Cost benefit analysis of short listed measures

LestAir Technical Paper 4

Report for Leicester City Council

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1 Introduction

The options screening assessment (task 6) carried out an emissions assessment of a long list of measures designed to reduce emissions in the AQMA in Leicester. This assessment identified a short list of measures, agreed with Leicester City Council (LCC), that were then taken forward into the Cost Benefit Analysis (CBA). This report sets out the results of the CBA (task 7) covering:

- The estimated costs associated with the implementation of each measure;
- Damage cost benefits associated with the emissions savings generated by each measures and assessed in the screening assessment;
- Abatement cost savings related to NO_2 compliance
- Aggregated benefit-cost results in terms of total net present value (NPV) and benefit cost ratio (BCR).

1.1 Summary of short listed scenarios

Leicester City Council agreed a shortlist of scenarios for Ricardo-AEA to take forward to the options appraisal stage (task 7) of the LestAir project based upon the results of the emissions modelling in the screening assessment work (task 6). These options comprise:

- A formal Low Emission Zone (LEZ 2), covering buses and HGVs based on regulation
- A restricted LEZ (LEZ2_bus) focused just on buses
- A bus retrofit scheme: Bus 1 (retrofit)
- A gas bus scheme: Bus 2
- A roll out of quality bus corridors: Bus 3
- The use of freight delivery and servicing plans: HGV5
- An electric vehicle scenario: EV
- A behaviour change scenario: Smart 1

1.1.1 The Low Emission Zone options

The Low Emission Zone (LEZ 2) scenario would restrict bus and HGV traffic from operating on the main AQMA corridors unless they met the Euro 4 emission standard. The scheme would be enforced by ANPR cameras, both fixed and mobile, operating on the main AQMA corridors. This would need to be complemented by traffic management measures to prevent 'rat-running' of HGV's trying to avoid the scheme. The scheme would be established through the use of a traffic regulation order (TRO).

An alternative LEZ scheme (LEZ2_bus) applying only to buses has also been modelled. This scheme is based on restricting bus access to the central area for all buses unless they meet the Euro 4 emissions standard. Even though this only applies to the central area it will essentially affect all bus traffic in the AQMA as virtually all routes pass through this central area. A bus only scheme can be established more easily than a formal LEZ by using a traffic regulation condition applied to bus operators through the Traffic Commissioner. Such a scheme would be enforced by limited random spot checks with failure to comply being raised with the Traffic Commissioner as a breach of the condition.

1.1.2 Alternative bus and freight measures

Three measures as part of a bus emission strategy have been assessed based on a voluntary approach working through the bus quality partnership. An example of this type of voluntary approach is in Birmingham where the City Council have agreed a base Euro 3 emission level with bus operators from 2013, rising to Euro 4 in 2017. Potentially this is a low cost way for an authority to implement a low emission scheme, but compliance can't easily be enforced.

The bus measures short listed and assessed in the CBA are:

- Bus 1 (retrofit) which assumes that 80% of buses comply with Euro 4 standard or are retrofitted with combined selective catalytic reduction and particle trap (SCRT) technology and a micro-hybrid electric fan.
- Bus 2 is a gas bus scheme which assumes gas buses will operate from the Arriva depot in the north of the city, with the gas buses operating on three main routes into the city.
- Bus 3 based on the concept of bus quality corridor measures such as new bus lanes and junction improvements, which generate a mode shift to reduce car.

A single freight measure, HGV 5, has been assessed which is based on the implementation of freight delivery and servicing plans (DSP's). HGV 5 assumes a 20% uptake of a freight DSPs by businesses in the AQMA delivering an overall reduction in freight traffic of 3%.

1.1.3 Wider emission reduction measures

The electric vehicle (EV) strategy will facilitate the uptake of electric vehicles. It is based on the provision of charging points to make it easier for electric vehicles to operate in the city. However, there are many other factors which will influence the uptake of these vehicles not least their capital cost. So this is mostly likely to be effective as part of a wider strategy that also address some of these others barriers or works in partnership to develop a specific vehicle/refuelling project. The EV strategy scenario assumes a 3% uptake of electric vehicles in the car and van fleet.

A general smarter choices package has also been considered which will provide information to encourage fewer car based journeys. Its actual impact will be hard to predict, but the scenario assumes that 3% fewer journeys are taken.

More information on the principal assumptions used to model the shortlisted scenarios is outlined in Table 1.

