study has attempted to assess the potential impacts of other measures and policies such as influencing the fuel choice of different vehicle classes and the impact of model shift.

The LEZ intervention scenarios listed in Table 4 do not represent an exhaustive list. However they do represent a mixture of deliverability and ambition, based on their anticipated theoretical ability to reduce emissions. The results are aimed at promoting discussion on which combination of potential measures might be required to achieve the aims of any future LEZ. Additionally, as modelling outputs have been produced, the data has been used to continually inform both the development of the WYLES and applications for Government funding aimed at promoting the uptake of low emission vehicles.

Indirectly, measures introduced to combat NOx and NO_2 emissions will also have an effect on Ozone (O_3) concentrations, due to complex photochemical reactions between these pollutants. However O_3 this has not been assessed specifically within this study

5.4 Emission Changes from LEZ Intervention Scenarios

The emission modelling for this study has used traffic flows based on the LTM (2011) outputs with predicted growth applied to 2016 and 2021. However, the modelling does not take account of any non-compliant vehicles which may choose to skirt/avoid crossing a LEZ boundary. Any scenario chosen for further assessment is likely to require this level of detailed traffic modelling to ascertain the most likely consequential impacts on vehicle movements and level of LEZ compliance. The resulting traffic data would then need to be re-assessed for the resulting impact on emissions and pollutant concentrations to determine the level of enforcement required to achieve the desired effect.

Table 3 in Section 5.1 illustrates how the local vehicle fleet has been adjusted to predict future predicted fleet age/emissions profile based on the NAEI UK average urban fleet forecasts. For each potential scenario, the business as usual fleet predicted for the relevant 2016 and 2021 horizon has been manually adjusted to represent the scenario being assessed. Table 3 also includes an example of an HGV subgroup adjustment to represent the scenario of replacing all HGVs which do not meet Euro IV standard with Euro VI vehicles by 2016. Only the urban fleet projections were altered. The fleet operating on the motorway links are assumed to remain largely unchanged and be much closer to the UK average motorway fleet.

The adjusted fleet hierarchy data was then entered in to PITHEM to calculate changes in the link based emissions. For the purpose of his study the Inner and Outer Ring Roads were chosen to act as the potential LEZ boundaries. Consequently, the LTM-H links which fall within the inner and outer ring roads were isolated so the emissions from those links could be compared of each scenario for the CBA. The full emission network was entered in to AIRVIRO to calculate the resulting change in concentration levels for HIA purposes.

Figures 5 and 6 compare the baseline emissions for 2012, 2016 and 2021 against the predicted changes in NOx emissions arising from each LEZ intervention scenario. Tables 7 and 8 compare the changes in emissions of for $PM_{2.5.}$ For the reasons described in Section 3.1, the modelling indicates that should any future intervention result in older HDVs being replaced with Euro V vehicles rather than Euro VI vehicles, the concentration levels of NO_2 within the central urban areas may initially deteriorate rather than improve as intended through the introduction of newer Euro VI replacing older pre-Euro V vehciles.

Figure 5 Changes in NO_x Emissions within Inner Ring Road (Tonnes) by Scenario

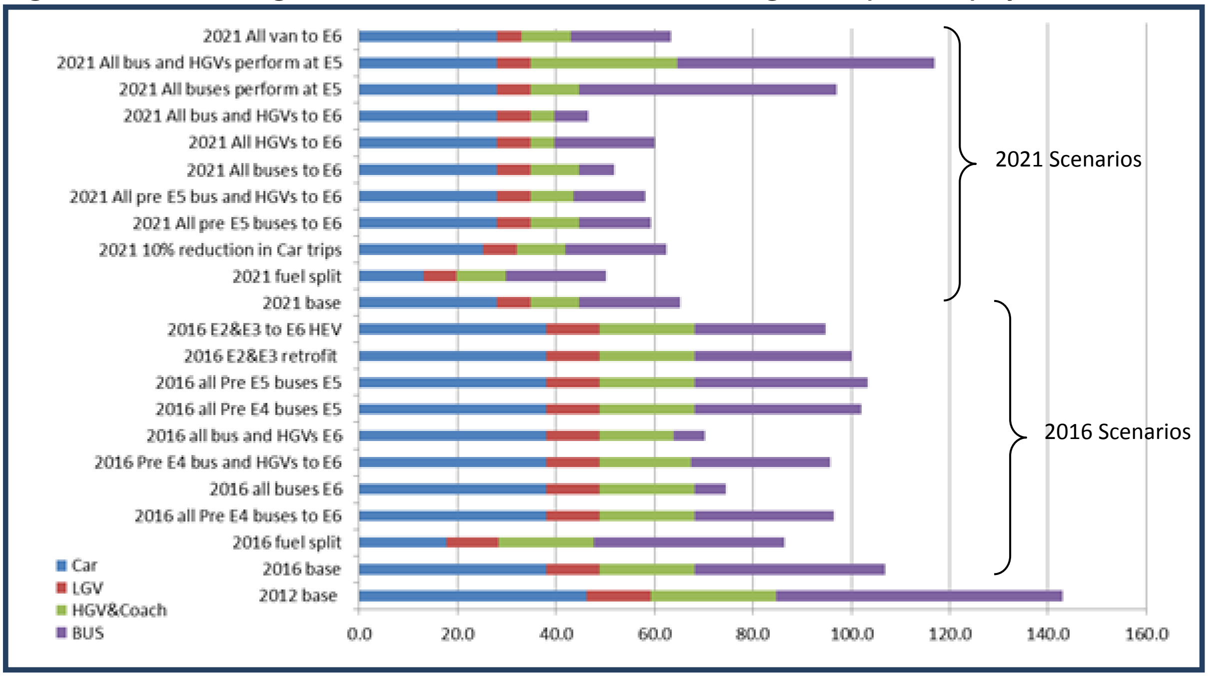


Figure 6 - Changes in NO_x Emissions within Outer Ring Road (Tonnes) by Scenario

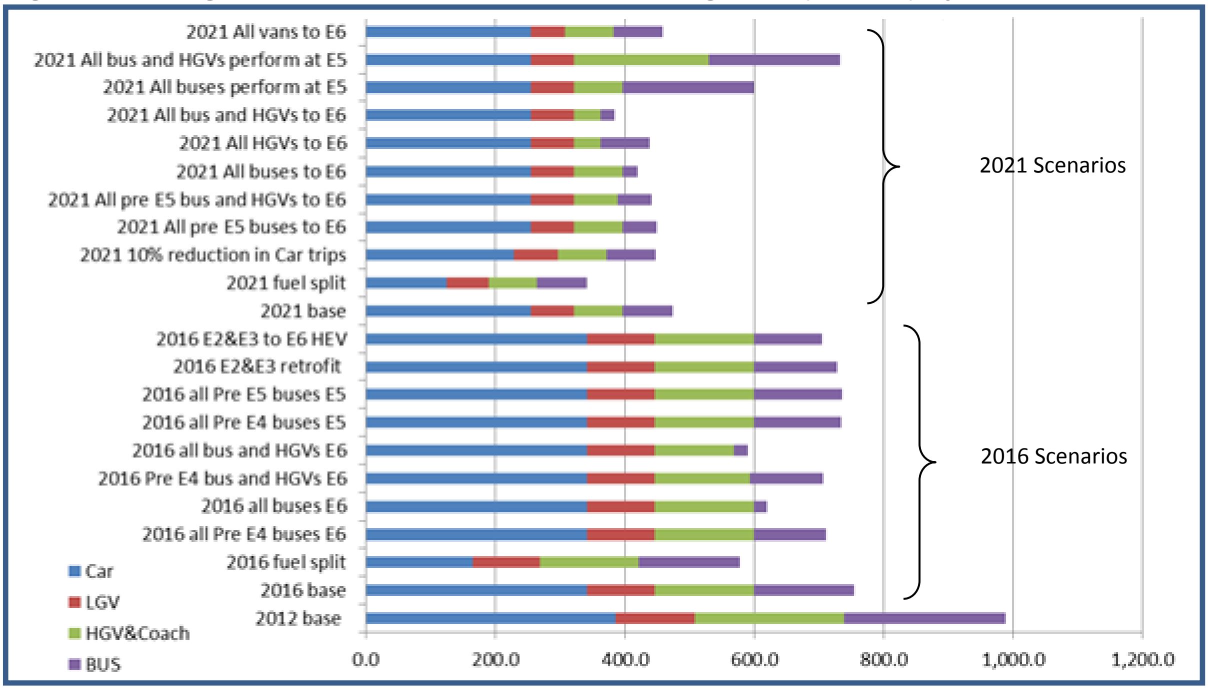


Figure 7 - Changes in $PM_{2.5}$ Emissions within Inner Ring Road (Tonnes) by Scenario

