Air Quality Consultants

Review of Bus Fleet Compositions and Implications for Emissions Reduction Strategies

Document Control

Client	Defra	Principal Contact	Janet Dixon

Job Number	J656

Report Prepared By:	Penny Wilson

Document Status and Review Schedule

Issue No.	Report No.	Date	Status	Reviewed by
1	656/1/D1	24th March 2008	Draft Report	Prof. Duncan Laxen
2	656/1/F1	22nd April 2009	Final Report	Prof. Duncan Laxen
3				

Air Quality Consultants Ltd
23 Coldharbour Road, Bristol BS6 7JT Tel: 0117 974 1086
12 Airedale Road, London SW12 8SF Tel: 0208 673 4313
aqc@aqconsultants.co.uk

Registered Office: 12 St Oswalds Road, Bristol, BS6 7HT
Companies House Registration No: 2814570

Contents

1 Introduction

1.1 This report sets out a review of bus fleet compositions across the UK and the implications for emissions reductions strategies. The primary aim of this review is to determine how effective local authority emissions reduction strategies targeted at buses could be in achieving the air quality objectives for nitrogen dioxide and PM_{10}.

1.2 Information about various bus fleets has been collated and compared with the national fleet compositions assumed for most local authority modelling studies. The effect of using more realistic fleet compositions on the results from these modelling studies has then been considered.

1.3 This review also includes a number of case studies where emissions reduction measures targeted at buses have been, or are going to be introduced. The effectiveness of these strategies has been considered, along with any barriers to, and lessons learnt from the introduction of specific measures.

1.4 The report focuses on areas where buses have been identified as significant contributors to exceedences of the air quality objectives. These are often congested streets with a relatively high proportion of buses, although bus emissions also contribute to exceedences across wider urban areas.

Aims

1.5 The primary aim of this report is to determine whether local authority emission reduction strategies targeted at buses could be an effective tool to reduce pollutant concentrations, in order to help achieve the air quality objectives for nitrogen dioxide and PM_{10}. This also recognises the important role that local authorities are seen to play in helping the UK Government to deliver the mandatory European air quality limit values. .

1.6 Exceedences of the daily mean PM_{10} objective are confined to a small number of locations outside London, whereas exceedences of the annual mean objective for nitrogen dioxide have been measured or predicted at many roadside locations across the UK. This report principally focuses on measures to reduce nitrogen dioxide concentrations, although approaches to reduce PM_{10} concentrations are also discussed. The focus is upon locations where annual mean nitrogen dioxide concentrations are currently above 40 µg/m^3, and are expected to remain above this level by 2010 when the EU limit value come into force.

1.7 Although some of the measures discussed will also reduce greenhouse gas emissions, this is not addressed within this report. In addition, this report only considers measures that will reduce pollutant emissions on a bus-kilometre basis. Measures that would increase bus patronage and reduce private car use are not taken into account.

1.8 This report focuses on mechanisms and measures to reduce pollutant concentrations outside London as the system of bus regulation imposed by Transport for London (TfL) is different to the rest of the UK.

2 Background

Air Quality Objectives and Limit Values

2.1 The Air Quality Strategy provides the policy framework for air quality management and assessment in the UK. It provides air quality standards and objectives for key air pollutants, which are designed to protect human health and the environment. The objectives for use by local authorities are prescribed within the Air Quality Regulations, 2000 and the subsequent 2002 Amending Regulations. The objectives for PM_{10} and nitrogen dioxide were to be achieved by 2004 and 2005 respectively, and maintained in each year thereafter.

2.2 The European Union has also set limit values for both nitrogen dioxide and PM_{10}. Achievement of these limit values is a national obligation rather than a local one. The limit values for nitrogen dioxide are the same levels as the UK objectives, and are to be achieved by 2010. The limit values for PM_{10} are also the same levels as the UK statutory objectives, and were to be achieved by 2005. The objectives and limit values for nitrogen dioxide and PM_{10} are summarised in Table 1.

Table 1: Relevant Objectives and Limit Values

Pollutant	Time Period	Objective/Limit Value
Nitrogen Dioxide	1-hour mean	200 $\mu g/m^3$ not to be exceeded more than 18 times a year
	Annual mean	40 $\mu g/m^3$
Fine Particles (PM_{10})[a]	24-hour mean	50 $\mu g/m^3$ not to be exceeded more than 35 times a year
	Annual mean	40 $\mu g/m^3$

[a] Measured by the gravimetric method.

Local Air Quality Management

2.3 Part IV of the Environment Act, 1995, places a statutory duty on local authorities to periodically review and assess the air quality within their areas. For each air objective set in Regulations, local authorities have to consider whether the objective is likely to be achieved by the due date. Where it appears likely that the air quality objectives are not being met, local authorities must declare an Air Quality Management Area (AQMA). Following the declaration of an AQMA, the authority must develop an Air Quality Action Plan (AQAP) which sets out the local measures to be implemented in pursuit of the objectives.

Euro Standards

2.4 Emissions standards for new buses are specified in European directives. These standards have tightened over time and are known as 'Euro' standards. The relevant standards and the dates when they came into force are set out in Table 2. It is important to note that the dates specified are for type approval; vehicles generally enter service around a year later, e.g. all new vehicles sold after October 2009 should be compliant with the Euro V standard.

Table 2: EU Emissions Standards for Heavy Duty Diesel Engines (g/kWh)

Tier	Date [a]	NOx	PM	CO	HC
Euro I [b]	Oct 1992	8.0	0.36	4.5	1.1
Euro II [b]	Oct 1996	7.0	0.25	4.0	1.1
	Oct 1998	7.0	0.15	4.0	1.1
Euro III	Oct 2000	5.0	0.16	5.45	0.78
Euro IV	Oct 2005	3.5	0.03	4.0	0.55
Euro V	Oct 2008	2.0	0.03	4.0	0.55
Euro VI [c]	Jan 2013	0.4	0.01	4.0	0.16

[a] Date for new type approval. Entry into service usually one year later.
[b] Euro I and II were based on a different test cycle to subsequent standards
[c] Proposal 16.12.2008

2.5 Emissions standards for Euro IV vehicles currently on sale are significantly more stringent than those for Euro II vehicles that were on the market 10 years ago. This means that nitrogen oxides (NOx) emissions from Euro IV vehicles are half of those from Euro II vehicles, with PM emissions 80% lower than Euro II, as measured over the regulated test cycle, although 'real world' emissions may differ from these standards for a number of reasons.

Local Transport Act 2008

2.6 The Local Transport Act 2008 has made a number of changes that could affect emission reduction strategies for buses. These include:

- Changes to the LTP process including greater flexibility in timescales for plans and integration of bus strategies within the LTP;

- Renaming of Passenger Transport Executives to Integrated Transport Authorities (ITAs). The ITAs will now be solely responsible for the LTP in their areas;

- Changes to Voluntary Partnership Agreements, Statutory Quality Partnerships and Quality Contracts, which should make them easier to introduce and enforce.

2.7 The implications of these changes to the Local Transport Act 2008 are discussed in the following sections.

Transport Authorities

2.8 The bodies responsible for regulating bus operations vary across the UK. In this report they are referred to collectively as 'local transport authorities'. Bus operations may be regulated by a:

- County Councils

- Unitary Councils

- Integrated Transport Authorities (ITAs) (formerly Passenger Transport Executives (PTE))

Local Transport Plans (LTP)

2.9 A Local Transport Plan (LTP) is a five year statutory document prepared by local authorities which sets out a strategy for the development of transport. The LTP indicates how money allocated by central Government will be spent in order to meet local and national targets and objectives. Funding may be available to support additional measures, depending upon the quality of the LTP submission. In County Council areas, it is the County, rather than District Council, that is responsible for transport policy and preparation of the LTP.

2.10 Prior to the Local Transport Act 2008, local transport authorities were required to include bus strategies as part of the LTP process. The Act has removed the requirement for a separate bus strategy, with the intent to more effectively integrate these measures into the core LTP strategy and implementation plan[1].

[1] DfT 2008, Consultation on Local Transport Plan 3 Guidance.

2.11 The LTP2 guidance identified air quality as one of the four shared priorities[2]. The draft LTP3 guidance[1] which supersedes this, does not include improving air quality as one of the five goals, although a challenge to 'reduce social and economic costs of transport to public health, including air quality impacts' is identified under the goal of 'contribute to better safety, security and health'.

Policy Tools

2.12 The Transport Act 2000 included powers aimed at providing local transport authorities with a range of options to influence bus operations in their area. However, the effect of these has been limited. The Local Transport Act 2008 updates and extends many of these powers, which should make them easier to implement. A summary of the options available to local transport authorities is set out below.

Tendered Services

2.13 Local transport authorities subsidise many routes and/or services which otherwise would not be commercially viable. This includes rural routes, school buses and other services such as Park and Ride. Local transport authorities may specify emissions standards within tendered service contracts, but there are potential implications of this, leading to higher prices and fewer bidders.

Traffic Regulation Conditions

2.14 A local transport authority can apply to the Traffic Commissioner for a Traffic Regulation Condition (TRC) under section 7 of the Transport Act 1985. This can be used to restrict any class of vehicle from using any road or carrying out certain activities and can be attached to a bus operator's licence. However, the local authority must demonstrate that the TRC would reduce or limit air pollution. If an operator does not comply with a TRC then enforcement action can be taken by the Traffic Commissioner.

Voluntary Partnership Agreements

2.15 Voluntary Partnership Agreements rely on voluntary agreements between local transport authorities and bus operators. They can range from descriptive ways of working, to signed documents. There is no penalty for operators who do not comply with such agreements.

[2] DfT 2004, Full Guidance on Local Transport Plans: Second Edition, December 2004.

2.16 The recent Local Transport Act 2008 includes a new competition regime for Voluntary Partnership Agreements. This should facilitate agreements involving more than one bus operator. Further information about Voluntary Partnership Agreements and the Local Transport Act 2008 is available from the DfT[3].

Statutory Quality Partnerships

2.17 A Statutory Quality Partnership is a commitment by a local transport authority to provide certain facilities to improve bus services and maintain them over a specified period, combined with an obligation by bus operators to meet certain quality standards if they use these facilities. These quality standards can relate to the emissions of vehicles used, but the draft DfT Guidance Notes specify that any standards must be 'reasonable'.

2.18 Statutory Quality Partnerships are registered with the Traffic Commissioner and impose statutory obligations. If operators do not comply, they can be prevented from using the facilities.

2.19 The Local Transport Act 2008 includes provision to allow local transport authorities to phase in improvements over a period of time. Draft Guidance on Statutory Quality Partnerships was produced by the DfT in 2008[4].

Quality Contract

2.20 A local transport authority can specify the route, timetables, ticketing arrangements and emissions standards using a Quality Contract. This can give bus operators exclusive rights to provide services in accordance with the local transport authority's specification.

2.21 There are currently no Quality Contract schemes in operation. This is largely due to the historic difficulty in implementing such schemes, which required Ministerial approval that this would be the 'only practicable way' to implement a bus strategy. However the Local Transport Act 2008 includes changes that should make Quality Contracts a more realistic option. This includes removal of the 'only practicable way' clause and introduction of local consultation boards to agree Quality Contracts.

---

[3] DfT 2009, Local Transport Act 2008 Improving Local Bus Services: Guidance on Voluntary Partnership Agreements. February 2009.

[4] DfT 2008, The Local Transport Bill Improving Local Bus Services: Draft Guidance Volume 3 Quality Partnership Schemes, July 2008.

Planning System

2.22 The planning system can potentially be used to secure improvements to local bus fleets on certain routes. Planning conditions or obligations can be attached to facilities such as airports or Park & Ride sites that require all buses using these facilities to comply with a specified standard.

Guidance

2.23 The draft LTP3 guidance[1] and associated documents[3 4] set out how the various powers, including those within the Local Transport Act 2008 can be implemented.

2.24 Defra has published Practice Guidance Notes on measures to encourage the uptake of low emission vehicles[5] and retro-fitted abatement equipment[6]. These set potential options for schemes and summarise the legal basis for implementation and enforcement. They also describe how to develop and quantify the potential benefits of such schemes, including worked examples.

5 Defra 2009, Local Air Quality Management Practice Guidance to Local Authorities on Measures to Encourage the Uptake of Low Emission Vehicles, February 2009.

6 Defra 2009, Local Air Quality Management Practice Guidance to Local Authorities on Measures to Encourage the Uptake of Retro-fitted Abatment Equipment on Vehicles, February 2009

3 Methodology

Interviews

3.1 Various local authorities throughout the UK who were thought to have considered or introduced emission reduction measures for buses were contacted. Initially, contact was made with the air quality professionals within the local authority, as they were able to provide the air quality context to the introduction of any measures. Following these discussions, and where relevant, transport planners, Integrated Transport Authorities (ITAs), and bus companies were contacted. A full list of interviewees is provided in Appendix 1.

3.2 The individuals contacted were asked, as appropriate, the following questions:

- What emission reduction measures for buses have been introduced?
- What was the trigger for these measures to be introduced?
- Which regulatory processes were used?
- Which departments/organisations were involved?
- How long did the measures take to implement?
- What constraints were there to the introduction of these measures?
- Is any fleet information available?
- Has there been any monitoring of the effectiveness of the measures?
- Are there any documents (e.g. Review & Assessment Reports, Air Quality Action Plan) available that set out the above information?