Table 1: Shortlisted scenarios for appraisal

ID	Measure	Description	Fleet composition	Traffic levels	Vehicle speeds
Regulatory LEZ					
LEZ2	Mid LEZ	Euro 4 standard for all Bus and HGV traffic operating on the main LEZ corridors.	Set bus and HGV to min Euro 4	-	-
LEZ2_Bus	Mid LEZ, bus only	Euro 4 bus standard applying to central area within the inner ring road.	Set bus to min Euro 4		
Bus strategy measures					
Bus 1 Retrofit	Partnership working to roll out SCRT retrofit	All buses not meeting the Euro 4 standard take part in an SCRT retrofit programme supported by the Council.	Buses less than Euro 4 have SCRT retrofit, 20% non-compliant	-	-
Bus 2	Gas bus scheme	Gas buses operating from main Arriva depot. Apply to Melton road, Devonshire road and Uppingham road	Gas buses on 3 agreed corridors.	-	-
Bus 3	Quality corridor measures	Assume same impact as scheme on Aylstone corridor to estimate roll out to all corridors.	-	Reduce car traffic by 3%	Speed improvement based on journey time reduced by 7-8 minutes.
Freight strategy measures					
HGV5	DSP	Assume target rollout to affect 20% of businesses in area. Estimate a 15% reduction in traffic for this group. Gives estimated freight traffic reduction by 3%.	-	3% reduction in LGV and HGV traffic	-
Area measures					
EV	EV strategy for cars and vans	EV strategy target set to 3% of all cars and vans. Main implementation based on charging infrastructure, but other complementary measures would also be needed	Set 3% of cars and vans to zero emission and CO2 reduction.	-	-
Smart	General smarter choices package	This can be considered as an overall target for trip reduction. Target of 3% overall to match bus measures in Bus3 and to present non-bus measures.	-	3 % reduction in car traffic	

2 Costs

2.1 Methodology

We have estimated both the initial capital costs (CAPEX) and annual operating costs (OPEX) of each option using evidence from other published studies such as the Leeds and Bradford LEZ study and the London TfL Low Emission Vehicle Road Map. The costs have been adjusted to match the scenarios proposed and where possible reflect Leicester City specific conditions.

For appraisal purposes the costs has been aggregated over a 10 year period to give a total net present value (NPV) cost.

2.2 LEZ 2

The Low Emission Zone 2 scenario would restrict vehicles operating on the AQMA corridors unless they meet the Euro 4 emission standard. The proposal is to focus on bus and HGV traffic only.

The scheme implementation costs are based on ANPR camera enforcement with a back office system. The camera costs were scaled up based upon £35k per fixed camera and £130k per mobile camera[1]. We have applied this to nine fixed cameras based upon one on each main corridor and five mobile cameras. We have assumed 60% of on road ANPR costs as back office costs and 25% as set up costs. In addition an annual operational cost of 70% of the camera and back office costs is assumed, along with a further 10% for maintenance. This equated to an estimate one off capital cost of £1.785m and operational cost of £722k per annum.

In terms of vehicle compliance costs this has been estimated for HGVs as around £2.7m. This is based upon the cost of replacing a rigid truck being £60k and an arctic being £73k[2]. This was scaled up to 40 rigid trucks and 5 artics[3]. The cost of the bus compliance is based on retrofitting with SCRT. The costs of this are estimated as £18,325 capital and £1,427 annual operating costs per vehicle (see bus 1-retrofit scenario cost details). This is applied to the estimated 50 non-compliant buses operating in the AQMA giving a total cost £911k capital and £71k operating.

This gives the total cost of LEZ scenario as £5.43m (capex) and £0.843 (opex). The estimated present value cost over the 10 year appraisal period is £12.772m.

2.2.1 LEZ 2 (Bus)

The LEZ 2 bus only scenario assumes that buses are retrofitted to comply with the Euro 4 standard. Costs for this are consistent with the bus element within LEZ 2 and the Bus 1 (retrofit) scenario. Thus it is assumed that the vehicle compliance costs are the same as in LEZ 2; £911,750 (capex) and £71,360 (opex). In addition a simple cost assumption of £150k has been assumed for the set up costs of the traffic regulation condition. This gives a total present value cost estimate of £1.623m, which is considerably less than the full LEZ 2 scheme.

[1] Cost data based on a review of LEZ studies carried out by AEA for Defra, 'Approasial of UK LEZ feasibility studies', AEA, 2012
[2] (Road Haulage Association data, cost tables, 2012)
[3] Assuming total HGV mileage in AQMA from our modelling is 8 million (rigid) and 2.2 million (Artic) and amount of trucks at Euro 4 standard or below is from 10% and 2% of all HGV milage respectively. We assume the average urban mileage of rigid trucks is 20,000km and the arctic is 10,000km.