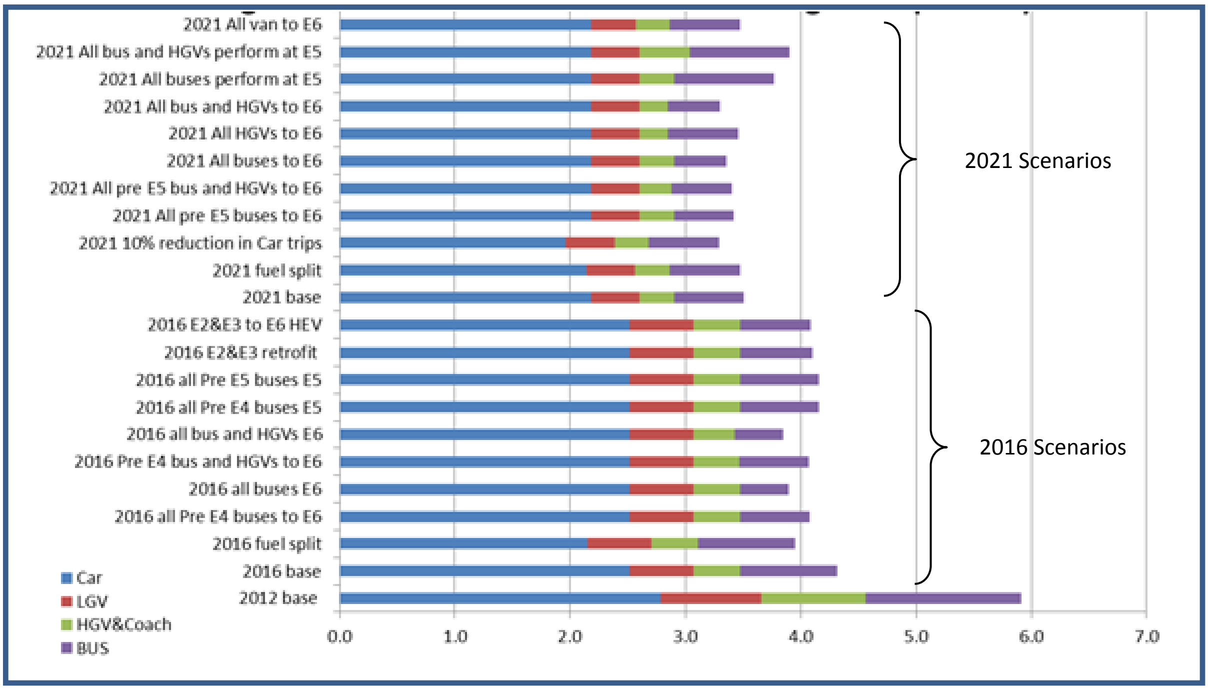
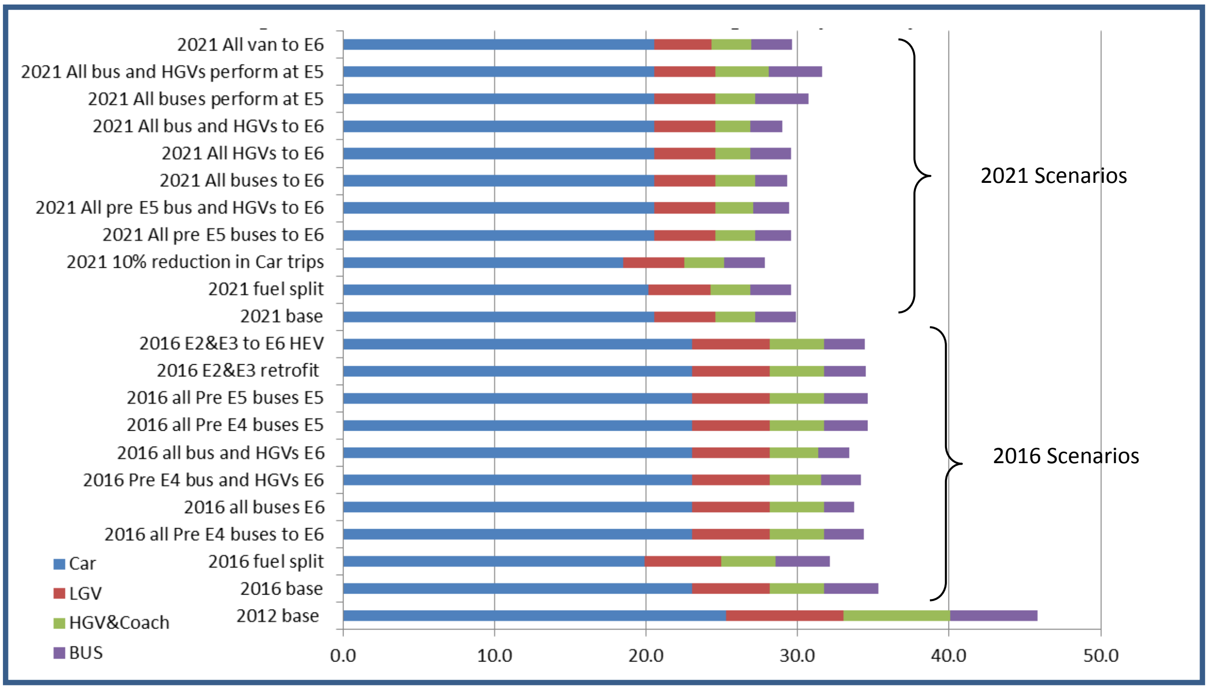


Figure 8 - Changes in $PM_{2.5}$ Emissions within Outer Ring Road (Tonnes) by Scenario



5.4.1 Assessment of the impact of LEZ interventions on Emissions

Accelerating the uptake of bus and HGV towards Euro VI within the Inner and Outer Ring Road areas shows significant potential for reducing NOx emissions but does not appear to have a significant impact on particulates.

Reversing the recent growth in smaller diesel vehicles also shows significant scope for reducing NOx emission benefits, particularly for the 2021 horizon, predicting five times the reduction of NOx emissions as reducing total car trips by 10%. However reducing the total number of car journeys would be more effective at reducing emissions particulates.

The emission reductions in the 2016 horizon are proportionately greater than in the 2021 horizon when the business as usual scenario assumes a much cleaner vehicle fleet. The cumulative benefits of reducing emissions at the earliest opportunity are discussed in Section 7. It is recognised that vehicle operators, if required to improve emissions, generally take action earlier than the target date providing earlier benefits.

Generally, the modelled LEZ scenarios show corresponding reductions in particulate matter along with NOx reductions with minimal impact on CO_2 emissions (Appendix 1). However, reducing car journeys by 10% does give an overall reduction of around 6% in CO_2 emissions and perform better than switching cars away from diesel for reducing particulates in the 2021 horizon. No attempt has been made to assess the additional impact of reduced congestion as part of this scenario.

Moving passenger cars away from diesel and back towards petrol indicates a marginal increase in CO_2 emissions will occur. However, whether the medium and long term aim to reduce CO_2 emissions from road transport will continue to be based on a diesel vehicle strategy is debatable and so the increase might not be considered significant. Evidence from countries such as Japan indicate that a petrol/hybrid/electric strategy for passenger and light goods vehicles could have a much greater potential to reduce CO_2 emissions whilst delivering significant air quality benefits.

5.4.2 Local Compliance Gap

As under the requirements of the Local Air Quality Management process, Leeds City Council has regularly monitored the concentrations of NOx and NO2 at representative locations within the Leeds District. A number of the sites have shown regular exceedance of the 40ug/m^3 Objective level for NO_2 (See Section 2). The compliance gap is the reduction in NOx emissions required to meet the NO_2 Objective at locations where annual concentrations of NO_2 exceed 40ug/m^3.

Using the Defra approved NOx to NO_2 calculator in an iterative process the total reduction in NOx emissions required within the study area has been estimated in order for sites currently exceeding the NO_2 Objective to achieve compliance. Table 5 shows the estimated total reduction of NOx emissions required inside the Outer Ring Road area to meet the NO_2 Objective at the representative monitoring sites which are not projected to meet those Objective under the business as usual scenarios.

Table 5 –NOx Emission Reductions Required Within the Outer Ring Road to Achieve NO2 Compliance

Monitoring Sites	Required NOx Reduction, tonnes	
	2016	2021
Back Norman Mount, Kirkstall	416	157
Otley Road, Headingley	304	54
Norman Row, Kirkstall	296	44
New Road Side. Horsforth	231	0

Table 6 lists the estimated NOx reductions likely to be achieved by each of the assessed LEZ Scenarios for the relevant base year. The modelling indicates that none of the interventions are expected to achieve compliance with the EU Objective for NO_2 levels at all locations within Leeds by either of the projected years on their own.