Fleet Composition

3.3 Information about various bus fleet compositions was provided by a number of the interviewees. Generally this was broken down into the percentage of the fleet that complied with Euro I, Euro II, Euro III, Euro IV and Euro V emissions standards. In some cases, information was also provided about the proportion of older vehicles that were built to pre-Euro standards.

3.4 This more detailed information has been compared with the national average fleet compositions in specific years. It has also been compared with the assumptions made in various local authority air quality modelling exercises.

3.5 It is important to note the limitations associated with this information. In most cases it has not been possible to determine whether the fleet compositions are based on the number of vehicles in the fleet or the bus-km travelled. This may potentially skew the data, especially where the older buses tend to travel shorter distances. In addition the information provided may relate to an entire company or district fleet, rather than the buses that actually travel through an AQMA or area of exceedence.

Impact on Emissions

3.6 The effect of fleet composition on total emissions has been considered. Emission rates have been calculated for each bus fleet using the emission factors within the Emission Factor Toolkit. To allow comparison of different fleets, an emission rate per one hundred vehicles has been calculated for each fleet.

Impact on Concentrations

3.7 In order to investigate the effect that varying the composition of the bus fleet can have on modelled concentrations, ADMS-Roads has been run for a single road. In each scenario it was assumed that 10% of the total traffic flow was buses and all traffic was travelling at an average speed of 10kph. These parameters were selected in order to reflect congested city centre streets with a high proportion of buses; such situations represent those locations where emission reduction strategies for buses could potentially be the most effective. Further details are provided in Appendix 2.

4 Emission Reduction Measures for Buses

Emission Reduction Technologies

4.1 A summary of technologies that can be retrofitted to existing vehicles is provided in Table 3. All new buses will need to incorporate either EGR or SCR to achieve Euro V emissions standards for NOx.

Table 3: Summary of Bus Emission Reduction Technologies

Method	Description	Pollutants	Capital Cost (Approx.)	Running Costs (Approx)
Diesel Particulate Filter (DPF) (Continuously Regenerating Trap (CRT) is a type of DPF)	Fine mesh filter to remove particles (up to 90-95%), with regeneration catalyst.	Reduces PM_{10} Can increase primary NO_2	£4,000	£200 once or twice a year to empty filter
Diesel Oxidation Catalyst (DOC)	Removes larger particles, reduces total PM by 30-50%. Suitable for older vehicles.	Reduces total PM	£1,000	Minimal maintenance
Selective Catalytic Reduction (SCR)	Urea and water injected into exhaust gases to produce nitrogen and water. Reduces NOx by 30-70%.	Reduces NOx	£7000	Engines need to be topped up with urea/water mixture
Exhaust Gas Re-circulation (EGR)	Exhaust gases recycled to lower combustion temperatures, so less NOx emitted. Reduces NOx by 40-50%.	Reduces NOx	£7000	Minimal maintenance
Engine Management	Engine management systems can be altered to reduce NOx emissions, although there could be a slight reduction in fuel efficiency	Reduces NOx	NA	None

Based on information in Scenarios and Opportunities for Reducing Greenhouse Gases and Pollutant Emissions from Bus Fleets in PTE areas, TTR on behalf of pteg, December 2008

Alternative Fuels

4.2 To date, most alternative fuels have only been used on a trial basis. However, their use is anticipated to increase, as the technology improves. The use of these alternatives is largely driven by a desire to reduce carbon emissions, although some alternative fuels may also prove beneficial in reducing NOx and PM_{10} emissions. Table 4 summarises the alternative fuels that are currently available and their advantages and disadvantages in relation to local air quality impacts.

Table 4: Summary of Alternative Fuels

Method	Description	Pollutants	Advantages	Disadvantages
Diesel-electric hybrid	Uses both a diesel engine and electric battery power. The battery is recharged by the operation of the bus, thus no additional battery charging required.	Reduces NOx and PM_{10}	No additional infrastructure required. Fuel costs lower than conventional diesel	Maintenance costs higher than conventional diesel
Liquid Petroleum Gas (LPG)	Mixture of propane and butane	Reduces NOx and PM_{10}	Fairly well established technology. Very low duty on LPG. Can be cost effective for high mileage vehicles	Cost around 15-25% higher than conventional diesel vehicles. Need refuelling infrastructure and additional safety measures.
Compressed Natural Gas (CNG)	Engines can be either mono fuel (CNG only) or dual fuel (CNG or diesel). NOx emissions reduced by 80% and PM_{10} emissions reduced to virtually zero. Advantages over diesel engines being reduced as diesel engine standards improved.	Reduces NOx and PM_{10}	Fuel costs lower	Purchase and maintenance costs higher than diesel. Need refuelling infrastructure.
Biomethane	Derived from biogas produced from decomposition of organic matter such as sewage, animal waste or municipal waste using anaerobic digestion. Can be used in the	Reduces NOx and PM_{10}	Fuel costs lower. Significantly reduces CO_2 emissions.	Purchase and maintenance costs higher than diesel. Need refuelling infrastructure.

Method	Description	Pollutants	Advantages	Disadvantages
	same vehicles as CNG			
Biodiesel	Produced from biomass or waste cooking oil.	Similar NOx and PM_{10} emissions to convention-al diesel. Possible slight increase in NOx emissions	Low (5%) biodiesel/diesel mixtures can be used in conventional diesel engines.	Doesn't reduce NOx or PM_{10} emissions. High blends of biodiesel need suitable vehicle specifications.
Bioethanol	Produced from fermentation of plant material such as sugar cane. Can be combined with conventional fuel.	Reduces PM_{10}	Reduces CO_2 emissions	Needs ignition improvement additives. Can be corrosive, high blends need special transport and storage equipment. Higher fuel consumption than diesel.
Hydrogen fuel cells	Hydrogen produced by electrolysis of water of breakdown of hydrocarbon source. Only by-product water	Reduces local NOx and PM_{10} emissions to zero	NOx and PM_{10} emissions zero.	Current cost 10-20 x diesel engine. Prototype technology
Electric Vehicles	Powered by battery	Local NOx and PM_{10} emissions zero	Local NOx and PM_{10} emissions zero.	Current technology not suitable for running electric buses.

Based on information in *Scenarios and Opportunities for Reducing Greenhouse Gases and Pollutant Emissions from Bus Fleets in PTE Areas*, TTR on behalf of pteg, December 2008

Driver Training

4.3 Studies have shown that training bus drivers to drive more smoothly and efficiently can greatly improve fuel efficiency[7]. This should also be beneficial in terms of nitrogen oxides (NOx) and PM_{10} emissions.

7 www.go-ahead.com/goahead/media/news/2008news/2008-09-15/

5 Bus Fleets

National Fleet Assumptions

5.1 Current national assumptions for buses conforming to Euro standards in each year are provided in Figure 1. These are the proportions assumed in the 1999 National Atmospheric Emissions Inventory (NAEI), which are also contained within the current versions of the DMRB, ADMS-Roads and ADMS-Urban. They are also the proportions assumed within the Emission Factor Toolkit.

5.2 National fleet assumptions have recently been revised. The revised fleet assumptions, based on April 2008 traffic projections from DfT, are presented in Figure 2. These are broadly similar to the 1999 NAEI assumptions, but indicate fewer pre-Euro and Euro I vehicles remaining in the fleet than anticipated in 1999, with a greater number of Euro III vehicles. This may result from incentives to replace the older vehicles, that were not anticipated in 1999. Such measures include increases in fuel costs, which incentivises the purchase of newer, more efficient vehicles, and schemes to discourage the use of older vehicles, such as the London LEZ. The 2008 national fleet projections also include an assumed take up rate for Euro VI vehicles.

5.3 The Disability Discrimination Act will have an impact on future bus fleets. All vehicles that do not comply with the accessibility requirements of the Act need to be removed from service between 2015 and 2017, depending on the type of bus. The effect of the Act is not taken into account in the current NAEI projections.

Figure 1: Composition of National Bus Fleet (1999 National Atmospheric Emissions Inventory)

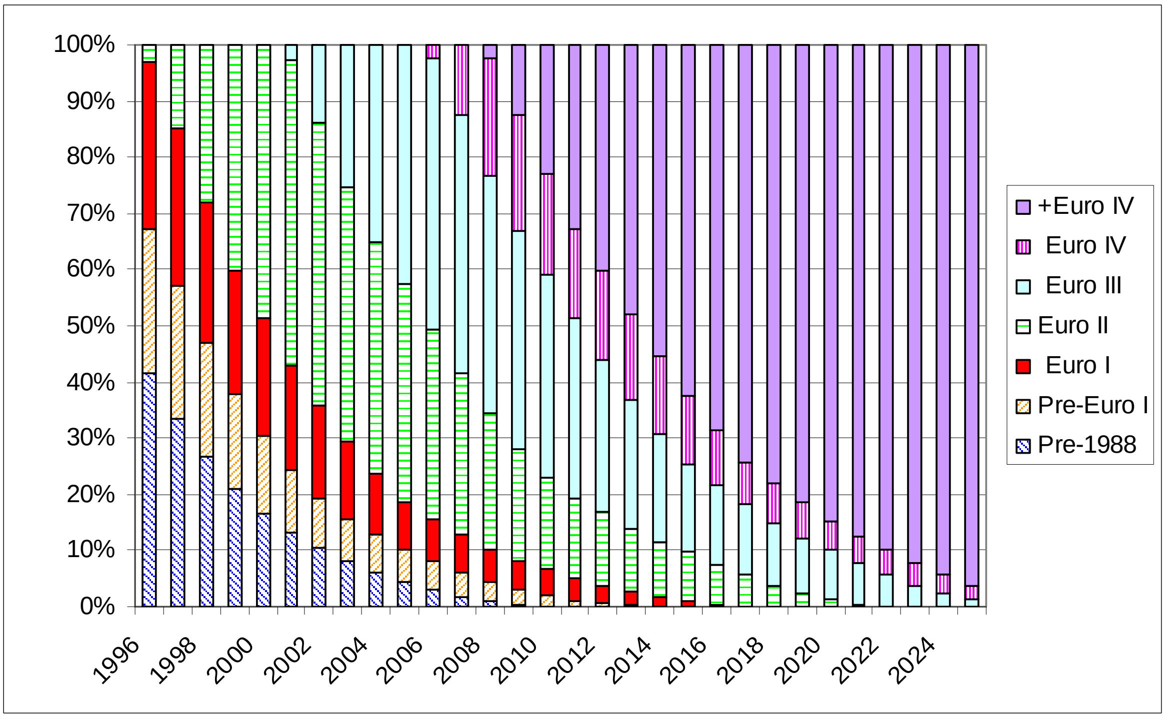
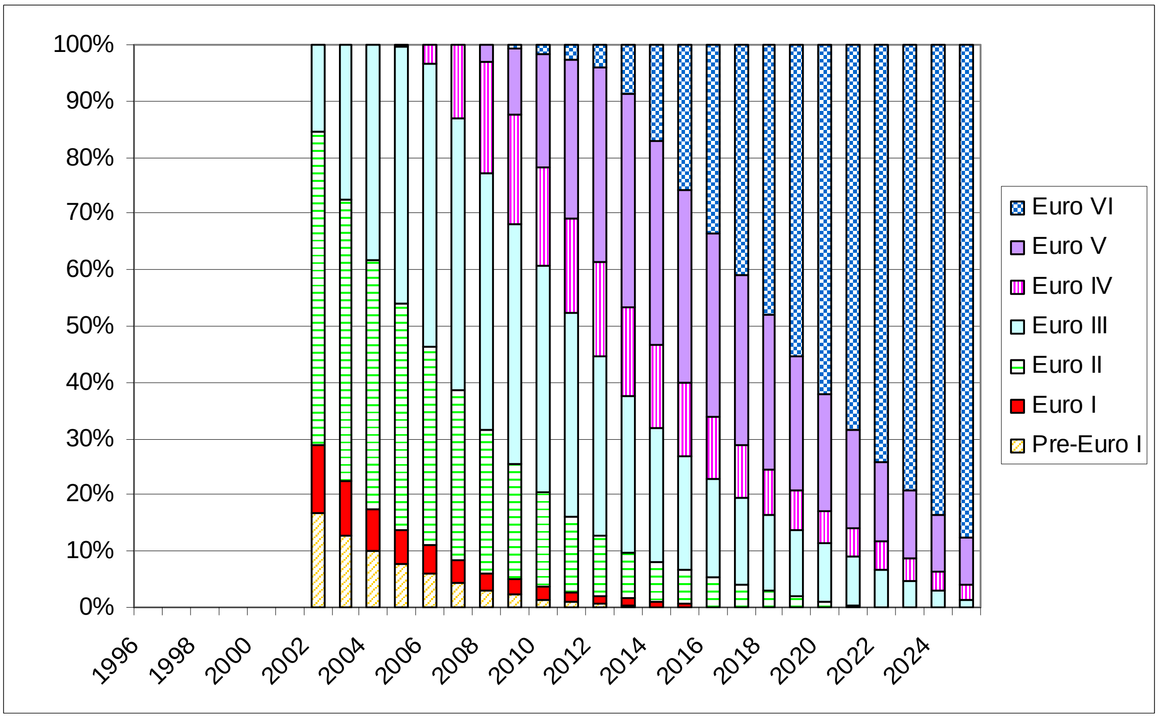


Figure 2: Composition of National Bus Fleet (2008 National Atmospheric Emissions Inventory)