2.2.2 Bus 1 (retrofit)

The Bus 1 retrofit scenario is based on a voluntary agreement with bus operators to fit all buses not meeting a Euro 4 standard with a combined selective catalytic reduction and particle trap (SCRT) technology and a micro-hybrid electric fan. It is assumed that 80% of buses to comply with the voluntary agreement.

Project BREATHE (Bus REtrofit: ATtenuating Harmful Emissions) estimated the cost of purchasing and fitting SCRT technology as £18,235 per bus (14,235 for SCRT technology and £4,000 for the microhyprid eFan). Additional operating costs net of savings (including fuel) was estimated at £2,136 per bus over five years or £427 per annum (it was anticipated that SCRT fuel increase will be offset by the micro-hybrid eFan fuel saving). Estimated additional maintenance costs net of savings per bus over five years was £5,000 cost per bus over 5 years (or £1,000 per annum).

We scaled these costs up to the number of buses we estimated would be retrofitted by the scheme. The number of buses was estimated as follows:

- total bus km travelled in the AQMA taken from the emissions model (7,623,897km)
- divided by an assumed average bus mileage (65,000km) to give 120 buses in operation (rounded to the nearest 10)
- the proportion of buses at less than Euro 4 standard is estimated at 39% based on the fleet data giving 50 buses that would be non-compliant,
- with 80% complying with the scheme we therefore assumed that 40 buses would require retrofitting.

This gives a total capital cost of £729k and an annual operational cost of £57k. We have assumed that the operating and maintenance costs (opex) are annual for the full ten years of the appraisal period. Thus, the total estimated present value cost is £1.190m.

2.2.3 Bus 2

The Bus 2 scenario assumes that gas buses will operate from the Arriva depot in the North of the city in place of diesel buses. The marginal capital cost of the gas buses over the diesel buses has been estimated at £25,000 per bus based on data from the CENEX biomethane toolkit (2009)[4]. This is consistent with recent information on a Stagecoach green bus fund project which quotes total capital cost for 17 Scania gas buses as £2.5m[5].

The gas buses were assumed to be running on three key bus routes into the city operating from the Arriva depot. This amounted to some 45 buses which would switch to gas. This is based upon the total mileage of buses operating on these corridors (3,140,433 km) from our emissions modelling divided by an assumed average bus mileage (65,000km).

The service and maintenance costs have been assumed as the same as diesel buses based upon the CENEX biomethane tool kit (2009).

Running costs (in terms of fuel use) based on data from previous study work[6] were estimated at £0.27 per km for the diesel buses and £0.17 per km for CNG buses. Thus, there is a cost saving of £0.10 per km from switching from diesel to gas. We have scaled up this saving based upon the total mileage of buses and this equates to a total saving of £312,850 per annum or £6,257 per vehicle per annum. We have assumed these savings continue for the 10 year duration of the appraisal.

[4] 'Biomethane Toolkit: a guide to the production and use of biomethane as a road transport fuel', CENEX, 2009.
[5] Stagecoach press release 2014, http://www.stagecoachbus.com/Gas%20Bus%20Open%20Day.aspx
[6] 'Strategy to Reduce Heavy Duty Vehicle Emissions in Abu Dhabi – Technology Review', STS and MVA, 2011

In addition to the buses a gas refuelling infrastructure is required. The scheme run by stagecoach in Sunderland noted above gave a cost of £1million for associated refuelling infrastructure. A study by Ricardo-AEA report for Transport for London (2013) gives a cost of about £0.5million for converting an existing site to CNG. For this project we have assumed a mid-point between these two of £0.75million as the initial capital investment. Running costs of the filling station as assumed to be covered in the fuel price.

Based on these assumptions the annual fuel savings will out weight the initial capital cost over a 10 year appraisal period. This gives a total estimated present value cost of -£1.095m which is a net cost saving.

2.2.4 Bus 3

Bus 3 assumes that bus quality corridor measures such as new bus lanes and junction improvements are implemented across the main AQMA corridors and generates a car traffic reduction of 3%.

A partnership bid to the Better Bus Area Fund by Leicestershire County Council and Leicester City Council for the A426 Quality Bus Corridor (2011) provides detailed cost information of one of the proposed interventions. The total funding sought for capital works is £1,039,500 in year 1 and £1,202,300 in year 2. The total cost considered improvements to bus lanes, resurfacing, bus cameras, bus stop improvements and real time passenger information. The total funding sought excludes the additional costs allocated to local partners.