The modelling does suggest that if all HGVS and Buses were to meet Euro 6 standard by 2016, there would be a reduction in total NOx emissions inside the Outer Ring Road of 235 tonnes over and above the business as usual scenario. This reduction in NOx emissions are estimated be sufficient to deliver compliance with the NO2 Objective at New Road Side, Horsforth, but not at the other sites used in this study.

However, of the four sites considered, New Road Side is the only location, expected to achieve compliance by 2021 without intervention. Of the remaining 3 sites, compliance with the Objective level might be achieved by 2021 if one or more of the interventions were either fully implemented. However, in the case of locations similar to Back Norman Mount, it is likely to require the most difficult of all the modelled interventions to deliver (reducing diesel car journeys) in addition to other interventions to achieve compliance with the NO_2 Objective.

Table 6 –NOx Emission Reductions within Leeds Outer Ring Road for each LEZ Scenarios for 2016 and 2021

LEZ Measure	Predicted Nox Reduction, tonnes	
	2016	2021
2016 fuel split	177.0	
2016 all buses Euro VI	134.2	
2016 all HGV Euro VI	100.8	
2016 all bus and HGVs Euro VI	235.1	
2016 All vans Euro 6	50.8	
2016 Euro II &Euro III retrofit	26.8	
2016 all Pre Euro IV buses Euro VI	50.2	
2016 all Pre Euro IV HGV Euro VI	5.8	
2016 Pre Euro IV bus and HGVs to Euro VI	56.0	
2016 10% reduction in car traffic	34.1	
2021 fuel split		131.9
2021 All buses to Euro VI		54.1
2021 All HGVs to Euro VI		35.0
2021 All bus and HGVs to Euro VI		89.0
2021 All vans to Euro 6		14.7
2021 All pre Euro V buses to Euro VI		24.6
2021 All pre Euro V HGV to Euro VI		8.1
2021 All pre Euro V bus and HGVs to Euro VI		32.7
2021 10% reduction in car traffic		25.5

The modelling results from this study provide strong evidence that a combination of intervention measures would need to be pursued in order to meet Government Objective Levels for NO_2 and also the EU Limit Value.

6. Health Impact Assessment

The Health Impact Assessment (HIA) was carried out as a joint exercise between Public Health England, NHS Bradford, Leeds City Council and Bradford MDC. The HIA is a way of gauging the positive and negative health impacts of projects and policies with the aim of identifying areas in Leeds and Bradford that would be most affected by changes in pollution and specific associated health benefits.

A study of 74,000 cohorts across Europe, including 11,000 in Bradford has concluded that the chance of stroke and heart attack reduced by 10% for each 100m from a major road[25]. The main reason, amongst others, is due to exposure to $PM_{2.5.}$ The HIA for this study focuses specifically on the health impacts of NO_2 and $PM_{2.5}$ and maps modelled concentration changes in pollution against Lower Super Output Area (LSOA) data to quantify the impacts of those changes on the health of the population. It is acknowledged that, while our understanding of the health effects caused by air pollution is increasing, it is likely that current methodologies are likely to under estimate all impacts[26]. Certain health issues, including links of pollution to cancer, are not quantified as part of this study.

The process has enabled effective partnership working to develop between transport, health and air quality professionals within West Yorkshire and collaboration will continue as a result of this study. The partnership has increased the potential to identify new sources of funding for pollution prevention policies and provide better evidence to support grant funding opportunities. It is proposed that Health Economists will look at the outputs of the LEZ Study in more detail, funded by the NHS England's Academic Health Science Network (AHSN) in partnership with the Bradford Health Observatory.

The HIA accompanying this LEZ Study has been peer reviewed by Centre for Research in Environmental Epidemiology(CREAL), Barcelona, who support the initial findings. CREAL have provided comments and input regarding the methodology used and wish to help develop and publish the work in due course[27].

6.1 Health Impacts

The HIA has attempted to quantify the health effects across the Leeds District arising from the changes in $PM_{2.5}$ and NO_x concentrations predicted for future LEZ intervention scenarios compared with the 2012 baseline data. A methodology and toolkit was developed to allow pollution concentration outputs for different modelled scenarios to be quickly and easily compared at a district and LSOA level. While not all the LEZ scenarios have been assessed, the findings give an indicative picture of the likely benefits arising from non-selected scenarios.

Table 7 shows results for 4 of the modelled changes indicating that the equivalent of between 14 and 17 deaths a year could be saved with a much higher number experiencing greater health benefits through reducing road traffic based pollution.

Reducing car journeys by 10% could be achieved through a variety of different policy measures. The interventions which result in an increased level of cycling and walking will also offer significant additional health benefits which have not been quantified as part of this study. However, this measure could play a significant role in reducing obesity levels and improving mental well being

[25] Pedersen M, Giorgis-Allem L, Bernard C, et al. Ambient air pollution and low birthweight: a European cohort study (ESCAPE). Lancet Respir Med 2013; 1(9): 695-704

[26] Takenoue Y, Kaneko T, Miyamae T, et al. Influence of outdoor NO_2 exposure on asthma in childhood: Meta-analysis. *Pediatrics International* 2012; 54:762-769

[27]Discussion with S.Jones (Bradford) when presenting to HELIX consortium meeting (June 2014)

http://www.creal.cat/en_noticies/view.php?ID=319

Table 7 - Health Impact Assessment: Summary of Impacts of Selected Interventions

Baseline Scenario 2012 (approximate deaths attributable to air pollution - PM $_{2.5}$)	350 (117 - 642)			
Scenario	**Pre- Euro IV buses & HGVs upgraded to Euro VI by 2016**	**All buses and HGVs upgraded to Euro VI by 2021**	**Year 2000 ratio of petrol to diesel met by 2021**	**10% reduction in journeys and increase in speed by 2021**
Approximate reduction in deaths attributable to $PM_{2.5}$ (annual)	14 (2-26)	16 (2-30)	16 (2-29)	17 (2-31)
Approximate reduction in cardiopulmonary deaths attributable to $PM_{2.5}$ (annual) *	7 (2-13)	8 (3-15)	8 (3-14)	8 (3-15)
Approximate reduction in coronary events attributable to $PM_{2.5}$ (annual)	Data not Available for Leeds			
Approximate reduction in low birth weight babies (<2500g) attributable to $PM_{2.5}$ (annual)	10 (3-18)	11 (4-20)	11 (4-20)	12 (4-21)
Approximate reduction in low birth weight babies (<2500g) attributable to NO_2 (annual)	11 (0-23)	22 (0-46)	23 (0-49)	20 (0-42)
Approximate reduction in children developing asthma attributable to NO_2 by age 18	172 (38-318)	344 (76-637)	368 (82-682)	321 (71-594)
Approximate reduction in pre-term births attributable to $PM_{2.5}$	2.8 (2.6-3)	3.3 (3-3.5)	3.2 (3-3.4)	3.4 (3.2-3.6)
Annual years of life gained for newborns (all birth combined)	224	260	257	270

Numbers in brackets are 95% confidence intervals. All estimates are number of deaths per year apart from childhood asthma which is prevalence by age 18 years.