Actual Fleet Compositions

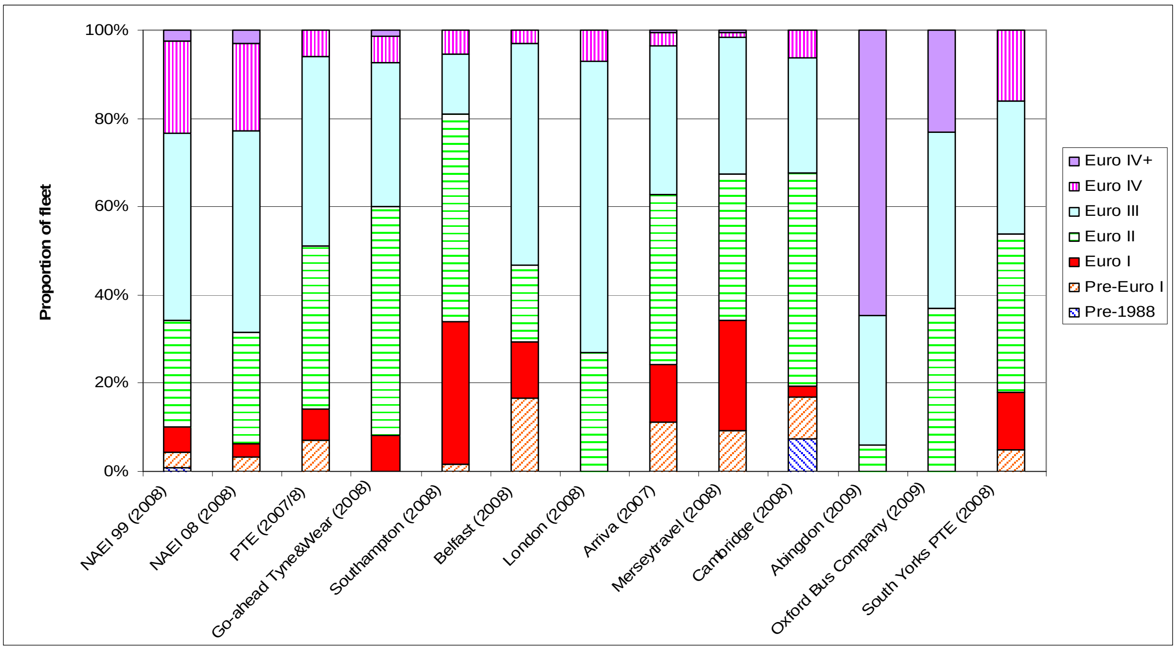
5.4 Figure 3 presents actual compositions for various bus fleets across the UK. This highlights the large variation in the composition of fleets; for example, 80% of First Bus's fleet in Southampton is Euro II or older, whereas in Abingdon, only 6% of the Oxford Bus Company's fleet is Euro II or older (OBC's Euro II buses are also fitted with Continuously Regenerating Traps (CRT)). By comparison, the national assumption is that around 30% of buses on the road in 2008 were Euro II or older. It is noteworthy that fleets in the former PTE (now ITA) areas are older than the national average.

5.5 It should be noted that in most cases it is not clear whether the information provided represents the proportion of vehicles operated, or the proportion of bus-km travelled by these vehicles. Generally, the oldest vehicles do the lowest bus-km per annum.

5.6 There can also be large variations in fleets owned by different operators in the same area. For example in Cambridgeshire in 2007, 98% of buses owned by the major operator were Euro II or above, whereas only 31% of buses owned by a medium-sized operator complied with the Euro II standard[8]. In most cases, measures such as Quality Partnerships tend to be aimed at the major operator in an area, even though it is often the smaller operators that use the oldest buses, with the highest emissions.

8 awbriefing.com/presentations/20070717_glenn_edge.ppt#295,5,Technology - Engine Standards

Figure 3: Current Composition of Various Bus Fleets



6 Impact on Emissions and Concentrations

Emissions

Emission Factors

6.1 The current bus emission factors used in the NAEI and the DMRB, ADMS-Roads and ADMS-Urban models are presented in Tables 5 and 6. These tables also include the revised emission factors, which were published for consultation by DfT in 2008.

6.2 It is important to note that these emission factors are derived from a variety of engine tests, and not solely the regulatory test cycle used for Euro standards. For buses, these emission factors are derived from a small number of tests, and do not take into account conditions such as gradients. However, they represent the best available data to compare emissions from various Euro standard vehicles.

6.3 The emission factors presented in Tables 5 and 6 demonstrate that both NOx and PM_{10} emissions from buses are significantly higher at 10 kph (6 mph) than at 50 kph (30 mph). Therefore measures that increase bus speeds in urban areas can reduce emissions.

6.4 The revised emission factors are generally higher, in some cases by a substantial margin (e.g. when comparing NOx emissions for Euro III buses at low speeds). However, these estimates should be treated with caution, as they assume that all buses are between 15-18 tonnes and do not take into account scaling factors for improved fuel and engine technology.

Table 5: NOx Emission Factors from Buses (g/veh.km)

	Current Emission Factors[9]			2008 Consultation Emission Factors[10] [a]		
Euro Standard	**10 kph**	**30 kph**	**50 kph**	**10 kph**	**30 kph**	**50 kph**
Pre-1988	18.028	15.649	14.652	27.082 [b]	14.854 [b]	11.845 [b]
Pre-Euro I	17.097	9.843	6.678	27.082	14.854	11.845
Euro I	14.740	7.854	6.515	17.409	9.055	7.172
Euro II	12.506	7.017	5.765	18.483	9.669	7.498
Euro III	8.739	4.903	4.028	19.679	8.197	5.856
Euro IV	6.176	3.465	2.847	10.576	4.828	3.685
Euro V	3.529	1.980	1.627	7.033	2.945	2.193
Euro VI	n/a	n/a	n/a	1.407	0.589	0.439

[a] Based on 15-18 tonne vehicles. Does not include fuel scaling factors. Mileage scaling factors not applicable to HDVs
[b] Assumed equivalent to pre-Euro I

Table 6: PM_{10} Emission Factors from Buses (g/veh.km)

	Current Emission Factor Toolkit[9]			2008 Consultation Emission Factors[10] [a]		
Euro Standard	**10 kph**	**30 kph**	**50 kph**	**10 kph**	**30 kph**	**50 kph**
Pre-1988	2.129	0.826	0.565	2.018 [b]	0.764 [b]	0.481 [b]
Pre-Euro I	0.924	0.358	0.245	2.018	0.764	0.481
Euro I	0.461	0.187	0.135	0.900	0.415	0.279
Euro II	0.214	0.101	0.073	0.388	0.191	0.136
Euro III	0.177	0.084	0.060	0.366	0.181	0.122
Euro IV	0.061	0.029	0.021	0.109	0.038	0.023
Euro V	0.061	0.029	0.021	0.111	0.039	0.023
Euro VI	n/a	n/a	n/a	0.037	0.013	0.008

[a] Based on 15-18 tonne vehicles. Does not include fuel scaling factors. Mileage scaling factors not applicable to HDVs
[b] Assumed equivalent to pre-Euro I

9 Defra 2002, National Atmospheric Emissions Inventory (extracted from Emission Factor Toolkit v2f)
10 DfT 2008. Consultation on New UK Road Vehicle Emission Factors Database

Emissions from Various Fleets

6.5 Figures 4 and 5 show the NOx emissions per 100 vehicle-km for the various fleets described in the previous section. These demonstrate the effect that bus fleet composition can have on total emissions. By example, emissions based on the Abingdon fleet are less than half those from the Southampton fleet.

6.6 Emissions from the majority of the fleets are slightly higher than the NAEI estimates, which is due to these fleets being slightly older than the national assumptions. The implication of this is that in many areas where source apportionment work has been carried out based on national fleet assumptions, the results may have underestimated the contribution from buses. Conversely, in areas where the bus fleet is comparatively modern, the contribution from buses may have been over-estimated.

6.7 Comparison of Figures 4 and 5 also illustrates the significant impact that speed has on emissions. At 50 kph (30 mph) emissions are less than half those at 10 kph (6mph). Therefore assumed speeds will have a significant impact on model results.

6.8 Figures 6 and 7 show the PM_{10} emissions per 100 vehicle-km for the various fleets. The variations in PM_{10} emissions are generally greater than the variations in NOx emissions; this is a reflection of the greater improvements in emissions standards for PM_{10}. In addition, the effect of speed is even greater, with emissions at 50 kph around one-third of those at 10 kph.

6.9 The Cambridge fleet has significantly higher PM_{10} emissions than the other fleets. This is predominantly due to the retention of pre-Euro, especially pre-1988 vehicles, within the fleet. These older buses make up only 17% of the fleet, but are responsible for around 60% of PM_{10} emissions. The age of the fleet has a much lesser effect on NOx emissions, where the pre-Euro vehicles contribute 24% of NOx emissions.

6.10 These results are consistent with the findings of local authority review and assessment reports. For example, in Oxford, it has been identified that buses make up 18% of traffic in the AQMA, but are responsible for 64% of NOx emissions[11]. In one particular street, bus emissions were found to contribute 95% of NOx emissions. Similarly, in Teignbridge, it has been identified that whilst buses account for only 2% of traffic on certain streets, they account for 15% of NOx emissions from road traffic[12].

[11] Oxford City Council 2006, Central Oxford Air Quality Action Plan

[12] Teignbridge District Council 2006, Further Assessment – Dispersion Modelling and Source Apportionment Report for Four AQMA Areas. December 2006.