This has been used to estimate the total cost for a more wide scale application of corridor measures. We have assumed indicative application of five such corridors to represent a wider roll our across the AQMA with an associated car traffic reduction of 3%.

Thus, the total public sector cost for the Bus 3 scenario is estimated as a total present value cost of £11.127 million.

2.2.5 HGV 5

HGV 5 assumes a 20% uptake of a freight delivery and servicing plans by businesses in the AQMA, reducing freight traffic by 3%. The cost is the effort to promote and monitor these plans, which could be similar to the smarter choices cost. The cost of the smarter choices programme is stated as 4p/km saved in 2009 prices[7]. This price has been updated to 4.4p/km, the 2013 price, using CPI data (ONS, 2013).

The number of journeys saved would equate to around 1,785,227km, which is 3% of the total HGV and LGV freight km from this project's modelling data. Thus, we have estimated the one off cost to equate to around £79k.

It is assumed that investment would need to continue annually to maintain the impact of the scheme during the appraisal period. We have assumed the annual cost of maintaining the scheme would be around 30% of the upfront cost. This is £23.7k per annum for the 10 year appraisal period.

The total present value cost of the HGV5 scenario is estimated to be £0.293m.

2.2.6 EV

The EV scenario assumes a 3% uptake of electric vehicles by providing charging facilities across the city. This is a very simple assumption as it is difficult to directly relate infrastructure provision to EV uptake, however, the costing has been based on this assumption. Within this measure no account has been taken of the private cost and benefits

[7] 'The Effects of the Smarter Choice Programmes in the Sustianble Travel Towns: Summary report', Sloman, L, et. al., 2010

in terms of the costs of purchasing EV's and the difference in running costs between petrol/diesel vehicles and the EV.

The Ricardo-AEA report for Transport for London (2013) 'Environments support to the development of a London Low Emission Vehicle Road Map' stated that the cost of standard (3-7kW) charging points at work places would be £1,800 (capex) plus £90 per annum (opex).

The costs have been scaled up based on 200 charge points that could service 10 vehicles each or 2,000 additional electric vehicles in total. The 2,000 EV's are the estimated number of vehicles required to meet the 3% uptake target. This is calculated from 3% of all car and van mileage at 11 million km and an annual average EV mileage of 6,000km.

The estimated total present value cost of the EV option is £0.492m.

2.2.7 SMART

The general smarter choices package will provide information, incentives and support to encourage fewer journeys. The Smart scenario assumes that 3% fewer journeys are taken.

The cost of the Smart scenario is derived using a similar method to the HGV 5 costs. The cost of the smarter choices programme is stated as 4p/km saved in 2009 prices. This price has been updated to 4.4p/km, the 2013 price, using CPI data (ONS, 2013).

The number of journeys saved would equate to around 10,258,695km, which is 3% of the total car km from this project's modelling data. Thus, we have estimated the one off cost to equate to around £455k.

Investment would need to continue annually in order to continue the impact of the scheme during the appraisal period. We have assumed the annual cost of maintaining a 3% car mileage reduction would be around 30% of the upfront cost. This is £136k per annum for the 10 year appraisal period.

The total present value cost of the SMART scenario is estimated to be £1.686m.

3 Damage cost saving

Air pollution impacts on human health and the natural and built environment. In particular, there are chronic mortality effects (loss of life years due to air pollution), morbidity effects (increase in the number of hospital admissions for respiratory or cardiovascular illness), damage to buildings (from particulates) and impacts on materials. The Interdepartmental Group on Costs and Benefits (IGCB, 2008) provides guidance[8] on monetising these damage costs for use in appraisal.

The damage cost approach has been used to calculate the damage costs savings from proposed policy scenarios in order to understand the magnitude of the benefits of changes in emissions. Where the magnitude is estimated to be greater than £50m, a full impact pathway assessment would be required, but this is not the case for this project.

3.1 Damage cost calculations

The IGCB guidance has been implemented in the form of a Damage Cost Calculator (IGCB, 2008) which has been used for this study. The calculator requires information on appraisal timeframe and emissions to be inputted.

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

For this assessment, 2016 was inputted as the base year by which emissions were compared to reflect our modelling scenario baseline. Benefits were calculated over a 10 year period to reflect an interest in a medium to long term effects of policies.