**Cardiopulmonary deaths are a subset of all deaths so (to avoid double counting) should not be added together to calculate total deaths*

6.2 Links Between Deprivation and Health

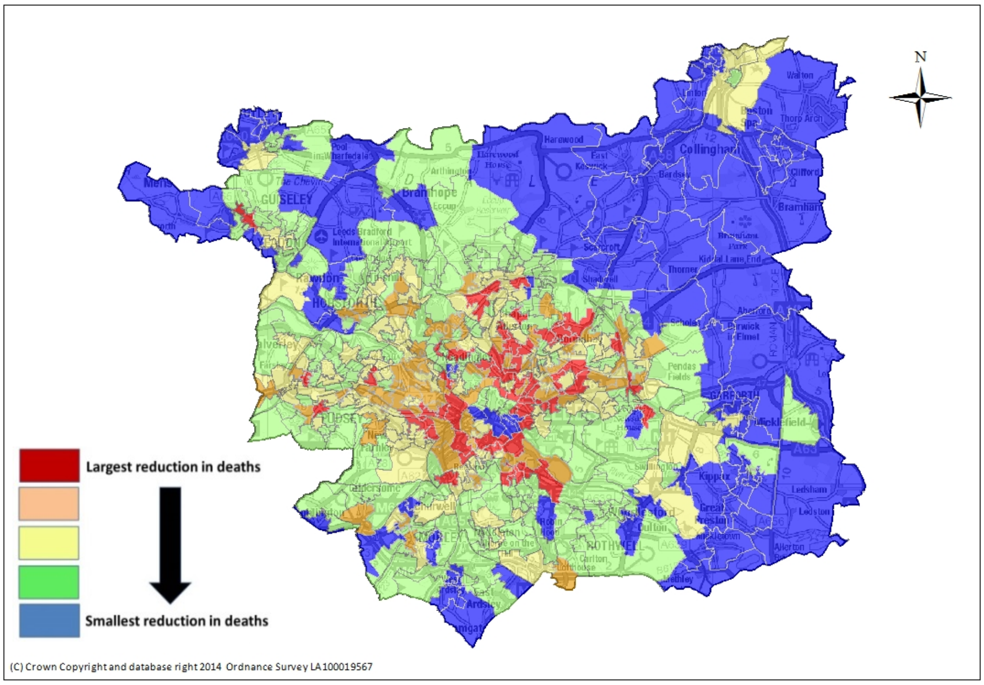
Another facet of the HIA Study was to assess the relationship between road traffic emissions and levels of deprivation. It was found that a significant correlation exists between high pollution levels and areas with deprived populations. Therefore an improvement in pollution levels through the reduction of road transport emissions could be an effective mechanism for improving the health of some of the most deprived residents in the District. Such an outcome is one of the key Health and Wellbeing objectives of Leeds' City Priority Plan (2011 -2015) in the ambition to be the Best City in the UK by 2030[28]

Map 8 illustrates the relative benefits arising within each LSOA over the existing situation from the reduction in $PM_{2.5}$ emissions estimated if all buses met Euro 6 standard across HIA study area by 2021. Map 9 identifies the LSOAs with the greatest levels of deprivation. Although it was possible to quantify the estimated reduction in deaths in each LSOA these figures are subject to large uncertainty at such a local level and are not presented.

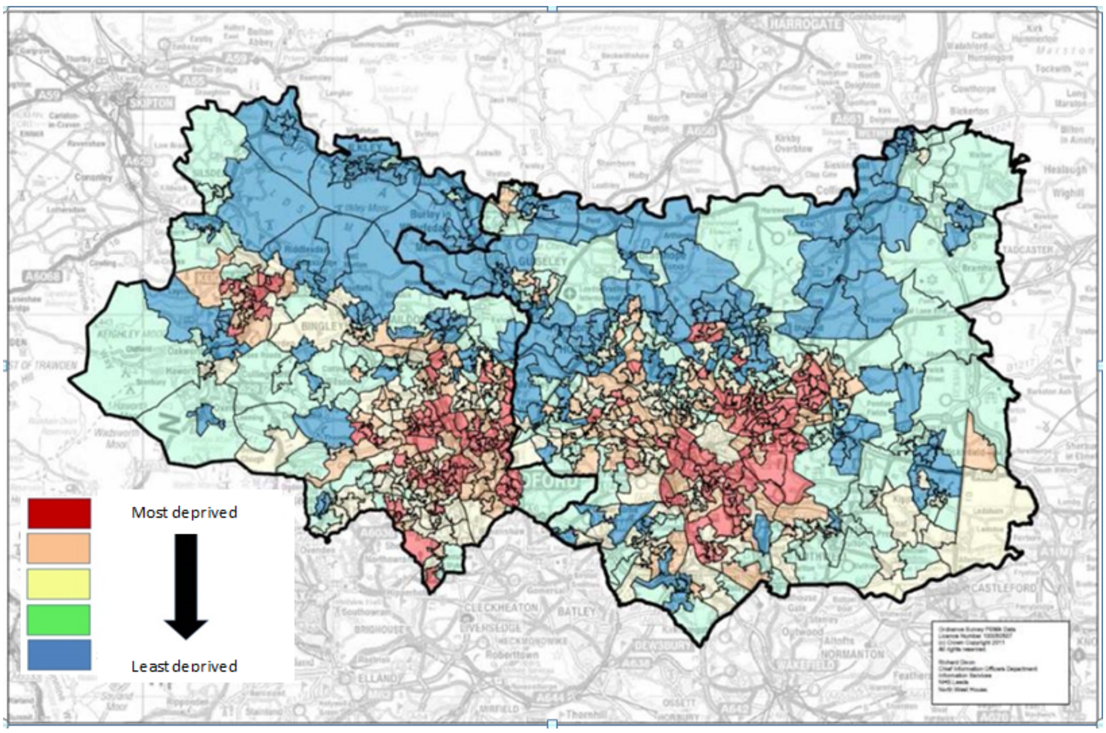
[28] Leeds Vision www.leeds.gov.uk/docs/Leeds%20City%20Priority%20Plan.pdf

However, the maps can be used to assess those parts of Leeds and Bradford where a vehicle based low emission strategy would have the largest beneficial health impact.

Map 8 - Reduction in Deaths as a Result of Falling $PM_{2.5}$ if all Buses Met Euro 6 Emission Standards by 2021.



Map 9 Deprivation in Leeds and Bradford (blue area are the least deprived, red areas the most deprived)



Within Leeds the impact of reduced mortality is predicted to be highest in the central deprived areas as well as along arterial roads running West and North East and South East from the city centre and along parts of the northern outer ring road.

6.3 Key Findings

The full Health Impact Assessment is available separately; however the key findings concluded that;

- There are an estimated 350 deaths per year in Leeds attributable to fine particulate air pollution ($PM_{2.5}$).
- The four scenarios predicted a fall of between 14 and 17 deaths per year in Leeds, however a larger group of people would experience health benefits.
- People living in deprived areas are the most likely to live in areas with the highest levels of road pollution. Although none of the least deprived population live in high pollutant areas, this rises to 10% of the deprived population living in high $PM_{2.5}$ areas and 19% living in high NOx areas. This gradient represents an inequality in exposure to harmful road pollutants, with adverse health effects more likely in poorer areas
- All four of the low emission zone scenarios assessed show improvements in air quality in most parts of Leeds. The biggest reductions in $PM_{2.5}$ and NOx were in the most deprived areas. This goes some way towards addressing the inequalities in exposure to pollution.
- Modelled reductions in NOx were highest for Scenario 3 (reducing the proportion of journey made by diesel cars by 2021) which appeared to have the biggest positive impact (affecting the greatest proportion of the deprived population).
- Health benefits are predicted to be greatest in inner city and deprived areas but also occur in the wider population due to commuting and travel within the Districts.
- A fall in premature and low birth weight babies and childhood asthma, and fewer hospital admissions for heart and respiratory problems are predicted.
  - Improvements in health are most likely to occur when policies to improve air quality span local authorities and also encourage increased active travel (walking, cycling and public transport),
- In combination these policies could lead to cleaner air as well as improvements in physical and mental health, reduced obesity rates and improved safety.

The HIA also recommends that;

- The methods developed here should be considered for investigating the impact of a low emission zone across West Yorkshire.
- The results should be summarised alongside other work packages within the LEZ feasibility study, and presented to:
  - Elected members in Leeds and Bradford Districts,
  - The West Yorkshire Combined Authority,
  - Joint Health and Well Being Boards of both Districts, to inform the Joint Strategic Needs Assessment.
- The option for development of a LEZ should be placed within the context of a wider package of public health and environmental policy (including a modal shift towards safe active travel and increased physical activity).

7. Cost Benefit Analysis

An economic assessment of the costs and benefits (CBA) of the different intervention scenarios investigated in this study has been carried out by Ricardo-AEA in accordance with Government best practice, including:

i) Assessment of the damage costs saved and abatement costs saved for each LEZ intervention scenario

ii) Assessment of the costs associated with introducing LEZ intervention scenarios
iii) Assessment of the costs of enforcing LEZ scenarios

The aim of the CBA is to look at the cost-effectiveness of potential LEZ intervention scenarios. A key issue with this type of CBA is that those who benefit from improvements in air quality are not necessarily the same as those who may incur costs from complying with the measures. For example, the most cost effective measure per tonne of pollution reduced is based on the cost of introducing that measure against the value of the emissions reduced to the economy as a whole. The consequential impacts of any costs incurred by the vehicle operators have not been assessed within the scope of this study.

Conversely, while it is likely that the introduction of a LEZ could have beneficial impacts across a wider area of the Leeds District than the LEZ boundary, the CBA only quantifies those benefits accrued within the Inner and Outer Ring Roads. Additionally, the CBA does not quantify the potential impacts on improved productivity through improved health and therefore the true benefits may be underestimated.