Figure 4: NOx Emissions from Various Bus Fleets at 10kph

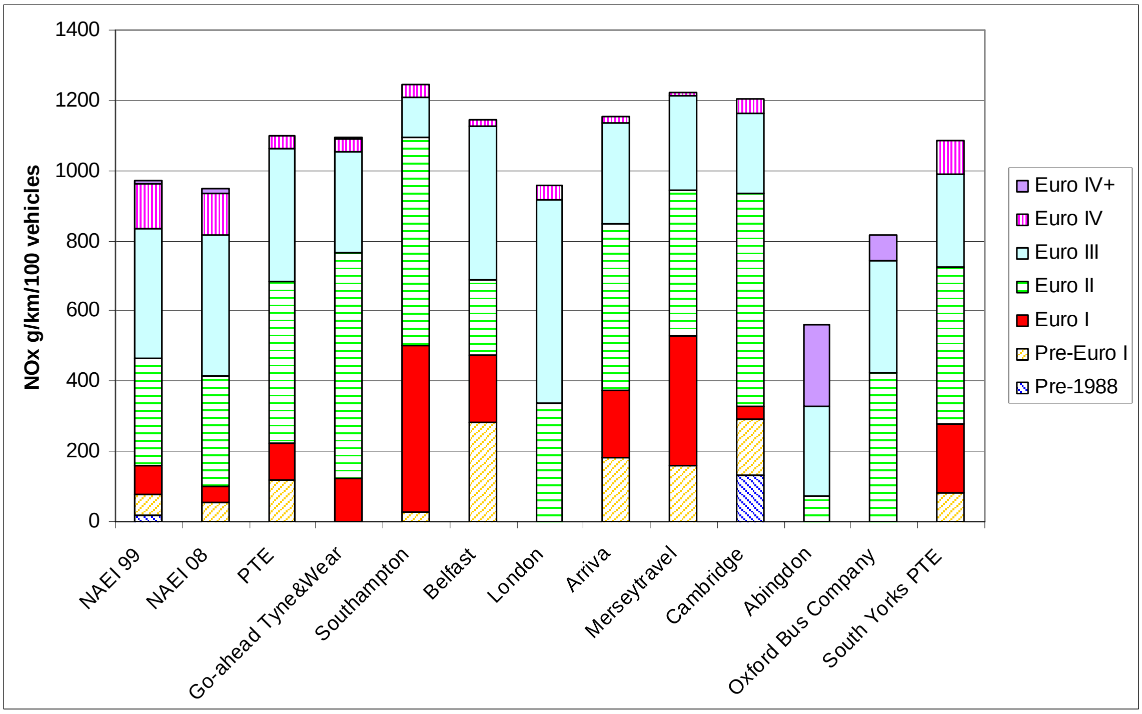


Figure 5: NOx Emissions from Various Bus Fleets at 50kph

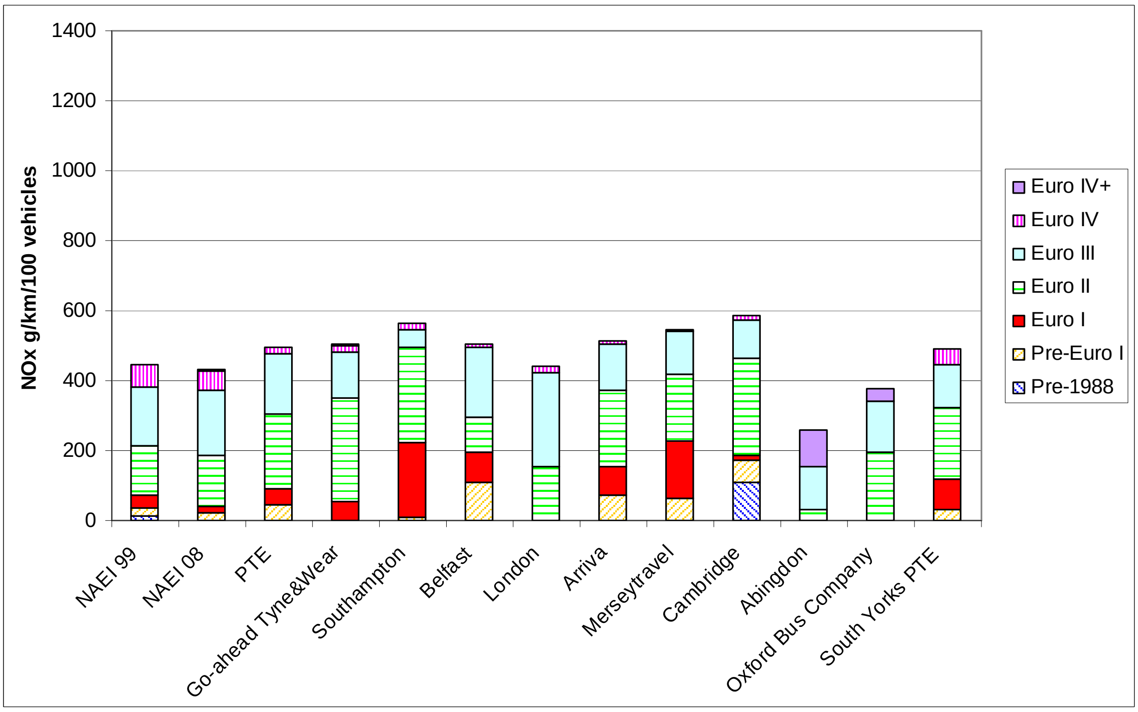


Figure 6: PM_{10} Emissions from Various Bus Fleets at 10kph

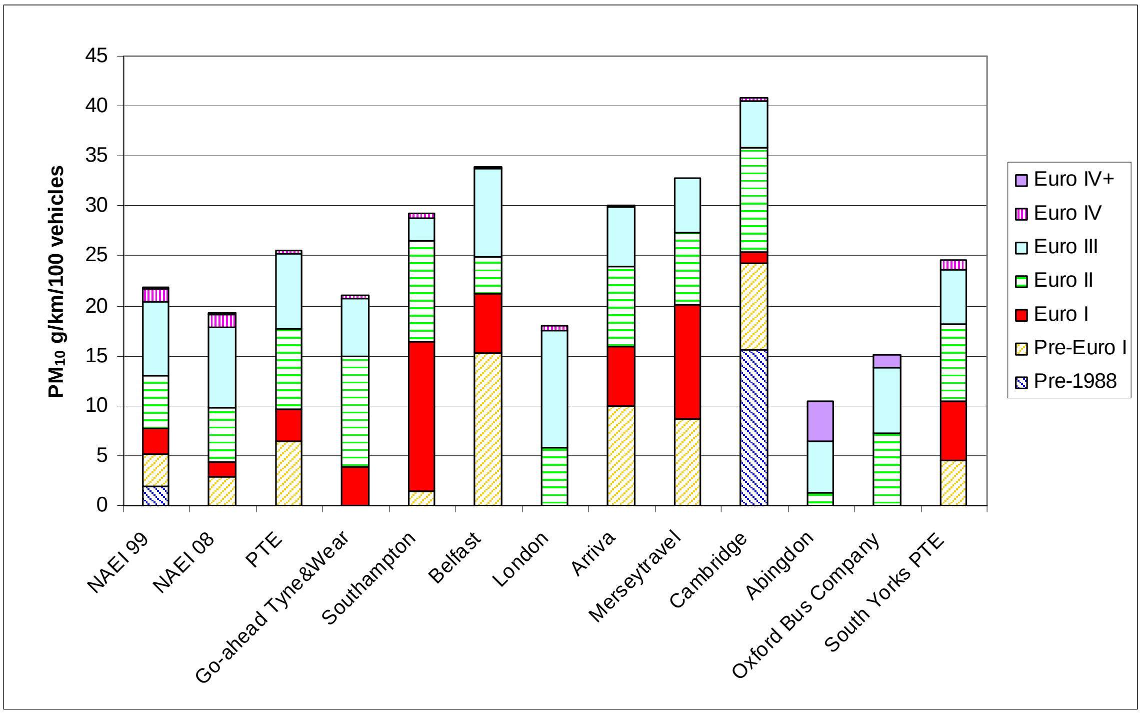
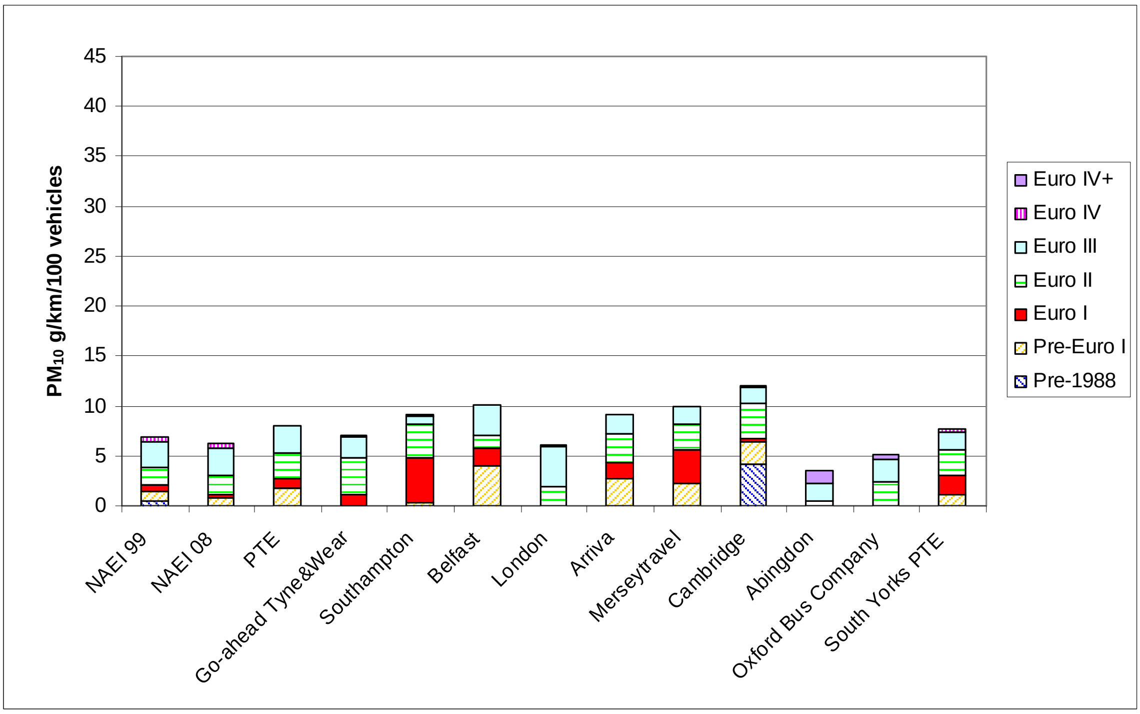


Figure 7: PM_{10} Emissions from Various Bus Fleets at 50kph



Impact of Emission Reduction Strategies for Buses

6.11 The Passenger Transport Executive Group (pteg) recently published a report on the opportunities for reducing greenhouse gases and pollutant emissions from bus fleets in PTE areas[13]. This considered the impact of various scenarios on total emissions from the fleet in the city regions covered by the PTEs (now ITAs). It found that without any further measures, NOx and PM emissions would be reduced by 29% and 49% respectively between 2007/8 and 2011/12, based on a realistic vehicle replacement rate of 5.5% per year. A higher replacement rate of 7.5% per year would lead to similar benefits as compared with a low ambition policy to promote diesel economy, with a further 9% reduction in NOx and 15% reduction in PM emissions. Greater benefits would be achieved with more ambitious policies to encourage greater fuel efficiency.

6.12 The pteg report highlighted that modern conventional diesel buses are hard to improve upon, when compared with current alternative technologies. It concluded that the most cost-effective way to reduce NOx and PM_{10} emissions in the short-term would be to replace the oldest buses with modern equivalents, or to retrofit abatement technology. It also identified driver training to improve fuel efficiency as a very cost effective, complimentary measure to reduce emissions.

6.13 The pteg report considered a range of alternative fuels and identified that hybrid vehicles could be the most effective way of reducing emissions in the long term. However, it concluded that due to the relatively high costs these are not currently commercially attractive. Changes in the relative costs of running these vehicles, possibly through the bus subsidy regime or fuel duty rates and improvements in the robustness of the technology are required before hybrid vehicles become a commercially attractive option for operators on a large scale.

6.14 A summary of some of the scenarios covered in the pteg report is provided in Table 7. This includes the percentage reduction in NOx and PM_{10} emissions from the bus fleet that could be achieved in these hypothetical scenarios. It shows that by modernising the bus fleet at a renewal rate of 16.5% per year would lead to significant reductions in emissions from buses, compared with a business as usual assumption of 5.5%.

6.15 LEZ studies for Bristol and Oxford have considered the effect of a range of measures on total traffic emissions. These show that upgrading all buses to Euro III or IV would have a significant effect on total traffic emissions. Both of these studies identified measures to reduce emissions from buses and HGV's as highly cost-effective.

---

[13] TTR Ltd, Scenarios and Opportunities for Reducing Greenhouse Gases and Pollutant Emissions from Bus Fleets in PTE areas, on behalf of pteg, December 2008.

Table 7: Summary of Hypothetical Impacts of Bus Emission Reduction Strategies

Source	Year	Location	Scenario(s)	Overall %Reduction in NOx emissions	Overall %Reduction in PM_{10} emissions
Pteg[13 a]	2011/12	Total PTE area	Business as usual 5.5% per year vehicle renewal between 2007/8 and 2011/12	29 (bus emissions only)	49 (buses only)
Pteg[13 a]	2011/12	Total PTE area	High Ambition package of policies leading to 16.5% per year vehicle renewal between 2007/8 and 2011/12	57(bus emissions only)	77 (bus emissions only)
Bristol LEZ feasibility study[19]	2010	Bristol Administrative Area	Particulate traps and EGR for all Euro II & III buses	2	4
Bristol LEZ feasibility study[19]	2010	Bristol Administrative Area	All buses Euro III	8	9
Bristol LEZ feasibility study[19]	2010	Bristol Administrative Area	All buses Euro IV	10	11
Central Oxford Air Quality Action Plan[11 a]	2011	Bus priority route	All buses, coaches and HGVs to Euro II	3	N/A
Central Oxford Air Quality Action Plan[11 a]	2011	Bus priority route	All buses, coaches and HGVs Euro III	22	N/A
Central Oxford Air Quality Action Plan[11 a]	2011	Bus priority route	All buses, coaches and HGVs Euro IV	40	N/A

[a] Based on actual bus fleet

6.16 Figures 8 and 9 illustrate the effects that upgrading entire bus fleets to at least Euro III or Euro IV standard would have on NOx and PM_{10} emissions. Figure 8 demonstrates that upgrading most fleets to Euro III would reduce NOx emissions by around one-third. If these fleets were upgraded to at least Euro IV, then emissions from the oldest fleets, such as those in Southampton and Cambridge, could be halved.

6.17 Figure 9 shows that the impact of upgrading fleets on PM_{10} emissions would be even more significant. PM_{10} emissions from the Cambridge fleet could be reduced by 60% if all buses were upgraded to Euro III, or by 86% if all buses were upgraded to at least Euro IV.