Our emissions modelling provided information on the estimated change in NOx, PM and CO_2 emissions compared to a 2016 forecasted baseline within the AQMA area which is the focus of the analysis. These data were entered into the Damage Cost Calculator.

The calculator then multiplied our emissions data by the adapted annual pulse damage costs, as set out within Table 2 of the Damage Cost Calculator Guidance (IGCB, 2008). The annual pulse damage costs were adapted by the calculator by inflating 2008 price data to 2016 prices assuming an inflation rate of 2.5% and uplifting the damage cost values by 2% per annum to reflect increases in willingness to pay. A damage cost schedule over 10 years was then discounted at a rate of 3.5% per year as set out in the Treasury's Green Book (2003) to estimate the 2016-2025 present value damage avoidance costs.

Table 2 presents the results of the analysis. It shows the damage costs saved by each policy scenario compared to the 2016 baseline. Separate damage cost savings are shown relating to the changes in emissions of oxides of nitrogen, particulate matter and carbon dioxide. The table illustrates the total damage cost saved for each scenario and the estimated range[9]. The low range reflects a potential 40 year time lag between a change in particulates and impact on health, while the high range reflects a 0 year time lag.[10]

Table 2: Present value damage costs avoided

Scenario	PV damage costs saved 2016-2025 (£millions)						Rank (most beneficial)
	NO_x	PM	CO_2	Total	Low range	High range	
LEZ2	0.15	0.38	0.07	0.61	0.48	0.69	5
LEZ2_BUS	0.11	0.28	0.03	0.42	0.33	0.48	6
BUS1 retrofit	0.11	0.19	0.03	0.33	0.26	0.37	7
BUS2	0.15	0.21	0.74	1.10	0.96	1.30	1
BUS3	0.04	0.15	0.50	0.70	0.61	0.83	4
HGV5	0.02	0.10	0.18	0.30	0.26	0.35	8
EV	0.04	0.03	0.63	0.70	0.63	0.84	3
SMART	0.03	0.27	0.53	0.83	0.72	0.98	2

On the basis of benefits alone, the Bus 2 gas bus scenario performs the best out of the scenarios with a potential damage cost saving worth around £1.1m. The SMART and LEZ 2 scenarios are the next most beneficial scenario with savings of around £0.8m. The least beneficial scenario overall is the HGV5 scenario at £0.3m.

3.2 Health impacts

The damage cost calculations were derived by monetising the effect of changes of health on healthcare services and employee productivity. We have presented these health effects separately in order to conceptualise the potential impact of the scenarios. This is not

[9] The calculator also provides high and low sensitivity ranges, but since these are the same as the low and high ranges, we have not provided them here.
[10] The Damage Cost Calculator Guidance, (IGCB, 2008), states that "although the evidence is limited, the recent expert judgement from COMEAP tends towards a greater proportion of the effect occurring in the years soon after a pollution reduction rather than later. This suggests that more weight should be given to the high end (0-year lag) of the damage costs range."

additional to the damage costs; the damage costs are inclusive of these factors. Therefore, this table is just for information.

Table 3: Estimate changes in hospital admissions and avoided loss of life

Scenario	Total			
	Avoided years of life lost over 100 years		Respiratory hospitals admissions avoided (per annum)	Cardiovascular hospitals admissions avoided (per annum)
	No lag	40 year lag		
LEZ2	27.96	27.67	0.27	0.27
LEZ2_BUS	20.65	20.47	0.20	0.20
BUS1 retrofit	16.60	16.71	0.17	0.17
BUS2	20.45	20.75	0.21	0.21
BUS3	9.86	9.64	0.09	0.09
HGV5	5.65	5.46	0.05	0.05
EV	4.42	4.62	0.05	0.05
SMART	13.80	13.12	0.12	0.12

The LEZ2, LEZ 2 (BUS) and BUS 2 scenarios have the highest potential health improvements compared to the 2016 baseline. This is followed by the Bus 1 Retrofit and SMART scenarios. The HGV 5 and EV scenarios have the lowest health impacts. The difference with the damage costs is that the health impacts are only a part of the total damage costs and are generated primarily by reductions in PM emissions.