As part of the WYLES, Bradford NHS (AHSN) is commissioning a further study to look at the local economic impacts associated with certain LEZ intervention scenarios which will also provide further detail of the health related economic costs of introducing future LEZ/Low Emission Strategy (LES) measures.

It should be noted that opportunities for central Government grant funding, while not considered as part of the assessment, can influence which intervention scenario options would have the most financial viability to be taken forward.

7.1 Damage Costs

Damage costs provide a means of estimating a value for the impacts of exposure to air pollution on health – both chronic mortality effects (which consider the loss of life years due to air pollution) and morbidity effects (which consider changes in the number of hospital admissions for respiratory or cardiovascular illness) – in addition to damage to buildings (through building soiling) and impacts on materials.

7.2 Abatement Costs

The abatement cost approach has two parts: the scientific assessment and the economic assessment. The scientific assessment reviews how a decision is likely to affect air quality and compliance with relevant legally binding objectives. The ‘compliance gap’ is the difference between air quality with the decision and the relevant obligation

The economic assessment then places a monetary cost estimate on the change in air quality represented by the compliance gap. DEFRA have developed estimates of the unit costs for emission abatement using a marginal abatement cost curve (MACC) to estimate the potential supply of abatement at a national scale. The MACC for NOx emissions reflects the abatement potential and cost for a range of different abatement technologies. Wider impacts on society are incorporated, including: impacts on other pollutants; energy and fuel impacts, and damage costs.

The abatement represented by the national average compliance gap is compared against the MACC to estimate an indicative unit cost of abatement. The value of the change in air quality using unit abatement costs provides an indicative marginal cost per tonne of emission.

Figure 9 illustrates a hypothetical MACC. The supply of abatement is illustrated by the coloured blocks which represent an available abatement technology for the pollutant being considered. The height of each block is the cost of the abatement whilst its width shows its abatement potential.

Demand for abatement is the difference between the prevailing level of air pollution and the legally binding obligation. The intersection of supply with demand identifies the marginal abatement technology. In the diagram the marginal abatement technology (the cheapest abatement option not yet exhausted) is marked as A and hence the price is set as P*. P* is therefore the value of any change in emissions resulting from the measure or policy assessed. If a policy reduces the demand for abatement, it would reduce uptake of measure A. Conversely a measure which required additional abatement would impose a cost of P* per unit of additional abatement

Figure 9 Example Marginal Abatement Cost Curve (MACC)

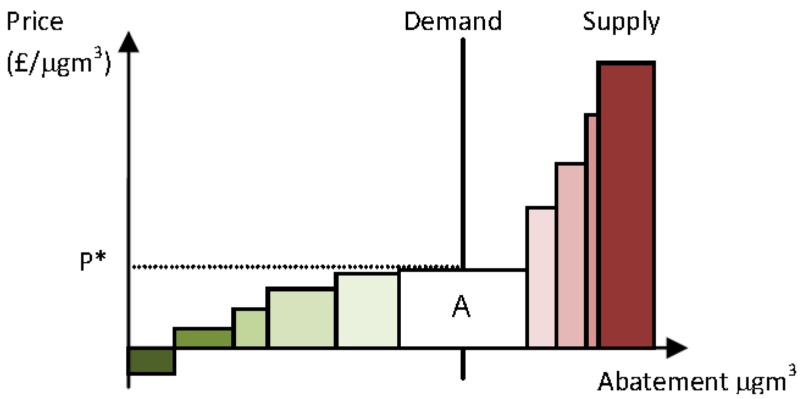


Figure 10 illustrates the DEFRA MACC for NOx emissions demonstrating the costs and abatement potential of a range of different abatement opportunities (excluding abatement technologies with a cost of above £100,000 per tonne). DEFRA guidance recommends that if there is no clear rationale to use a particular measure a default value of £29,150 per tonne of NO_x is used. A lower figure is used for the Euro II & III bus retrofit scenario as the national MACC assumes that these measures will be implemented anyway.

The abatement cost methodology is applicable while NO_2 concentrations at relevant receptors remain above the limit value within the area assessed. Existing concentrations and future projections indicate that the concentrations at the most polluted sites in Leeds will remain above the limit value for nitrogen dioxide beyond 2021.

Figure 10 **DEFRA MACC for Nox Emission Reductions Under £100,000 per tonne.**

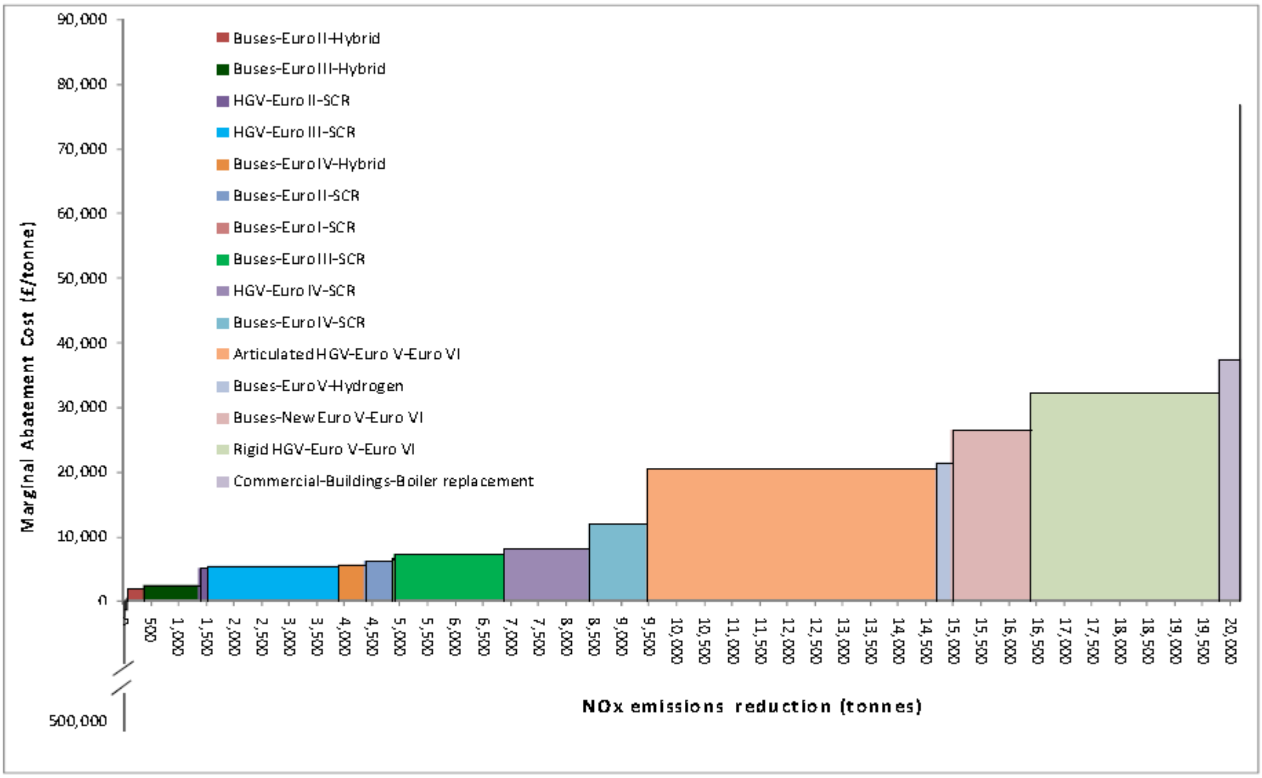


Table 8 shows the abatement costs avoided (or value of the emission reductions) that each scenario is expected to deliver inside the Leeds Outer Ring Road alongside the actual emission reductions forecast for each measure, compared with the 2016 or 2021 business as usual.

The table shows the value of the national abatement costs avoided by each measure for the relevant single year, 2016 or 2021. It also shows the value of the costs avoided over the period 2016-2021 for five measures. A discount rate of 3.5% was applied to future year abatement costs avoided.