Figure 8: Impact of Upgrading Fleets on NOx Emissions

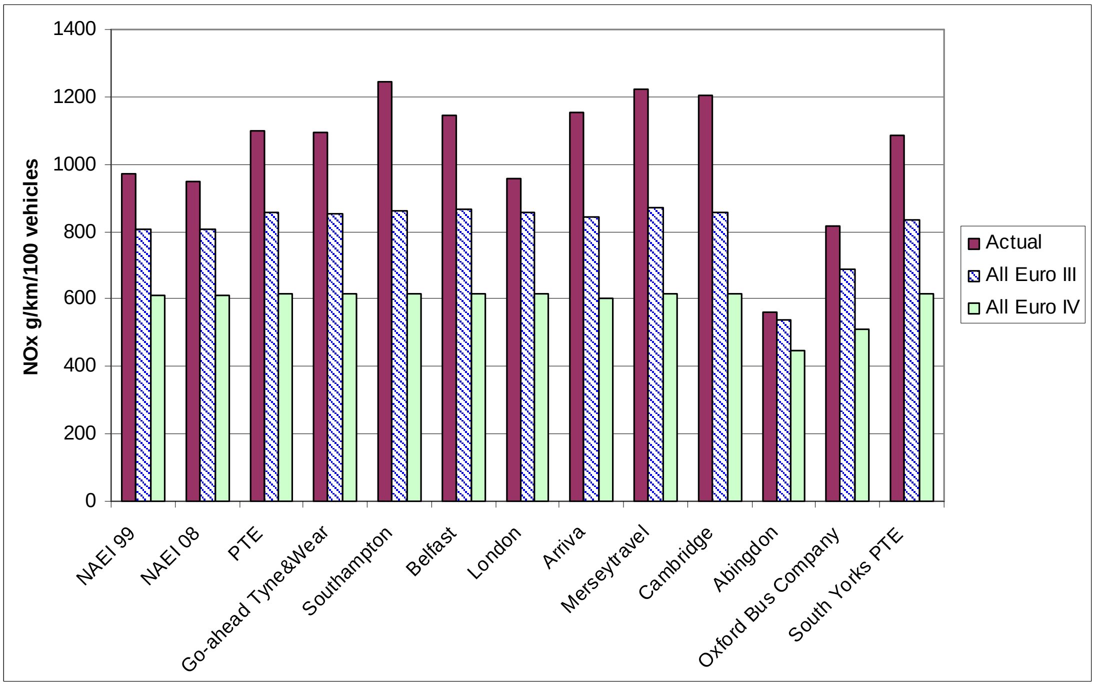
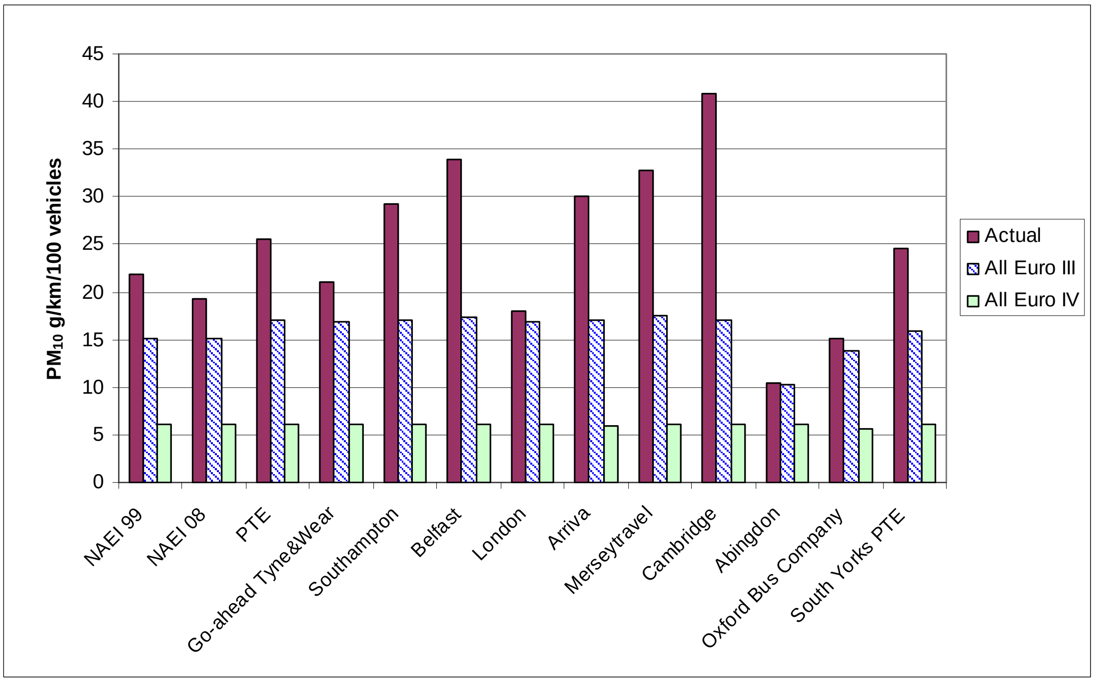


Figure 9: Impact of Upgrading Fleets on PM_{10} Emissions



Concentrations

6.18 It has not been possible within the scope of this report to quantify the extent to which bus emissions contribute to exceedences of the objectives on a national basis. National modelling to determine compliance with the objectives and EU limit values has been carried out[14]. This modelling indicates that along some road links where exceedences of the limit value are predicted, bus emissions contribute significantly. However, many of the locations identified in this report, such as Bath, Cambridge, Oxford and Norwich, are not identified in the national modelling as having roads where the EU limit value for nitrogen dioxide is expected to be exceeded in 2010. It is recognised that the national modelling is not sufficiently detailed to identify all congested streets with high numbers of buses, which are often in small historic towns, where the objectives are exceeded and bus emissions are significant.

6.19 In order to investigate the effect that varying the composition of the bus fleet can have on modelled concentrations, the ADMS-Roads model has been run for a single road. In each scenario it was assumed that 10% of the total traffic flow was buses, with all traffic travelling at an average speed of 10kph. These parameters were selected to reflect circumstances in congested, town centre streets with high proportions of buses, and where emission reduction strategies targeted at buses could potentially be most effective. Further details are provided in Appendix 2.

6.20 The results are presented in Table 8 and Figures 10 and 11. These show that although buses make up only 10% of the traffic flow, they are responsible for around 50% of the NO_2 contribution derived from traffic and 35% of the PM_{10} contribution.

6.21 Figures 10 and 11 demonstrate the effect that various bus fleets have on modelled NO_2 and PM_{10} concentrations. Predicted NO_2 concentrations based on the Cambridge fleet are around 2 $\mu g/m^3$ higher than those predicted using the NAEI fleet, whereas the predicted NO_2 concentration based on the Abingdon fleet is around 3 $\mu g/m^3$ lower than the NAEI fleet. A similar pattern is exhibited in the PM_{10} results.

6.22 The results show that upgrading all buses to at least Euro III or IV would lead to reductions in NO_2 and PM_{10} concentrations. These strategies would be most effective in areas where older fleets are in operation.

6.23 These results have important implications for measures that may have been considered in the development of local authority Action Plans. Where the actual bus fleet is older than the national average, the potential benefits of emission reduction strategies may have been underestimated if

[14] Personal Communication with John Stedman AEAT 16th March 2008

the NAEI fleet assumptions were used for assessment. Conversely, in areas where the bus fleet is newer than that assumed in the NAEI, the benefits of upgrading the fleet could be negligible.

6.24 The results described above are consistent with other local authority studies carried out to support the development of Action Plans. For example, a study completed for Newcastle City Council in 2005[15], identified that in one particular street near the bus station, 54% of the nitrogen dioxide concentration was attributable to bus emissions. The study also considered the potential effects of reducing emissions from a number of sources, and concluded that reducing bus emissions by 50% (roughly equivalent to replacing Euro II buses with Euro IV) along this particular street would reduce nitrogen dioxide concentrations by 19 µg/m^3, from 71 to 52 µg/m^3. In comparison, reducing car emissions by 50% would have a less than 1 µg/m^3 impact. This highlights the very significant improvements that can potentially be delivered by bus emission reduction strategies at certain locations. It should be noted that these estimates were based on the NAEI fleet rather than the actual fleet in Newcastle.

Table 8: Predicted Concentrations (µg/m^3) for Single Road 2008

Fleet	Background	All Rd	Car	Bus	Light	HDV	Total
Nitrogen Oxides (NOx)							
NAEI	68.8	61.7	9.2	31.7	2.7	18.1	130.5
Cambridge	68.8	69.3	9.2	39.3	2.7	18.1	138.1
Abingdon	68.8	48.3	9.2	18.3	2.7	18.1	117.1
NAEI All Euro III	68.8	56.4	9.2	26.4	2.7	18.1	125.2
NAEI All Euro IV	68.8	50.0	9.2	20.0	2.7	18.1	118.8
Nitrogen Dioxide (NO_2) [a]							
NAEI	36.0	18.3	2.7	9.4	0.8	5.4	54.3
Cambridge	36.0	19.9	2.6	11.3	0.8	5.2	55.9
Abingdon	36.0	15.0	2.9	5.7	0.8	5.6	51.0
NAEI All Euro III	36.0	17.0	2.8	8.0	0.8	5.5	53.0
NAEI All Euro IV	36.0	15.5	2.8	6.2	0.8	5.6	51.5
PM_{10}							
NAEI	27.2	1.5	0.3	0.5	0.3	0.4	28.7
Cambridge	27.2	2.0	0.3	1.0	0.3	0.4	29.2
Abingdon	27.2	1.2	0.3	0.3	0.3	0.4	28.4
NAEI All Euro III	27.2	1.3	0.3	0.4	0.3	0.4	28.5
NAEI All Euro IV	27.2	1.1	0.3	0.1	0.3	0.4	28.3

[a] Variations in predicted NO_2 for cars and HDV due to the complex NOx to NO2 relationship (see Appendix 2 for further details)

15 Air Quality Consultants 2005, Further Assessment of Air Quality in Newcastle City Centre, the Quayside and Jesmond Road, on behalf of Newcastle City Council.

Figure 10: Impact of Upgrading Fleets on NO_2 Concentrations in 2008

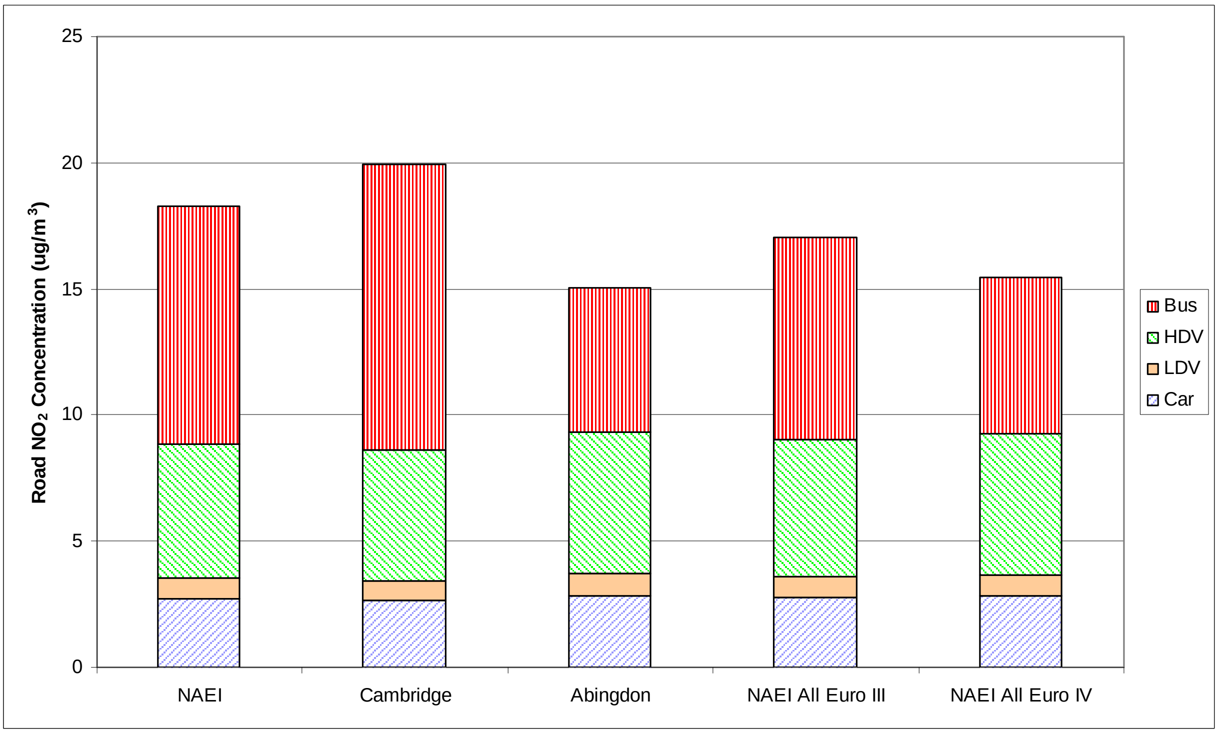
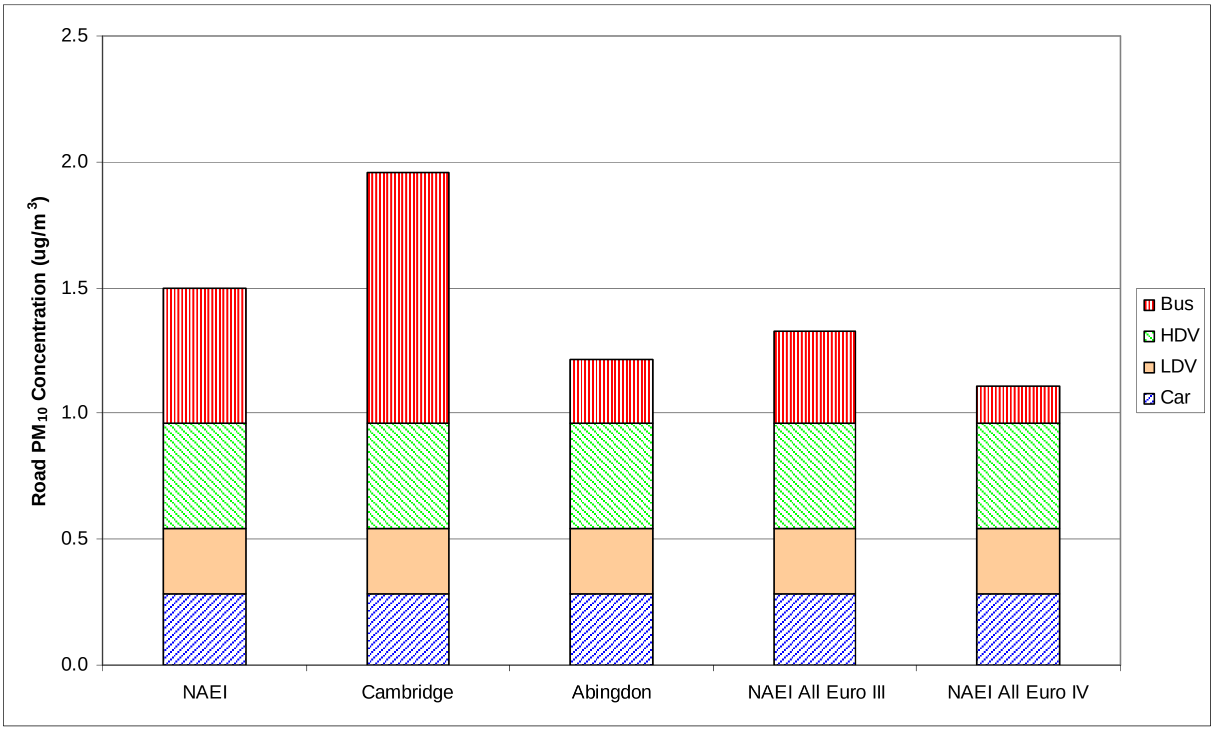


Figure 11: Impact of Upgrading Fleets on PM_{10} Concentrations in 2008



7 Case Studies

7.1 As described in the methodology section, a number of local authorities were contacted to obtain information on emission reduction measures for buses. A summary of these case studies is provided below. Further details of interviewees contacted are provided in Appendix 1.