3.3 Qualitative impacts

There are a number of impacts which have not been included within the damage cost estimates. These include[11]:

- ‘Effects on ecosystems (through acidification, eutrophication, etc);
- Impacts of trans-boundary pollution;
- Effects on cultural or historic buildings from air pollution;
- Potential additional morbidity from acute exposure to PM;
- Potential mortality effects in children from acute exposure to PM;
- Potential morbidity effects from chronic (long-term) exposure to PM or
- other pollutants;
- Effects of exposure to ozone, including both health impacts and effects on
- materials;
- Change in visibility (visual range);
- Macroeconomic effects of reduced crop yield and damage to building
- materials; and
- Non-ozone effects on agriculture’

These impacts have not been monetised due to the difficulty in estimating the link with emissions and monetised impact. For the majority, if these effects were monetised we would

[11] List sourced from IGCB, 2008

see an increase in the magnitude of damage cost savings for each scenario proportionate to emissions.

4 Abatement cost saving

4.1 Introduction

The ‘abatement cost guidance for valuing changes in air quality’ (Defra, 2013) states that where air quality is in breach of a regulation and a full impact pathway assessment is not necessary, the use of the abatement cost approach is required. So in the case of Leicester AQMA which breaches the NO_2 limits we also need to consider the abatement cost approach.

This approach reflects the cost of mitigation to comply with the regulation. .In essence the approach aims to determine the abatement costs that would be necessary to comply with the limit which are avoided by the proposed measures in Leicester. This is in contrast to the damage cost approach which aims to quantify the damage costs avoided by the emissions savings. The abatement costs are to be applied only to the emissions which exceed legally binding obligations, so in this case only applies to NOx emissions that contribute to the NO_2 breaches. In addition it only applies to the emissions savings that would be needed to reach compliance and not emission savings that would go beyond compliance.

4.2 Compliance assessment

Within the LestAir project a city wide emissions model has been built for a base year of 2011 and a forecast year of 2016. The emissions assessment of all the measures has been calculated using this model. In order to estimate NO_2 concentrations and compliance with the limit values we have used the DEFRA NOx to NO_2 tool to calculate concentrations at 6 compliance points where monitoring data exists.

Initially the tools are used to calculate concentrations for the base 2011 year and calibrated with the measured data. We then estimate the concentrations for 2016 based on the change in emissions at these 6 sites from 2011 to 2016. This gives the results shown in Table 4. These results predict that all the non-compliant sites will remain non-compliant in 2016 with the exception of Abbey Lane.

Table 4: NO_2 compliance assessment results

Monitoring site	NO2 concentrations, ug/m3		Required reduction in road emissions, %	Required reduction in emissions in AQMA, tonnes
	2011 base	2016 base		
AbbeyLane	45.0	39.17		
Glenhills Way	59.8	52.44	39.5%	106
Imperial Avenue	35.0	29.63		
London Road	27.1	22.79		
Melton Road	46.0	40.61	3.5%	9
St Matthews Way	55.0	48.49	37.9%	102
Uppingham Road	32.0	27.41		
Vaughan Way	73.0	67.72	67.8%	183
Glenhills Way 2	60.0	51.94	38.4%	104

Using the 2016 concentration data and NO_2 to NOx conversion tool we can estimate the reduction required in transport NOx emissions to comply with the 40 µ/m^3 limit. The point with the highest NO_2 pollution requires a 67.8% reduction in NOx emissions from road transport to comply. So to get full compliance across all these compliance points NOx needs to be reduce by 67.8% against the 2016 baseline. Since none of the scenarios being modelled will reach that level of reduction, the abatement cost method can be used to estimate benefits for the full NOx reduction.

4.3 Choice of unit abatement costs

Defra developed estimates of the unit costs for NOx emission abatement using a marginal abatement cost curve (MACC). The MACC reflects the abatement cost of a range of different abatement technologies. Wider impacts on society are incorporated, including: impacts on other pollutants; energy and fuel impacts, and health impacts (damage costs). The abatement represented by the national average compliance gap is compared against the MACC to estimate an indicative unit cost of abatement. It is only indicative because both the gap and the abatement potential from different technologies will vary between areas.

The unit cost is provided in terms of the marginal cost of emissions, usually measured in £/tonne. Defra's guidance recommends that the appraiser should decide which value is most appropriate for a particular case. If there is no clear rationale to use a particular measure the recommended default value is £29,150 per tonne. For simplicity and clarity we have opted to use the default value for all scenarios, so that they are all assessed in the same way.