Table 8 - Abatement Costs Avoided in the Leeds Outer Ring Road area

Scenario	NOx Emission reduction, tonnes		Abatement cost, £(2015)
	2016	2021	
2016 fuel split (reduction in diesel cars)	**177**		4,985,072
2016 all buses Euro VI	134.2		3,779,643
2016 all HGV Euro VI	100.8		2,838,957
2016 all bus and HGVs Euro VI	235.1		6,621,415
2016 All vans Euro 6	50.8		1,430,744
2016 Euro II &Euro III retrofit	26.8		187,911
2016 all Pre Euro IV buses Euro VI	50.2		1,413,845
2016 all Pre Euro IV HGV Euro VI	5.8		163,353
2016 Pre Euro IV bus and HGVs to Euro VI	56		1,577,198
2016 10% reduction in cars	34.1		960,401
2021 fuel split		131.9	3,127,816
2021 All buses to Euro VI		54.1	1,282,903
2021 All HGVs to Euro VI		35	829,974
2021 All bus and HGVs to Euro VI		89	2,110,505
2021 All vans to Euro 6		14.7	348,589
2021 All pre Euro V buses to Euro VI		24.6	583,353
2021 All pre Euro V HGV to Euro VI		8.1	192,080
2021 All pre Euro V bus and HGVs to Euro VI		32.7	775,433
2021 10% reduction in cars		25.5	604,695
2016-2021 fuel split	926.7		24,130,780
2016-2021 all buses Euro VI	564.9		14,873,559
2016-2021 all HGVs Euro VI	407.4		10,751,676
2016-2021 all buses and HGVs Euro VI	972.3		25,625,858
2016-2021 all vans Euro 6	196.5		5,199,413
2016-2021 10% reduction in car journeys	178.9		4,657,007

The Euro VI bus options were also used as a proxy for compressed natural gas (CNG) scenarios, although evidence suggests that CNG buses would actually emit less pollution than diesel equivalents[29].

7.3 Costs of Introducing a LEZ Measures Leeds

The implementation of a LEZ will most likely result in additional costs to Leeds City Council for the required enforcement of the measures adopted and additional costs to the owners of the vehicles that require replacing or retrofitting in order to comply with the minimum standard set by the LEZ.

[29] Personal communication with Prof. D Carslaw (Kings College London) Sept. 2014 following series of drive by emission testing of >1000 buses

7.3.1 Cost of Compliance

The costs set out in Table 10 below depend on the assumptions made in the analysis as set out below. The costs for introducing different measures may include:

- Additional capital expenditure by the operator
- Additional or reduced operational costs (e.g. Urea consumption in SCRs and fuel penalty)
- Additional or reduced maintenance costs

However no assessment of what the consequences of any increased costs might have to the vehicle operators concerned has been attempted as part of this study.

7.3.1.1 Bus Replacement Measures

Many of the bus companies operate large fleets of buses across the UK and, in theory it might be possible to accommodate non-compliant buses by redeploying them elsewhere, at minimal cost. In practice, this will not always be possible and it will then be necessary to sell surplus buses second-hand. This assessment has assumed a capital cost for a new bus in 2016 of £180,000.

Relatively few buses operating regular passenger services in Leeds are older than 15 years old. The price of second hand buses advertised on *coachandbusmarket.co.uk* was used to assess the likely value of any non-compliant buses which would need disposing of and deducted from £180,000 to calculate the net capital replacement cost for each chosen scenario.

Buses services in Leeds are operated by various bus companies. First Leeds operates most services in Leeds with almost all of their regular bus routes entering the Inner and Outer Ring Road areas. It is therefore expected that First Leeds would need to ensure almost all of their fleets complied with the requirements of a Low Emission Zones. Other bus operators operate relatively few bus services into the Leeds Ring Road.

The CBA has calculated the theoretical minimum number of buses on each route, calculated from the frequency of buses and the round trip time. In practice, the bus companies will need more than this minimum number to allow for maintenance, crew changeover etc. Comparing the theoretical minimum on routes operated by First Leeds with their total fleet indicates a fleet size approximately 50% larger than the theoretical minimum number is required. The required fleet sizes for the other bus companies operating in Leeds has been estimated in a similar way.

The scenarios which involve the introduction of Euro VI buses have also been used as a proxy for the option of introducing compressed natural gas (CNG) buses. As part of this study, bus operators using CNG buses were contacted to obtain further information regarding operational costs. Reading Buses have recently started operating a fleet of 20 CNG buses and have a further 34 on order. Operating cost Information provided by Reading Buses is shown in Table 9 below. The operating costs shown include a £1M refuelling station depreciated over 15 years, with support funding from round 4 of the DfT Green Bus Fund.

7.3.1.2 HGV Replacement Measures

DfT Vehicle Statistics table VEH0105[30] reports 5408 HGV were registered in Leeds in 2013. Vehicle Statistics table VEH0122 gives the numbers of cars, motorcycles and other vehicles (including HGV) registered in each postcode district in the last quarter of 2013. Postcode districts LS1-LS18 and LS28 are within or intersect the Leeds Outer Ring Road; of these, substantial parts of LS1, LS2, LS10 and LS11 are within the Inner Ring Road. The number of HGVs registered in each postcode district was estimated, pro-rata, from the veh0105 statistics on the

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[30] https://www.gov.uk/government/statistical-data-sets/veh01-vehicles-registered-for-the-first-time#table-veh0110

basis of the “other” vehicle counts in the veh0122 statistics. On this basis, it was estimated that 3564 HGVs were registered within the outer ring road (ORR) and 568 HGVs registered in inside the inner ring road (IRR)

The ANPR camera survey data was referenced against the DfT licensing data to provide details of each unique vehicle registered inside the ORR. This produced a vehicle sample of 446 rigid (94%) and 29 articulated HGVs. The age profile of these HGVs was assumed to continue through the future business as usual base years.

The assessment assumed a capital cost for a new articulated tractor unit in 2016 of £80,000 and a capital cost for a rigid HGV of £65,000. The assumption was made that non-compliant HGVs based within the ring road areas would have to be replaced or upgraded to meet the higher standards specified for a LEZ. However, it was assumed that haulage companies with fleets based outside the proposed LEZs would be able to manage their operations using compliant vehicles already within their fleet at minimal additional cost.

Prices of second hand HGVs advertised on *trucklocator.co.uk* were used to determine the average value of the non-compliant vehicles needing to be replaced depending on the scenario being assessed. This value was deducted from the assumed price of a new HGV to determine the net capital cost to the operator. Scenarios which would require any Pre-Euro V vehicles replacing have also assumed an additional ad-blue and fuel penalty of £427 per annum with £1,000 per annum additional service costs.

Table 9 Comparable operating costs for buses operated by the Reading bus company

Vehicle	Euro rating	Pence per mile	Avg miles between breakdowns (normalised)	Servicing interval
CNG single deck	Euro V	13	220	8 wks
Lightweight diesel midibus	Euro V	14	190	8 wks
Series hybrid double deck	Euro V	24	140	12 wks
Diesel single deck	Euro IV	26	144	8 wks
Diesel double deck	Euro IV & V	28 - 32	100 - 132	8 wks

Like-for-like comparison

7.3.1.3 LGV Replacement Measures

New vans entering service in 2016 are expected to operate for approximately 12 years. Under the business as usual case, older vans would gradually be replaced throughout the period 2016-2027 with vans that meet or exceed the Euro 6 standard.

For scenarios which would require non-compliant vans to be replaced, the net capital cost was calculated as the capital cost of a new van less the second hand price of the replaced vehicle and less the business as usual capital cost. It was assumed that replacing older vans with Euro 6 models would not increase operating and maintenance costs and that new van will cost an average price of £35,000.

It was assumed that non-compliant vans based within the ring road areas would be replaced or upgraded to meet the standards specified for the LEZs. However, it was assumed that van fleet operators based outside the proposed LEZ boundary would be able to manage their operations using compliant vehicles already in their fleet at minimal additional cost. It is recognised that this assumption may not hold for the small business and self–employed which will only operate a low number of vehicles.

DfT Vehicle Statistics reports that there were 33,661 LGVs registered in Leeds in 2013. The number of LGVs registered in each postcode district was estimated, pro-rata, from statistics based on other DfT vehicle data. On this basis, there were an estimated 22,183 LGVs registered within the ORR and 4,761 LGVs registered inside the IRR. The business as usual assumption is that the oldest twelfth of the LGV fleet is replaced each year.

7.3.1.4 Discouraging Diesel Cars within the Leeds Urban Area

It can be seen from the all the assessments that diesel cars are a key contributor to NO_2 issues across Leeds and measures to control or limit their use could have significant benefits. However, this is a complex issue depending on how discouragement of diesel cars within the Leeds urban area is formulated into a policy. The initial cost figures shown in Table 10 assume that a large number of diesel car drivers in Leeds would switch to a petrol engine car and the costs only take account of operational costs based on advertised economy figures.

There were 216,976 cars registered within the ORR in 2012. The recent trend in new car sales suggests that the number proportion of diesel engine cars will continue to increase in future years under the business as usual forecast. The scenarios modelled would require 26% of the car fleet to switch away from diesel engines by 2016. This would increase to 33% needing to switch by 2021. The development of policies to limit/control the use of diesel cars will require analysis of the financial complexities that go beyond the remit of this study and may be affected by future national Government policy.