Winchester – MIRACLES/Bus Quality Partnership

7.2 A successful programme for reducing bus emissions by retrofitting and bus replacement has been implemented in Winchester. A Bus Quality Partnership was set up, with additional funding initially provided as part of the EU MIRACLES project. In September 2003, thirteen new Euro III buses were introduced on two key routes. In addition, 10 buses were re-powered (engines replaced) from Euro I to Euro III, and four Euro II buses operating on the Park and Ride route were fitted with CRT. Some short-term trials of diesel/electric hybrid buses were also carried out.

7.3 The MIRACLES project ended in 2006. Problems were encountered with re-powering and retrofitting buses. It was concluded in light of the ever tightening Euro standards, that fleet replacement was the most cost effective option[16].

7.4 The funding was provided to Stagecoach, who operate around 90% of buses in Winchester. A lasting legacy of the MIRACLES project is that Stagecoach has continued to upgrade the fleet operated in Winchester; this is partially driven by the on-going Bus Quality Partnership. However, Stagecoach now take pride in their Winchester fleet which they claim is one of the newest in the country, and the company is now trialling a Euro V bus on behalf of the manufacturer. However, there is anecdotal evidence that this has led to a greater number of older buses in other areas, such as Southampton.

Cambridge – Voluntary Partnership Agreement

7.5 Cambridgeshire County Council has set up a voluntary Bus Quality Partnership. This includes a requirement by the operator to submit an annual emissions action plan to demonstrate how it will support year-on-year improvements to air quality in the 'core area'. The provisional implementation plan supports the LTP target of all buses in the core area being Euro II or better by

16 Personal Communication with Andy Wren Hampshire County Council 20th January 2009

2009; it also identifies an aspirational target of Euro III by 2015. However, each operator only demonstrate an 'aspiration' to meet the Euro II target.

7.6 There is no statutory recourse for operators that do not comply with the agreement. However, the County Council may refuse to issue transponders, which operate bollards allowing buses to enter the core area, if operators' action plans are not felt to be sufficiently challenging.

7.7 A member of the air quality team at Cambridge City Council is on the board involved in setting up the partnership. An Annex to the agreement[17] sets out in detail the nature of the air quality problem in Cambridge and describes measures that operators could adopt to reduce emissions. In addition, the Annex describes how the County Council will calculate NOx and PM_{10} indices for each bus fleet based on Euro standards and distances travelled. The officer would have preferred to see specific emissions standards set within the agreement, however it was felt that this would not have been practical for some operators who may then not have signed up to this voluntary agreement if emissions standards had been higher.

7.8 The Quality Partnership was launched in January 2009 and took around 2 years to set up. Although air quality was identified as a main trigger to setting up the Partnership, it was felt that there were conflicts between the aims of the County Council, who were responsible for setting up the Partnership, and the City Council who are responsible for air quality. Although there is now an agreement in place, which should eventually remove pre-Euro and Euro I buses from the AQMA, it does little to encourage the introduction of the very cleanest Euro IV and V buses that are required to work towards achievement of the air quality objectives.

Bath – Traffic Regulation Condition

7.9 In August 2005 Bath and North East Somerset Council successfully applied to the local Traffic Commissioner for a Traffic Regulation Condition (TRC). The TRC, which was granted in July 2006, related to the operation of tour buses in the city. It stated that 80% of all tour buses must comply with Euro III or higher exhaust emissions standards with immediate effect. The remaining 20% of buses were required to comply with Euro II standards, and to be upgraded to Euro III or higher by April 2008[18]. In addition, it limited the number of buses, the routes and bus stops used, and banned the use of loud speaker public address systems to reduce noise impacts.

[17] Cambridge County Council 2008 Quality Bus Partnership Agreement 2008-2011

[18] Decision of the Traffic Commissioner Western Traffic Area, Application by Bath & North East Somerset Council for Traffic Regulation Conditions, July 2006.

7.10 Prior to the TRC there had been a number of tour bus operators in the city. There were a large number of buses, with low occupancy rates. The majority of these were old buses which were pre-Euro I. The Council received a large number of complaints about noise and pollution from these buses, which were the driving force for the Council to take action against the tour bus operators.

7.11 Following the TRC there is now only one tour bus operator in the city, which is using modern buses. The TRC does not require any further improvements in emissions; however, the TRC could be amended if it was felt necessary.

7.12 The application, which included air quality evidence, was submitted in September 2005. A public inquiry was held in May 2006 and the TRC was agreed in July 2006. Prior to the TRC application, a lot of time was spent on putting the case together. Initially, the Council tried to put a voluntary agreement in place, however this was unsuccessful and found to be against competition rules.

7.13 Approximately 90% of scheduled bus services in the city are operated by the First Bus group. They upgraded their whole fleet in the city to new buses in 2005 (Euro III) and it was not felt necessary to include scheduled services in the TRC.

7.14 Overall the TRC has been successful in reducing emissions from tour buses in the city. However, significant time and cost were involved in achieving this. It is likely that the number of buses operating in the city would have reduced over time due to commercial pressures, although it is unlikely that the fleet of the remaining operator would have been upgraded without the TRC.

Bristol – LES – Engine Management

7.15 The Bristol Low Emission Strategy Feasibility Study[19] was completed in 2006. It considered the air quality impacts and cost-effectiveness of a range of measures including a Low Emission Zone, mandatory bus emission controls, voluntary emissions agreements with freight operators, and scrappage and retrofitting schemes for older cars. The study identified that mandatory controls on bus emissions could lead to a 2-10% reduction in nitrogen oxides (NOx) emissions from road traffic and a corresponding 4-12% reduction in particulate matter emissions. It also concluded that the mandatory bus emission controls would be the most cost-effective scheme. These conclusions are consistent with a number of LES studies that were carried out around the same time.

[19] TTR 2006. Bristol Low Emission Strategy Feasibility Study, July 2006.

7.16 Prior to the LES study, Bristol City Council had successfully funded retrofitting of older buses with DPF using European funding as part of the VIVALDI project. However, it was found that retrofitting DPF can lead to high maintenance costs.

7.17 Following the conclusions of the LES study, Bristol City Council is now looking to introduce another scheme. This will involve funding changes to the engine management systems of Euro IV buses, so that emissions are reduced to Euro V levels. Calculations carried out by the Council indicate that this approach would be more cost effective than retrofitting, as costs are lower. However, this scheme has not yet been rolled out due to concerns about the legality of providing funding to the operator. Under EU competition rules, the level of funding that a local authority can provide to a private bus operator is capped. Bristol City Council is therefore seeking legal advice before continuing with this scheme.

7.18 Bristol City Council has also entered into a Quality Bus Partnership with the main operator (First) for a number of 'showcase' routes. Although there is no specification of emissions standards for buses operating on the 'showcase' routes, they do need to be new buses and therefore will have relatively low emissions.

Norwich LEZ

7.19 A Low Emission Zone was introduced in July 2008 to reduce nitrogen dioxide and PM_{10} concentrations in the Castle Meadow area of Norwich. A Traffic Regulation Condition has been granted by the Traffic Commissioner, which specifies that certain proportions of an operators' fleet using Castle Meadow must comply with Euro III emissions standards. For services that operate wholly within Norwich City, 100% of buses must comply with Euro III by April 2010.

7.20 The LEZ has been introduced as part of the European funded CIVITAS initiative. Some of this funding was used via the LTP to provide grants to operators to cover 65% of the cost of retrofitting equipment, so that the Euro III standard could be achieved. For CIVITAS partner operators, the additional 35% of funding could be obtained from the EU. Under this scheme 30 buses were retrofitted with equipment to achieve Euro III standard. Eight new buses were also purchased.

7.21 CIVITAS funding covered obtaining the Traffic Regulation Conditions, publicising the LEZ and officer time. Norfolk County Council also offered free places on eco-driving training courses. In addition, an 'Engine Switch Off' Traffic Regulation Order has been introduced in Castle Meadow, to further reduce emissions in this area.

7.22 The Norwich LEZ is a good example of partnership working between Norfolk City Council and Norwich County Council, although, as with other projects, engaging bus operators was found to be a challenge. It is also notable that like some of the other more successful schemes, it was assisted by European funding. It is unlikely that the LEZ would have been introduced without this funding.

7.23 The Air Quality Action Plan[20], published as part of the LTP in 2004, estimated that the implementation of the LEZ, in conjunction with a Bus Quality Partnership and retrofitting abatement technology could reduce nitrogen dioxide concentrations in the Castle Meadow Area by 5 µg/m^3. Monitoring of nitrogen dioxide concentrations is being carried out in the LEZ by the University of East Anglia, as part of the CIVITAS project. However the results will not be published until the project is complete.

Belfast – Air Quality Action Plan

7.24 The operation of buses in Belfast differs from much of the rest of UK. Buses in the city are operated by Translink, which operates bus and rail services in Northern Ireland. Translink is controlled by the Board of Northern Ireland Transport Holding Company, which is responsible to the Department for Regional Development. It has therefore been easier to engage this single, publicly accountable operator in the development of an Air Quality Action Plan.

7.25 Belfast City Council's Air Quality Action Plan[21] includes a number of measures aimed at reducing emissions from buses, for which Translink was named as the 'lead authority' to implement these measures. Actions that have been implemented include:

- Introduction of a bus replacement programme to reduce the average age of the fleet to 8 years;
- Retrofitting Continuous Regenerative particulate Traps (CRT) to Euro II and Euro III buses operating in the city;
- Introduction of a requirement to purchase new vehicles complying with the prevailing Euro standard.

7.26 Whilst the measures introduced are not particularly onerous, and generally represent actions that Translink proposed to take independently of the Air Quality Action Plan, it appears that Belfast City Council has not encountered the same barriers to engaging the bus operator, as has been apparent elsewhere.

[20] Norfolk County Council 2006. Provisional Second Local Transport Plan for Norfolk 2006-2011, Appendix B – Air Quality Action Plans.

[21] Belfast City Council 2006. Belfast City Air Quality Action Plan. May 2006

Sheffield – Statutory Quality Partnership

7.27 A Statutory Quality Bus Partnership was been set up in North Sheffield in 2006. This specifies that all core services must comply with Euro III standards and all complementary services must comply with Euro II, with an agreement to improve to Euro III.

7.28 As a result approximately 110 buses are required to meet at least Euro III standards, 48 of which are actually Euro IV. This is a substantial proportion of the bus fleet and has benefits across the city, as most operate cross-city services.

7.29 South Yorkshire Integrated Transport Authority is now considering similar SQP's in Doncaster and Barnsley, with minimum Euro III standards for frequent services and Euro II standards for other services. However, there is opposition from smaller operators who claim that even Euro II standards are unachievable.

Tyne & Wear LTP

7.30 Although no specific bus emission reduction measures have been implemented in Tyne & Wear, the studies undertaken in Newcastle City Centre[22] to support the Action Plan identified bus emissions as a significant source of nitrogen oxides in some locations. Therefore, the LTP and associated documents identify targets to reduce bus emissions. The Tyne & Wear Local Transport Plan Core Team has prepared the Tyne & Wear Air Quality Delivery Plan[23]. This identifies the 'number of Euro engine buses operating in AQMAs and future AQMAs' as an Indicator and a desire to encourage the most 'environmentally friendly vehicles' in these sensitive areas.

7.31 The Air Quality Delivery Plan sets out actions that will have a positive effect on this indicator. This includes use of the powers within the Local Transport Act 2008 to enter into formal partnership agreements to improve the quality of buses in AQMAs. Other actions include encouraging eco-friendly driving courses for bus drivers to prevent bus idling and better enforcement to prevent engine idling in city centres.

Oxford – Oxford Bus Company

7.32 Oxford Bus Company is an example of a organisation that operates a bus fleet with significantly lower emissions than the national average. The average age of the fleet is around 5 years,

[22] Air Quality Consultants 2005, Further Assessment of Air Quality in Newcastle City Centre, the Quayside and Jesmond Road, on behalf of Newcastle City Council

[23] Tyne & Wear Local Transport Plan Core Team. Tyne & Wear Air Quality Delivery Plan

compared with the national average of 8 years. All of the company's buses are Euro II plus CRT or better, with Euro V buses making up over 20% of the fleet.

7.33 The Company cites the market conditions in Oxford as a key motivation for adopting this modern fleet. It has set out to distinguish itself from other companies, based on the quality of the buses it uses, because it feels that this is important to bus patrons in the city. Oxford Bus Company also wants to be prepared for the introduction of an LEZ in the city, rather than playing 'catch up' with other operators.

7.34 The Company also carry out intensive driver training and monitoring. They claim that this has improved fuel efficiency by 5%[24].

7.35 Although the Oxford Bus Company operates a high quality fleet for public and corporate social responsibility reasons, economic factors are important. The reduced maintenance and fuel costs as a result of operating a modern, low mileage fleet provide the economic case for this approach.

7.36 Oxfordshire County Council's pricing preference scheme, which encourages the use of new buses on subsidised routes may also have encouraged renewal of the Oxford Bus Company's fleet. Another economic incentive for the early introduction of Euro V vehicles is the Reduced Pollution Certificate Scheme, which provides a discount of up to £500 per year for Euro V vehicles registered before 1 October 2009.