Table 5: Marginal abatement costs of national measures to reduce oxides of nitrogen emissions

Sub sector	Baseline Technology	Abatement Measure	Marginal Abatement Cost (£/Tonne of NOx) 2015
HGV	Euro II	SCR	5099
HGV	Euro III	SCR	5380
Buses	Euro II	SCR	6251
Buses	Euro I	Hybrid	6500
Buses	Euro I	SCR	6625
Buses	Euro III	SCR	7257
Buses	Euro II	Hybrid	7462
HGV	Euro IV	SCR	8053
Buses	Euro III	Hybrid	9423
Buses	Euro IV	SCR	11889
Buses	Euro I	Electric	14669
Buses	Euro II	Electric	14872
Buses	Euro III	Electric	17352
Articulated HGV	New Euro V	Euro VI	17743
Buses	Euro IV	Hybrid	18391
Buses	New Euro V	Euro VI	24852
Rigid HGV	New Euro V	Euro VI	28374
Buses*	**Euro IV**	**Electric**	**29150**
Buses	Euro V	Hydrogen	72932
Diesel LGV - class 1	New Euro 5 class I	Euro 6	79323
Diesel LGV	Euro 1	Electric	100665

Diesel LGV	Euro 2	Electric	111619
Petrol cars	Euro 1	Electric	112030
Diesel cars	Euro 1	Electric	135949
Diesel LGV - class 2	New Euro 5 class II	Euro 6	144124
Diesel LGV - class 3	New Euro 5 class III	Euro 6	144124
Diesel cars	Euro 2	Electric	156046
Diesel LGV	Euro 5	Electric	240484
Diesel LGV	Euro 3	Electric	262466
Petrol cars	Euro 2	Electric	280450
Diesel cars	Euro 3	Electric	304593

Note: * this is the value that should be used as the default.

4.4 Abatement costs avoided

Table 6 shows the abatement costs avoided for each of the emission reduction measures applied to the Leicester AQMA. It shows the unit abatement cost applied in each case and the net present value (base year 2016) of the abatement cost avoided by the measure. A discount rate of 3.5% was applied to future year abatement costs avoided (up to 10 years).

Table 6: Abatement cost savings

Scenario	Abatement cost savings (£/t)	NOx saved per annum (tonnes)	Abatement cost saved per annum (£)	Total PV abatement benefits 2016-2025 (£)	Rank
LEZ2	£ 29,150	14	£ 418,242	£ 4,182,416	1
LEZ2_BUS	£ 29,150	11	£ 318,276	£ 3,182,762	3
BUS1 retrofit	£ 29,150	11	£ 310,793	£ 3,107,930	4
BUS2	£ 29,150	14	£ 416,517	£ 4,165,166	2
BUS3	£ 29,150	4	£ 122,320	£ 1,223,199	5
HGV5	£ 29,150	2	£ 58,077	£ 580,770	8
EV	£ 29,150	4	£ 119,266	£ 1,192,660	6
SMART	£ 29,150	3	£ 90,624	£ 906,241	7

The “LEZ2” option provides the largest abatement cost avoided. The HGV5 and SMART options provide the smallest cost avoided.

4.5 Significance of the impact on compliance

The abatement cost guidance for valuing changes in air quality recommends that more detailed analysis is required if the net present value of the air quality impacts valued using unit costs is greater than £50m. The net present value of the abatement costs avoided in the Leicester AQMA area is substantially less than £50m.

5 Aggregating costs and benefits

We have aggregated the present value cost of each scenario (as outlined in chapter 2) with the benefits. For NOx we have used the abatement cost approach to valuing cost savings (see chapter 4) and for PM and CO_2 we have used the damage cost approach.

The net present value results are outlined in the table below. We have presented the Net Present Value results (net present benefits minus net present costs) and the results for the benefit cost ratio test (net present benefits divided by net present costs). We understand that for air quality, the preferred option is made on the basis of benefit cost ratio. This is the measure which will reap more benefits per pound spent.

Table 7: Cost-benefit analysis results

Scenario	Total PV benefits 2016-2025 (£millions)	Total PV cost 2016-2025 (£millions)	NPV (£millions)	Rank (NPV)	Benefit Cost Ratio	Rank (BCR)
LEZ2	4.64	12.77	**-8.13**	7	**0.36**	7
LEZ2_BUS	3.49	1.62	**1.87**	3	**2.15**	5
BUS1 retrofit	3.32	1.19	**2.13**	2	**2.79**	4
BUS2*	8.04	1.83	**6.21**	1	**4.40**	1
BUS3	1.88	11.13	**-9.25**	8	**0.17**	8
HGV5	0.86	0.29	**0.57**	5	**2.93**	3
EV	1.85	0.49	**1.36**	4	**3.76**	2
SMART	1.70	1.69	**0.02**	6	**1.01**	6

* Opex savings have been added to damage and abatement cost savings to give a true BCR

The scenario with the highest BCR and total NPV is the Bus 2 gas bus scenario. This scheme generates significant emission savings along the 3 corridors where it has been modelled and over the appraisal period the fuel cost savings out weight the initial capital investment. The benefits have been enhanced as the scenario assumes the use of biomethane which has significant CO_2 benefits as well as NO_x and PM benefits.