It should be noted the Leeds City Council fleet currently includes a large number of small diesel powered vehicles which currently operate predominately inside the urban areas. As part of the ongoing Low Emission Strategy work, an assessment of the Leeds City Council fleet emission profile and options for accelerating the uptake of low emission vehicles is currently being carried out.

7.3.1.5 Reducing Car Journeys within the Urban Area

The cost of reducing car journeys through the promotion of walking and cycling has been based on the costs of national programmes such as Cycling Demonstration Towns (CDT) and Sustainable Travel Towns (STT) where costs of £30.00 and £46.93 respectively is applied per person. The cost of TravelSmart was estimated at £25 per person if 10.8% of the population took up the offer of personal support.

The costs for the introducing TravelSmart programme in Leeds is therefore estimated as an overall cost of £2.03m, which is less than the total damage and abatement costs avoided calculated for a 10% reduction in car traffic (22% of the costs avoided). Therefore the assumption is made that introducing a TravelSmart programme could be cost neutral with respect to air quality benefits if it achieved a 2.2% reduction in car traffic in Leeds.

Interventions to promote walking and cycling will have significant additional benefits to air quality improvements, including health benefits resulting from greater levels of activity and reduced congestion. A University of Sheffield health, economic and modelling report[31] estimated the cost of intervention per Quality-Adjusted Life Year (QALY) saved resulting from greater levels of physical activity for each intervention. These were £5000, £900 and £300-2500 per QALY for CDT, STT and TravelSmart interventions respectively. The report assumes a “value” of £20,000 per QALY: on this basis the value of the benefits from walking and cycling measures are substantially greater than the cost of introducing them.

[31] Walking and cycling: local measures to promote walking and cycling as forms of travel or recreation: Health economic and modelling report. University of Sheffield, 2012. https://www.nice.org.uk/guidance/ph41/resources/economic-modelling-report2

A summary of the costs of implementing the LEZ intervention measures in Leeds are presented in Table 10 which indicates the cost of the measures for implementation in 2016 and 2021 (net present value, base 2015). The costs for the HGV measures include the estimated cost of enforcement of the LEZ. In general, the cost per tonne abated is lower for implementation in 2016 than in 2021 for comparable measures. Therefore it is assumed to be more cost effective to implement measures sooner rather than later and cost effectiveness is reduced if implementation is delayed.

The options to reverse the recent increase in diesel use within the urban area and accelerate the anticipated uptake of Euro VI buses and HGVs provide the largest abatement cost avoided. Upgrading All Pre Euro V HGVs to Euro 6 standard and retrofitting Euro II and III buses provide the smallest cost avoided as it is expected that natural fleet turn over would remove most of these vehicles from the roads by 2021 in any event.

7.3.2 Cost of LEZ Enforcement

The CBA has looked at the costs and implications for enforcing selected intervention scenarios. Parking enforcement in Leeds and the police currently use manual and camera methods for enforcing vehicle offences aimed at parking restrictions and improving road safety. Vehicle emissions in Leeds are not currently controlled other than through MOT provisions.

7.3.2.1 Bus Measures

Enforcement of bus emission standards could be achieved through the Traffic Commissioner only issuing licences for compliant vehicles. Alternatively, bus emission standards could be included within Quality Contracts or Bus Partnerships. These issues are currently under discussion between the West Yorkshire Combined Authority (WYCA) and the Association of Bus Operators in West Yorkshire (ABOWY).

There is currently a draft emission standard for buses prepared by WYCA which states that all buses *"should meet Euro III Standard within 3 years subject to commercial viability".* The results of this study suggest that this draft standard would not be sufficient to make meaningful improvements in the air quality of Leeds. However officers within WYCA are aware of the preliminary findings of this Study which may influence the final bus emissions standards.

7.3.2.2 HGV and LGV Measures

The HGV and LGV intervention options will most likely require ANPR systems for enforcement. The CBA has factored these costs into the cost per tonne of NO_x abated.

The cost of installing and operating ANPR systems depends to a considerable extent on the existing infrastructure. Start-up costs include the costs of the cameras, site preparation, signage, mounting structures and associated civil engineering, security provision, back office accommodation and equipment, and back office training.

Operating costs include maintenance of the cameras and back office staff, accommodation and supervision costs. The existing infrastructure already covers some of these aspects. It has been estimated that installation costs of £10,000 per camera[32] plus operating costs associated with four full time staff equivalents at approximately £160,000 per year[33]. The net present value (base 2015) of installing and operating 22 cameras in Leeds over the period 2016-2021 is estimated to be £1,065,000. Manual enforcement options and issues around identification of certain vehicle types, according to their emissions, are discussed in the CBA.

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[32] Discussions with Bradford MDC enforcement team through the WYLES project

[33] Assumption made that Bradford would need 2 Full time staff and Leeds would need 4 based on number of cameras and vehicle movements

Table 10 Costs of measures per tonne of NOx abated within the Outer Ring Road

Measure	Discounted cost , £million 2015		Discounted emission reduction, tonnes 2015			Cost per tonne abated, £(2015)	
	2016 implementation	2021 implementation	2016-2021	2021 onwards	2016-onwards	2016 implementation	2021 implementation
Fuel split	83.8	89.9	827.8	652	1479.8	57,000	138,000
All buses Euro VI	23.2	7	510.2	137	647.2	36,000	51,000
All buses Euro VI (CNG scenario)	0.5	0.6	510.2	137	647.2	1,000	4,000
All HGV Euro VI	46.6	6.9	368.8	68	436.8	107,000	101,000
All bus and HGV Euro VI	69.8	13.9	879.1	206	1085.1	64,000	67,000
Pre Euro IV buses to Euro VI	2.9		144			20,000	
Pre Euro IV buses to Euro VI (CNG scenario)	0.7		144			5,000	
Pre Euro IV HGV to Euro VI	1.6+		10			160,000	
Pre Euro IV bus and HGV to Euro VI	4.5+		154			29,000	
All vans Euro 6	156	51	178.4	41	219.4	711,000	1,244,000
Euro II and Euro III bus retrofit	2.5		64.7			39,000	
Pre Euro V buses to Euro VI		1.5		52			29,000
Pre Euro V buses to Euro VI (CNG scenario)		0.4		52			8,000
Pre Euro V HGV to Euro VI		1		7			143,000
Pre Euro V bus and HGV to Euro VI		2.5		58			43,000
Promotion of walking and cycling(TravelSmart)	2.0		39.9			50,000	

Measure	Cost per tonne abated , £ 2016 implementation
All buses Euro VI (CNG scenario)	1,000
Pre Euro IV buses to Euro VI (CNG scenario)	5,000
Pre Euro IV buses to Euro VI	20,000
Pre Euro IV bus and HGV to Euro VI	29,000
All buses Euro VI	36,000
Euro II and Euro III bus retrofit	39,000
Promotion of walking and cycling(TravelSmart)	50,000
Fuel split	57,000
All bus and HGV Euro VI	64,000
All HGV Euro VI	107,000
Pre Euro IV HGV to Euro VI	160,000
All vans Euro 6	711,000

+ *Includes cost of LEZ enforcement for Outer Ring Road*

7.3.2.3 Discouraging Diesel Cars within the Leeds Urban Area

Incentives and disincentives to discourage the use of certain diesel cars in the urban area will require further consideration, including national measures such as Vehicle Excise Duty (VED) which currently provide advantages for diesel vehicles over petrol vehicles based on CO_2 emissions. Green parking permits, differential parking rates and mileage allowances are some of the measures that could help reverse the dieselisation of the urban passenger car fleet if combined with public awareness campaigns.

The major cost to Leeds City Council would be the cost of any incentive introduced to encourage non-diesel cars or the cost associated with enforcement against them, i.e. using ANPR cameras as described above. Manual enforcement would be more difficult following the recent removal of the windscreen mounted VED disc.

7.4 External Funding Streams

The feasibility of introducing different measures can be influenced through funding opportunities which are not accounted for in the CBA. For example, the Euro II and III bus retrofit option appears to be one of the least cost effective measures to introduce however, this measure is already being implemented within West Yorkshire.

The WYCA have been successful in attracting DfT Clean Bus Technology fun funding to retrofit all the Euro III and IV school buses they operate within West Yorkshire. Bradford MDC was also successful in an application to the 2014/15 DfT Clean Vehicle Technology Fund (CVTF) to work in partnership with First Bus and Transdev (who are providing match funding) to retrofit 25 Euro III buses with selective catalytic reduction and particle traps (SCRT).