Liverpool – Variable Charging and Fixed Penalty Notices

7.37 Merseytravel, which is the ITA for Merseyside, recognises that bus deregulation has led to a large number of competing operators in their area. Many of these small operators use old, higher emissions buses. To date, attempts to encourage modernisation of the fleet have been limited, although they do operate variable charging at bus stations, where newer buses pay lower departure fees.

7.38 Officers from Liverpool City Council carry out on-street surveys of idling buses and ask drivers to switch off engines. If the driver does not comply, they are issued with a £20 fixed penalty notice. The driver is personally responsible for paying the fine.

24 www.go-ahead.com/goahead/media/news/2008news/2008-09-15/

8 Evaluation of Current Emissions Reductions Strategies

Factors that Influence the Implementation of Emissions Reductions Strategies for Buses

8.1 Based on the interviews carried out, and case studies described above, a number of common themes emerge that prevent or enhance the implementation of emission reduction strategies for buses. These are summarised in Table 9 and discussed below.

Table 6: Factors that can Prevent or Enhance the Implementation of Bus Emission Reduction Strategies

Prevent	Enhance
Inability to engage bus operators	Bus operators willing to engage and interested in public perception of the fleet
Lack of funding	External funding
Large urban areas	Specific and 'visible' air quality problem, e.g. small historic towns and cities
Large number of bus operators.	Single main bus operator (if willing to engage)
County vs District	Unitary authority
Lack of prioritisation	An individual championing the approach
Competition rules	Clear guidance on mechanisms available

Nature of Air Quality Problem

8.2 It emerges from the case studies that most bus emission reductions strategies to date have been implemented in small historic towns and cities. This may be because the air quality problems are confined to specific streets in the town/city centre. Exceedences of the air quality objectives in these areas are often influenced by the physical nature of these streets, which are narrow 'canyon-like' streets that reduce dispersion of pollutants. These areas are often central shopping and/or tourist areas and therefore often served by a relatively large number of bus services. The presence of a specific visible problem, i.e. a large number of buses in a small public area, in combination with a will to make these predominantly tourist areas more attractive, appears to help prioritise bus emission reduction measures in these areas. In addition, the presence of tour buses in these historic cities has contributed further to air quality problems.

8.3 The implementation of emission reduction strategies for buses has been far less effective in large urban areas, where exceedences of the air quality objectives are more widespread. This is possibly because bus operations are not as visible, and the reduction of bus emissions has not been seen as a priority. However, a number of Low Emission Strategy feasibility studies, including those in Bristol and Oxford, have identified targeting bus emissions as a cost-effective approach to improving air quality. There may also be other barriers to implementing bus emission reduction strategies in large urban areas, such as the council structure and the larger number of operators than found in smaller towns and cities.

8.4 Very localised air quality problems can occur near to bus stops, if vehicles are stationary for a period of time with engines left running. Measures that prevent stationary idling could be very cost effective. Officers from Liverpool City Council carry out on-street surveys of idling buses and ask drivers to switch off engines. If the driver does not comply, they are issued with a £20 fixed penalty notice. An ‘engine switch-off’ Traffic Regulation Order has been implemented in the Castle area of Norwich. However, simple signs and driver training could also prevent these localised problems near to bus stops.

Council Structures

8.5 In some cases, the structure of the council has affected the ability to implement bus emission reduction strategies. Conflicts between the priorities of the District Council (responsible for air quality) and the County Council (responsible for transport) have been identified by a number of authorities. In spite of these conflicts, strategies have been introduced. However, these conflicts have led to delays in implementation and influenced the stringency of the measures introduced.

8.6 There has often been a key person responsible for driving forward the measure. In most cases where successful strategies have been introduced, this person has been within the transport department. This is because for most measures it is the transport department that is responsible for funding and, where relevant, regulation. Air quality officers have often been integral in identifying and providing the evidence to justify measures but without control of the necessary budgets or responsibility for regulation their influence is limited.

8.7 The reduction in priority of air quality within the LTP3 guidance suggests that in the future, it will be even harder to justify schemes on air quality grounds. This is at odds with Defra’s aims to achieve the objectives.

8.8 The political priorities of councils have also influenced the introduction of emission reduction measures for buses. This may be a reason why more measures have been implemented in small towns and cities, where there is a greater political drive to make an area more attractive to visitors.

8.9 With the exception of the SQP in South Yorkshire PTE, no significant measures have been introduced in PTE areas to date. Interviewees indicated that this is because the powers of the PTEs to regulate emissions from bus operations have historically been limited. However the Local Transport Act 2008 has increased the powers of the PTEs (now ITAs) to reduce bus emissions. Now that the ITAs have sole responsibility for Local Transport Plans, measures could more easily be introduced. The absence of bus emission reduction measures in PTE areas could also be caused by the lack of requirement on PTEs to reduce the impact of buses on air quality. Again now that the ITAs have sole responsibility for the LTP, air quality should become a higher priority.

Funding

8.10 As with any scheme, funding of measures is important. It is noteworthy that a number of the implemented schemes were assisted by significant funding from the EU, (Winchester, Bristol and Norwich). This included funding officer time to implement the scheme as well as grants to assist with the costs of retrofitting or purchasing new buses. In addition, these projects have included trials of alternative fuelled vehicles. It is acknowledged that without this funding some of these schemes would not have been possible.

8.11 The aim of the EU funded projects was to finance innovative measures to improve air quality in order to determine which were successful. A similar level of funding would be required to introduce measures elsewhere, and without this funding it is unlikely that other similar projects will go ahead. However, particularly in Winchester, this historic funding has been successful in enabling the main operator to experience the benefits of a modern bus fleet. Following the completion of the project, the operator has continued to upgrade its fleet, without further financial assistance.

8.12 Bristol City Council is currently aiming to fund upgrades to the engine management systems of the main operator’s buses through the LTP process. However, provision of funding by a local authority to a company potentially conflicts with EU rules on fair competition and is capped. Bristol City Council is currently seeking legal advice before proceeding with this initiative.

Bus Operators

8.13 The number of bus companies operating in an area varies widely across the UK and this can have a significant effect on the bus fleet, and the willingness of operators to engage in voluntary agreements. In areas where a single company dominates operations (up to 90% of operations in some areas) it can be easier to engage and target funding than within an area where there are a large number of small operators in competition.

8.14 In large urban areas, there are often a large number of smaller companies competing for passengers. These smaller companies tend to operate older buses with higher emissions. It is these companies that tend to resist any requirement to upgrade the bus fleets, and argue that their operations would become economically unviable if such measures were introduced. However, as discussed in Section 6, targeting those companies which operate the oldest fleets may be the most effective way to reduce emissions from buses.

8.15 Some larger companies take great pride in operating modern, low emission buses. These companies can afford the initial investment in new buses and recognise the benefits, such as lower maintenance and fuel costs, as well as the positive publicity. In addition, these companies often operate nationally and therefore can reorganise their fleet, so that the newest buses operate in the high profile areas where air quality problems exist, with the older buses can be relocated to more suburban or rural areas.

8.16 It is noteworthy that in Belfast, where there is a single, publicly accountable bus operator, the company has been easily engaged in the Air Quality Action Plan process. In this case the bus operator is named as the party responsible for implementing bus emission reduction measures.

Policy Mechanism

8.17 A summary of implemented bus emission reduction strategies identified as part of this study is presented in Table 10. No other statutory measures have been identified, but there may be other Voluntary Partnership Agreements in place, where ‘new’ buses are specified rather than a certain Euro standard.

8.18 The first measure to be implemented, in Winchester, was voluntary but funding was provided by the EU to achieve Euro III standards. Norwich and Bath used statutory Traffic Regulation Conditions to specify Euro III standards for a certain route and tour buses, respectively. Sheffield

City Council specified Euro III standards as part of a wider Statutory Quality Partnership Agreement.

Table 10: Summary of Implemented Bus Emission Reduction Strategies

Location	Year	Mechanism	Statutory or Voluntary?	Euro Standard
Winchester	2003	Funding (EU)/Voluntary Partnership Agreement	Voluntary	Euro III
Bath	2006	Traffic Regulation Condition	Statutory	Euro III
Sheffield	2006	Statutory Quality Partnership	Statutory	Euro III
Norwich	2008	Traffic Regulation Condition	Statutory	Euro III
Cambridge	2009	Voluntary Partnership Agreement	Voluntary	Euro II

8.19 It is significant that the recently introduced Voluntary Partnership Agreement in Cambridge only specifies Euro II standards, whereas the earlier, statutory schemes were based on Euro III standards. Defra's Practice Guidance Note of Low Emission Zones concludes that until 2010-2012 a Euro III standard should be considered as the minimum standard for LEZ schemes[25]. Most Euro II vehicles are now over 8 years old, which is the average age of the fleet in the UK, and therefore this obligation is not particularly onerous. However, this is the highest standard that could be agreed with the operators. If a statutory mechanism had been used it may have been possible to introduce a higher standard.

8.20 Where measures are being investigated but not implemented, transport authorities are being encouraged to pursue voluntary agreements rather than statutory measures. However, in these areas, there has been difficulty in engaging bus operators to discuss and sign up to voluntary agreements that would actually be effective in modernising the bus fleet.

8.21 The recent Local Transport Act 2008 includes a number of provisions that may make it easier to implement bus emission reduction strategies in future. These include facilitating Voluntary Partnership Agreements between more than one operator, making Quality Contract Schemes a more realistic option and clearer powers for authorities to subsidise improvements in the standard

[25] Defra 2009 Local Air Quality Management Practice Guidance to Local Authorities on Low Emissions Zones, February 2009.

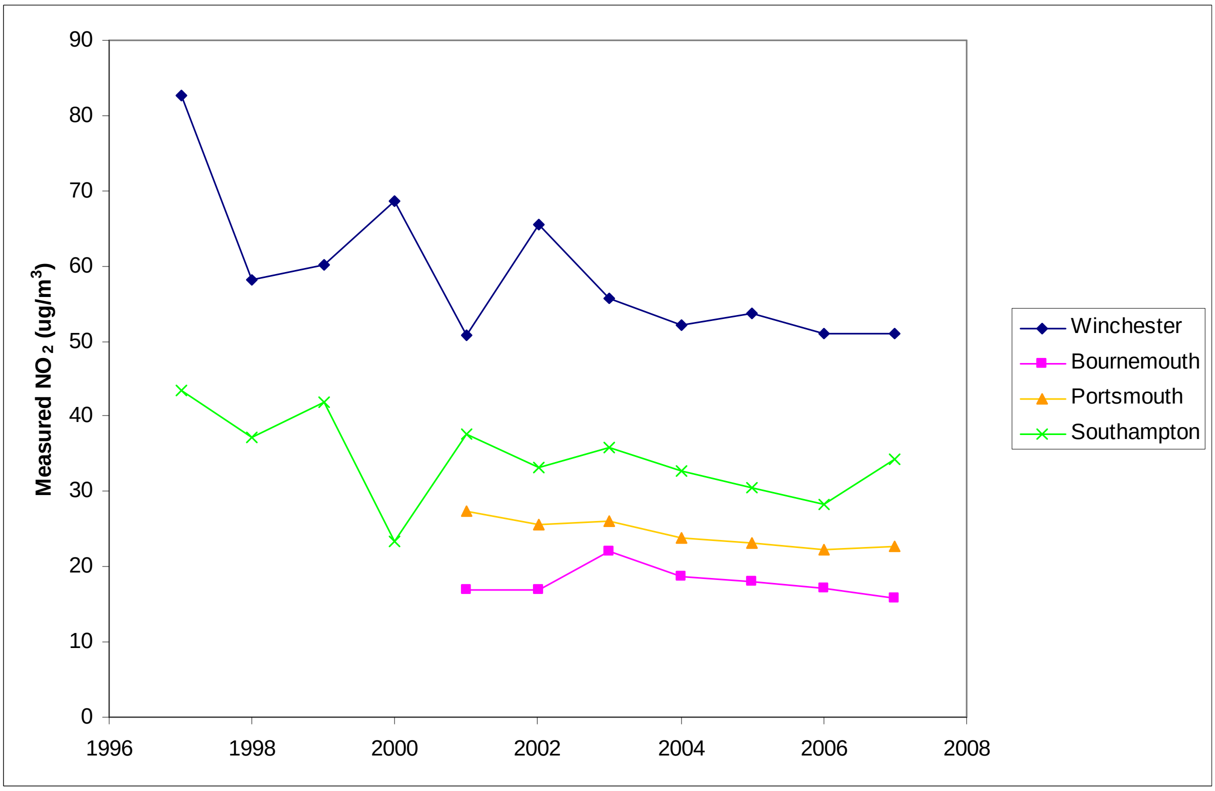
of bus services. The Act also allows local authorities to phase in improvements within statutory Quality Partnership Schemes over time. This could be a useful way to allow improvements to stay in step with the phased introduction of tightening Euro standards.

Monitoring Effectiveness

8.22 Measured pollutant concentrations at a particular location can vary greatly from year-to-year, due to meteorological conditions and long-range transport of pollutants. Therefore, it is very difficult to demonstrate the effectiveness of a particular emissions reduction strategy from monitoring.

8.23 Figure 12 presents nitrogen dioxide concentrations from a roadside site in Winchester city centre. Also included to provide information about regional variations in annual mean concentrations, are data from background monitoring sites in Bournemouth, Portsmouth and Southampton. The Winchester emissions reduction scheme was implemented in 2003. There is no obvious downward trend in concentrations in Winchester post-2003 that could be attributed to the emissions strategy.