In terms of BCR the next most effective options are HGV5, the freight delivery and servicing plans, and EV the electric vehicle strategy. However, in terms of NPV the LEZ2_Bus scenario and Bus 1_retrofit scenario are the next most effective as they generate greater overall benefit but at higher cost.

The least effective options are Bus 3 the bus quality corridor measures and the full LEZ 2 option. In the case of bus 3 this is has significant costs for the air quality benefits that it generates, although it will have wider benefits such as congestion reduction which would make it a useful measure in a wider transport context. With regards the full LEZ 2 the cost of setting up automatic enforcement are high, yet the additional emission benefits from including HGVs are small. Therefore the bus only scheme is much more effective.

6 Conclusions

The concept of the LestAir project was to identify cost effective measures to reduce emissions in Leicester, working towards compliance of the air quality limits. A formal LEZ was seen as potentially overly bureaucratic and costly, with a mixture of more 'voluntary' measures being the preferred route. In carrying out the analysis we included both the formal LEZ options and the more 'voluntary' measures.

The LEZ option short listed was the Euro 4 Bus and HGV scheme (LEZ2) as it provided reasonable emission savings and was seen as achievable. However, the CBA has confirmed that such an LEZ is a costly option for the benefits generated having a negative NPV and a BCR less than 1. One of the reasons is limited additional benefit of including HGV's in the scheme as most will already comply with the Euro 4 standard by that date. A higher emissions standard, generating greater emissions benefits, would be needed to justify this kind of scheme.

A bus only alternative was suggested for the CBA by LCC and this gives a much more positive result with a positive NPV of £1.87M and a BCR of 2.15. This is because the scheme generates nearly the same emissions benefit as a full LEZ and is much lower cost. The low cost is based on the assumption that it would be implemented through a traffic regulation condition with no formal ANPR enforcement.

The other bus options also prove effective with the exception of the bus quality corridor (Bus 3). The bus retrofit scheme is very similar to the bus only LEZ, but is voluntary rather than regulatory, giving slightly lower cost but also benefit. The gas bus scheme generates the best results of all giving good emissions reduction and overall a 10 year period a cost benefit over running diesel buses. This gives the gas bus scheme the best overall NPV and BCR of all the measures accessed. As noted above the quality bus corridor is an expensive measure for the air quality benefits it generates, although it will generate a wide range of other benefits.

In terms of HGVs most of the measures assessed in the screening working showed low emissions savings. This is because the fleet is generally much newer that the bus fleet and so the emission standards being promoted are already largely complied with. Therefore in the medium term measures to reduce freight traffic are likely to be more effective and promoting low emission vehicles unless we are looking at much stricter standards (e.g Euro 6). In this context the freight delivery and servicing plan scheme (HGV 5) was taken forward for the CBA. Overall its emissions benefits are high so it damage cost savings are low, but the cost of implementation is potentially very low giving it a good BCR.

Of the other measures assessed the EV strategy gives good results providing the second best BCR and a good NPV. Thus encouraging the uptake of EV's would seem a good option. However this should be caveated as it based on a simple assumption of infrastructure encouraging take up and not private costs and benefits being assumed. The behaviour change scenario (SMART), like the HGV 5 scenario, is a good general measure in that it reduces traffic levels and emissions and has a positive NPV and BCR. In fact if the suggested BCR from the sustainable travel towns project of 4.5 based on congestion benefits is added the BCR calculated here based on based on emissions benefits the total BCR would be around 4.6 making it the best option of all.

In going forward based on these results we would propose that the core of a Low Emission Strategy should be based around bus measures. The bus LEZ would make a good central measure, with a strong message. This should be supported by a gas bus scheme if possible as it has the best CBA of all, but also with wider compliance done through retrofitting.

This could then be complemented by a set of wider measures including:

- Measures to reduce freight traffic based around the DSP concept (HGV 5) and other consolidation measures working through the FQP and business groups
- Smarter choices measures to help reduce overall car traffic levels
- An EV strategy to promote the use of electric cars and vans
- Potentially encouraging from freight operators to work implement some gas vehicles in co-operation with the gas bus scheme.

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