Other funding streams will be identified that may assist in introducing low emission measures in Leeds, including:

- Up to £35m OLEV (2015-2020) funding to create 2 to 4 'Low Emission Cities'
- £30m OLEV (2015- 2020) funding for low emission buses, including gas buses and infrastructure.
- £20m OLEV (2015-2020) funding towards Low emission Taxis
- £32m OLEV (2015-2020) funding for EV recharging infrastructure

A briefing note on OLEV funding opportunities has been provided to WYCA Local Transport Plan Board.

7.5 Conclusions of the CBA

The cost of the measures was estimated taking into account the number of vehicles potentially requiring replacement and their net capital replacement cost compared to the capital cost for the business as usual case. The estimate included additional operating and maintenance costs for Euro VI vehicles. The costs for CNG buses takes into account the estimated additional capital and operating costs of the required gas compression plant but also the lower cost of CNG fuel compared to diesel.

The CBA concludes the most cost effective option to reduce road traffic pollution in Leeds would be to implement a policy requiring all buses to meet Euro VI diesel standard within the Outer Ring Road, providing operators switch non-compliant buses to CNG where practicable. If bus operators consider it impractical to operate CNG buses within Leeds due to refuelling and servicing constraints, the next most cost-effective measure would be to replace existing Pre-Euro IV buses with conventional Euro VI buses, however this could be between 4 and 20 times more costly per tonne of NOx reduced then introducing CNG buses.

The benefit of improved air quality resulting from TravelSmart personalised travel support would exceed the cost of the intervention in Leeds. The other measures considered cannot be justified on the basis of improved air quality alone. However, interventions to promote walking and cycling will have other benefits, most importantly improved health resulting from increased physical activity.

All other interventions assessed are likely to exceed the current value (or abatement cost) of the emission reductions they could deliver.

The costs for the fuel split measures to return the proportion of diesel cars to 2000 levels substantially exceed the abatement costs avoided in both Bradford and Leeds largely because of the large numbers of cars affected by the policy and the increase in damage costs attributable to higher CO2 emissions. However, the exact shape of a measure focussed on switching the purchase of diesel to petrol cars needs much further thought as this could have a large impact on the costs and benefits of such a policy. Encouraging much older diesels (e.g. pre-Euro 4) to switch to petrol would have a beneficial air quality impact but be less expensive to implement. The time period for implementation also needs consideration

It is recognised that diesel cars cost more to buy and maintain than petrol cars[34] and that unless a motorist travels more than 12,000 miles per year, it is likely that a petrol car will be the cheapest option for the owner. Further analysis is being carried out to look at the costs of measures which may discourage the use of certain diesel vehicles in Leeds, incorporating wider considerations than just fuel costs.

[It should be noted that the abatement costs avoided were calculated on the basis of the default value of £29,150 per tonne of oxides of nitrogen emitted. DEFRA abatement cost guidance recommends that sensitivity analysis is carried out to reflect the uncertainty in the abatement costs. If the default value of £29,150 is used then it is suggested that a range of £28,000 - £73,000 is appropriate. The measure to replace pre Euro IV buses in Leeds with Euro VI buses remains attractive if the lower range value of the unit abatement costs is used. Measures to replace all non-Euro VI buses in Leeds in 2016 or 2021 become attractive if the higher value of the range is used].

[34] http://www.which.co.uk/cars/driving/driver-tools/petrol-vs-diesel/choosing-between-petrol-and-diesel/

8 Conclusions

The LEZ Feasibility Study has shown that;

1. Passenger cars, in particular the proportion of diesel cars, are the most significant contributor of particulates and elevated levels of NO_2 within the Leeds Outer Ring Road.
2. Buses and cars are the most significant contributors within the Inner Ring Road area;
3. Buses and HGVs provide a disproportionately higher contribution to NO_2 concentrations than their VKM driven. These observations also correlate with emissions of fine particulates ($PM_{2.5}$).
4. Total NOx emissions from LGVs are marginally less than HGVs, total emissions of both primary NO_2 and $PM_{2.5}$ are greater than for HGVs.

The above observations are maintained in projections for 2016 and 2021 horizons.

5. Whilst future emission reductions under business as usual conditions could be optimistic, the natural replacement of vehicles is not expected to be sufficient to meet EU Objective Levels for NO_2 at all locations within Leeds by 2021.
6. Measures to accelerate the improvement in bus and HGV emissions and measures to reverse the increasing use of diesel cars appear to give the best improvements in air quality.
7. The modelling suggests no single intervention scenario will deliver compliance with the air quality objective levels for NO_2 across Leeds.
8. A combination of measures could achieve significant reduction in NO_2 levels.

Whilst course and fine particulate (PM_{10}/$PM_{2.5}$) concentrations in Leeds do not breach EU Limit Values, current levels are identified as having a significant impact on the health of the local population. The Health Impact Assessment indicates that;

9. There is a health burden in Leeds related to vehicle emissions.
10. Vehicle related emissions have a disproportionate impact on deprived communities.
11. There is likely to be an underestimation of the impacts of air pollution on health
12. Several of the measures to reduce emissions would have a measurable impact on the health of the local population.
13. Measures to reduce emissions from vehicles will have a disproportionate benefit for the most deprived communities, which is one of the key Health and Wellbeing objectives within the Leeds City Priority Plan (2011 – 2015).
14. Measures to improve the take up of walking and cycling will have additional health benefits on the local population over and above the significant improvement in air quality delivered through the reduction in car journeys.

The HIA Study has demonstrated that there could be significant benefits to be made for the local community, the Council, NHS and National Government from introducing measures to reduce road transport emissions. However, the costs of achieving these benefits are often borne by certain sectors of the community which do not necessarily benefit from the reduction made. It is therefore important to consider the most cost-effective options for reducing emissions.

The CBA has compared the total cost of implementing each LEZ measure against the value of the emissions saved to the wider economy to determine which measures would be most cost effective. However there has been no attempt to understand the consequential impacts of the costs incurred or saved by the vehicle operators (i.e. Impact on bus fares, bus services or delivery charges) or the potential impact on second hand vehicle market.

The Cost Benefit Analysis indicates that;

15. Improving bus emissions, particularly through the uptake of gas bus technology may be the most cost effective option.
16. More analysis is required regarding the economics of discouraging diesel cars in the urban areas and the wider benefits of walking and cycling.
17. External grant funding opportunities can significantly improve the cost effectiveness to operators of measures to introduce new low emission vehicles, provide the necessary infrastructure for alternative, cleaner vehicle fuels or simply retrofit older vehicles with emission abatement technology.
18. Larger fleet operators such as national bus operators might comply with any imposed emission standards by redeploying their national fleet. Conversely fleet operators being able to manage their fleets in this way could have a detrimental impact to Leeds should minimum emission standards either not be introduced, or are set lower than are introduced elsewhere.

This Study has looked at the feasibility of introducing different interventions to determine their ability to influence the makeup of the future vehicle fleet in Leeds via a LEZ. However it does not represent an implementation plan and further detailed examination of the most promising measures is required to determine the most appropriate course of action for Leeds to take. A key area of consideration in developing the identified possibilities into future policy measures will be the detailed assessment of the consequential financial and operational implications for all stakeholders affected.

Significant emission reductions could be achieved through LEZ measures aimed at reducing the impact of Buses, HGVs and cars. However, the majority of the most cost effective interventions could be delivered through policies delivered through policies introduced through a comprehensive Low Emission Strategy (LES) without the need of the associated back office costs enforcement costs of a LEZ. Alternatively, a smaller Low Emission Zone could deliver similar benefits to the areas assessed in this study if introduced in a location able to affect the majority of the target vehicles operating within Leeds.

Any future LEZ or LES intervention based on engine Euro standards must be carefully specified to ensure the desired outcome is achieved. Euro V buses using SCR technology appear to have higher NOX/NO_2 emissions than older Euro IV and retrofit Euro III buses at the lower speeds experienced in central urban areas. Therefore any policy measure which unintentionally increases the number of Euro V buses in Leeds (through fleet redeployment) rather than replacing older buses with Euro VI engines would not achieve the desired effect.

The elected membership of WYCA, including its Transport Committee, has not yet had the opportunity to consider this study. Nevertheless, the Acting Director Transport considers the findings to be consistent with the approved West Yorkshire Local Transport Plan and welcomes steps to improve air quality and reduce harmful impacts on health.

The Acting Director Transport will commit WYCA staff resources to support further work through the proposed LES project group and future consultation, which will need to consider any potential cost implications for other organisations.

The findings of this report should form the background evidence base towards developing recommendations for future policy measures aimed at improving air quality and reducing the health burden in Leeds.

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Appendix 1 Relative changes in Ultimate CO2 emissions for each scenario modelled