Figure 12: Measured Nitrogen Dioxide Concentrations in Winchester



8.24 There are no monitoring data available for the other implemented schemes. A more useful approach to monitoring the effectiveness of bus emission reduction strategies could be to regularly compile accurate fleet lists and use these to estimate emissions. Cambridge City Council intends to obtain this information in order to calculate emissions per fleet as part of its' Voluntary Partnership Agreement.

9 Conclusions and Way Forward

Conclusions

9.1 Information about bus fleets across the UK has been gathered from a number of sources. This shows that the actual fleet composition with regards to age and Euro standard can differ greatly from the national assumptions that are used for most local authority air quality modelling studies. These variations in fleet composition can potentially have significant effects on NOx and PM_{10} emissions and the modelled concentrations.

9.2 Bus emission reductions strategies can be an effective tool for reducing nitrogen dioxide and PM_{10} concentrations. The most effective strategies are those that replace the oldest, most polluting vehicles, with modern low-emission buses. Hybrid vehicles have the potential to reduce NOx and PM_{10} emissions; however, they are not currently a commercially viable option.

9.3 Possible mechanisms for the implementation and enforcement of emission reduction strategies for buses have been reviewed. Effective mechanisms and guidance for introducing strategies are limited. However, the Local Transport Act 2008 has introduced greater powers for local transport authorities to implement measures, and some authorities are currently investigating possible strategies using these new powers.

9.4 To date, few bus emission reduction strategies have been implemented. Most of these strategies are within small historic towns and cities, where bus-related air quality problems are concentrated into a small area. The most effective measures are either statutory partnerships and/or those where external funding has been provided. Factors that influence the implementation and effectiveness of bus emission reduction strategies include the nature of the air quality problem, council structure, funding availability, individual bus operator attitudes and policy mechanisms.

Way Forward

Further Research

9.5 There is still limited information available about the contribution that bus emissions make to exceedences of the objectives within Air Quality Management Areas. Therefore **before any additional measures to reduce bus emissions are considered, an investigation of the scale**

of problem should be carried out. It should be noted that the current national modelling approach is not sufficiently detailed to identify many of these exceedence areas, as it does not take into account specific local characteristics such as congestion, street canyons and actual bus fleet composition.

9.6 There are few monitoring data available to demonstrate the effectiveness of emissions reduction measures that have been introduced. Therefore **consideration should be given to further research into the effectiveness of bus emission reduction measures**. This could perhaps focus on fleet inventories and emissions, rather than air quality monitoring.

9.7 There is little information available about costs incurred by local authorities and bus operators in implementing emissions reduction measures. **Further investigation of the costs of implementing bus emission reduction measures is therefore required**.

Additional Guidance

9.8 Actual bus fleet composition can vary significantly from the national average, leading to large discrepancies between emissions based on the NAEI and actual emissions from buses in use. This can have significant implications for source apportionment studies and the prioritisation of measures within Air Quality Action Plans. Therefore **guidance should be provided to assist local authorities to compile and use actual bus fleet information, rather than relying on national assumptions.** This guidance could also provide some indication of the relative benefits of introducing various Euro classes as minimum standards.

9.9 Where successful emissions reduction measures have been implemented, they have been driven by key individuals within the transport departments of local authorities. **Consideration should be given to providing advice to local authority transport departments on the benefits of bus emission reduction strategies and mechanisms that encourage air quality considerations to be prioritised**. This could be by raising the profile of the Local Air Quality Management Practice Guidance Notes within transport departments.

Local/National Policy Actions

9.10 Removing the oldest pre-Euro and Euro I vehicles from the fleet can be an effective way to reduce bus emissions. **Local or national measures that could encourage the scrappage or retrofitting of these vehicles, or as a minimum removing them from areas where air quality is poor should be investigated.** Measures that promote the replacement of the very oldest vehicles with the very newest are the most effective. Therefore **consideration should also be**

given to incentivising the replacement of old buses with the newest Euro standards available. Without this, it is possible that setting a minimum standard of say Euro II or III may actually slow the introduction of Euro IV or V vehicles.

9.11 Hybrid vehicles have the potential to reduce NOx and PM_{10} emissions in the long-term. However, at present they are not a commercially viable option for bus operators. **Consideration should be given to mechanisms that could make hybrid vehicles more commercially viable.** This may be via financial incentives or improvements to the robustness of hybrid technology.

9.12 The next round of Local Transport Plans (LTP3) does not currently include air quality as a 'shared priority', although 'reducing social and economic costs of transport to public health, including air quality' is identified as a challenge under one of the five goals. This downgrading of air quality within the LTP process could lead to less priority being assigned to bus emission reduction strategies in the future. Therefore **the potential consequences of this should be communicated to DfT and local authority transport departments**.

9.13 Some of the most successful measures have been based on external (usually EU) funding provision to operators to upgrade fleets. In one example (Winchester) the operator has continued to upgrade the fleet after the funding concluded. **Consideration should be given to providing targeted funding in areas where bus emissions contribute significantly to exceedences of the objectives; in some cases, this could be an initial "pump priming" incentive.**

9.14 Bus driver training can potentially have significant beneficial impacts on emissions. **A national programme to encourage driver training to reduce emissions should be instituted**.

10 Recommendations

10.1 Based on the findings of this study, the following recommendations are made:

Further Research

- Before any additional measures to reduce bus emissions are considered, an investigation of the scale of problem should be carried out.
- Consideration should be given to further research into the effectiveness of bus emission reduction measures.
- Further investigation of the costs of implementing bus emission reduction measures is required.

Additional Guidance

- Guidance should be provided to assist local authorities to compile and use actual bus fleet information, rather than relying on national assumptions.
- Consideration should be given to providing advice to local authority transport departments on the benefits of bus emission reduction strategies and mechanisms that encourage air quality considerations to be prioritised.

Local/National Guidance

- Local or national measures that could encourage the scrappage or retrofitting of these vehicles, or as a minimum removing them from areas where air quality is poor should be investigated.
- Consideration should be given to incentivising the replacement of old buses with the newest Euro standards available.
- Consideration should be given to mechanisms that could make hybrid vehicles more commercially viable.
- The potential consequences of downgrading air quality within the draft LTP Guidance should be communicated to DfT and local authority transport departments.

- Consideration should be given to providing targeted funding in areas where bus emissions contribute significantly to exceedences of the objectives; in some cases, this could be an initial "pump priming" incentive.
- A national programme to encourage driver training to reduce emissions should be instituted.

11 Glossary

Standards A nationally defined set of concentrations for nine pollutants below which health effects do not occur or are minimal.

Objectives A nationally defined set of health-based concentrations for nine pollutants, seven of which are incorporated in Regulations, setting out the extent to which the standards should be achieved by a defined date. There are also vegetation-based objectives for sulphur dioxide and nitrogen oxides.

Exceedence A period of time when the concentration of a pollutant is greater than the appropriate air quality objective. This applies to specified locations.

AQMA Air Quality Management Area

PM_{10} Small airborne particles, more specifically particulate matter less than 10 micrometers in aerodynamic diameter.

NO_2 Nitrogen dioxide.

NO Nitric oxide.

NOx Nitrogen oxides (taken to be NO_2 + NO).

mg/m^3 Microgrammes per cubic metre.

HDV Heavy Duty Vehicles (> 3.5 tonnes)

LTP Local Transport Plan

PTE Passenger Transport Executive

ITA Integrated Transport Authority

EU European Union

12 Appendix 1 – Summary of Interviews

Table A1.1: Interviewees

Organisation	Dept	Name	Comments
Councils			
Liverpool	Air Quality	Alan Wilkins	Fixed penalty for idling buses
Sheffield	Air Quality	Ogo Osammoor	Statutory Quality Partnership in North Sheffield LES study indicated that controlling bus emissions would be cost effective Working group recently set up
Bath	Air Quality	Andrew Jones	Traffic Regulation Condition for tour buses – see case study
Bath	Public transport	Andy Strong	Traffic Regulation Condition for tour buses – see case study
Bath	Transport Planning team leader	Rab Smith	Traffic Regulation Condition for tour buses – see case study
Norwich	Air Quality	Mark Leach	LEZ and Traffic Regulation Condition for engine switch off – see case study
Norwich	Norfolk CC CIVITAS	Jonathan Taylor	LEZ and Traffic Regulation Condition for engine switch off– see case study
Bristol	AQAP - air quality	Steve Crawshaw	Upgrading engine management Euro IV to V Previously funded retrofitting
Bristol	upgrading	Ed Minihane	Upgrading engine management Euro IV to V Previously funded retrofitting
Winchester	Air Quality	Phil Tidridge	MIRACLES Project – see case study
Winchester	Hampshire County Council	Andy Wren	MIRACLES Project – see case study
Winchester	Hampshire County Council Passenger Transport	Andrew Wilson	MIRACLES Project – see case study

Organisation	Dept	Name	Comments
	Infrastructure		
Cambridge City	Air Quality	Jo Dicks	Voluntary Partnership Agreement – see case study
Cambridge County	Transport - Public Transport	Glenn Edge	Voluntary Partnership Agreement – see case study
Cambridge County	BQP co-ordinator	Glen Wakefield	Voluntary Partnership Agreement – see case study
Birmingham	Air Quality	Peter Fallon	Nothing in place
Walsall	Air Quality	John Grant	Bus station AQMA but nothing in place
Wolverhampton	Air Quality	Bob Goodyear	Bus station AQMA but nothing in place
Leeds	Air Quality	Dave Cherry	Nothing in place
Edinburgh	Air Quality	Janet Brown	Nothing in place. LEZ rejected. Now considering Voluntary Partnership Agreement
Cardiff	Air Quality	John Vesey	Nothing in place
Swansea		Phil Govier	Nothing in place
Belfast	Air Quality	Owen Williams	Publically accountable bus operator – see case study
PTE/ITA			
Sheffield	South Yorks PTE	Mike Holmes	Statutory Contract North Sheffield
Greater Manchester	Greater Manchester PTE	Peter Black	Nothing in place
Liverpool	Mersey Travel Env manager	Steven Littler	Variable departure charges at bus stations based on emissions
Tyne & Wear	LTP	Gary McDonald	Would like to encourage use of newest buses in AQMA Investigating new initiatives under LTA 2008. – see case study
Tyne & Wear	LTP/AQ	Rebecca Rosenquist	Would like to encourage use of newest buses in AQMA Investigating new initiatives under LTA 2008. – see case study
Bus Companies			
Oxford Bus	Operations	Lousia Weeks	Fleet details provided

Organisation	Dept	Name	Comments
Company	Director		
Other			
TTR		Tom Parker	directed to PTEG report on buses
AEA		Tim Murrels	Provided updated NAEI fleet mix

13 Appendix 2 – Model Input Data

13.1 In order to investigate the effect bus fleet composition can have on nitrogen dioxide and PM_{10} concentrations, ADMS-Roads was run for a simple hypothetical scenario. A summary of model parameters is provided in Table A2.1.

Table A2.1: Model Input Parameters

Parameter	Input
Road geometry	Single north-south road
Road width	8m
Receptor	6m from road centre (2m from kerb) to east of the road (worst-case).
Background NOx	68.8 µg/m^3 (central Birmingham)
Background NO_2	36.0 µg/m^3 (central Birmingham)
Background PM_{10}	27.2 µg/m^3 (central Birmingham)
Meteorological Data	Birmingham Airport 2008

13.2 A constant flow of cars, light goods vehicles, heavy goods vehicles and buses was assumed for each scenario, as shown in Table A2.2. An average speed of 10 kph was assumed.

Table A2.2: Traffic Flows

Vehicle Classification	AADT Flow
Cars	15,000
Light Goods Vehicles	2,000
Heavy Goods Vehicles	1,000
Buses	2,000

13.3 Emissions of NOx and PM_{10} in g/km/s for each vehicle class in 2008 were entered directly into the ADMS-Roads model. These were derived from the Emission Factor Toolkit. The ADMS-Roads model was then run, with a source group for each vehicle class. This produced NOx and PM_{10} concentrations for each vehicle class, based on the NAEI.

13.4 To determine the NOx and PM_{10} concentrations for each alternative scenario, the bus NOx and PM_{10} concentrations were scaled in proportion to the bus fleet emission rates from the NAEI. For example, the modelled NOx concentration from buses based on the NAEI was 31.7 µg/m^3. The NOx concentration based on the Cambridge fleet was estimated as 31.7 µg/m^3 x (12.0/9.7) = 39.3 µg/m^3.

13.5 Total and road (i.e. total – background) NO_2 concentrations were calculated from the estimated total NOx concentrations for each scenario using the NOx to NO_2 calculator provided by Defra[26]. NO_2 concentrations for each class were then calculated from the road NO_2 concentrations based on the proportional contribution to total NOx concentrations. This approach has led to some slight variations in car, light goods vehicle and heavy goods vehicle NO_2 concentrations between scenarios, even though the flows have remained the same. This is a result of the complex relationship between NOx and NO_2 assumed in the NOx to NO_2 calculator.

Table A2.3: Bus Fleet Emission Rates 2008 (g/veh. Km)

Scenario	NOx	PM_{10}
NAEI	9.7	0.22
Cambridge	12.0	0.41
Abingdon	5.6	0.10
NAEI All Euro III	8.1	0.15
NAEI All Euro IV	6.1	0.06

26 www.airquality.co.uk/archive/laqm/tools/no2tonox8_ja_b.xls