IMPROVING AIR QUALITY IN TOWNS AND CITIES

Why buses are an integral part of the solution

Professor David Begg

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EXECUTIVE SUMMARY

The Government will announce its new clean air strategy imminently. In response to the successful High Court challenge it will be tougher and geographically more comprehensive than previous policies. This is justified. The evidence is compelling about the harm to people's health and premature deaths from NOx emissions.

There is an optimistic and a pessimistic scenario for the future health and prosperity of our cities resulting from the introduction of Clean Air Zones (CAZs). The outcome depends on the framework set by Government and how CAZs are implemented by local authorities.

In the optimistic scenario, our town and city centres become more pleasant places to shop, work and socialise, with clean air, safe streets, priority for pedestrians and cyclists, and fast, efficient and affordable bus services. Bus is recognised as an integral part of the solution. CAZs are part of a wider urban and national strategy to tackle both air quality and congestion.

In the pessimistic scenario air quality targets are not met and our towns and cities suffer from increasing levels of congestion. Buses are viewed as a problem and not part of the solution. The downward spiral caused by congestion which has already resulted in 10% fewer bus passengers every decade[1] accelerates. Those without a car, many on low income, are severely disadvantaged and marginalised.

The quickest and most cost-effective solution to our air quality epidemic is to put the bus at the centre of the strategy

If we are to ensure the success of CAZs in our cities the role of the bus must be maximized. Progress in clean diesel bus technology has dramatically exceeded diesel car technology. Real world testing of Euro VI diesel buses demonstrates a 95% reduction in NOx emissions compared with Euro V[2]. Currently a journey by a Euro 6 diesel car emits 10 times the per passenger NOx of a comparable journey by a Euro VI diesel bus.[3]

Measures to encourage modal switch from car to bus can be transformative. Bus priority measures can deliver 75% fewer emissions per bus passenger km than for car passengers[4]. And buses also reduce congestion. A fully loaded double decker bus can take up to 75 cars off the road.

Putting buses at the centre of air quality strategy would support UK manufacturing. At least 80% of urban buses sold in the UK are built in the UK[5]. Government financial support for bus retrofitting provides more than 15 times as much value as scrappage allowances for diesel cars to convert to Euro 6 or electric, and 11 times as much value from a bus scrappage scheme compared with diesel car scrappage.

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[1] The Impact of Congestion on Bus Passengers, Professor David Begg 2016
[2] The Journey of the Green Bus, Low CVP 2016
[3] Low Carbon Vehicle Partnership 2017 analysis using COPERT Factors at 25km/h average speed, using average passenger loading (DfT)
[4] Professor Peter White, University of Westminster 2015
[5] Low Carbon Vehicle Partnership, 2017

Modern Euro VI diesel buses and retrofits can deliver the seismic reduction in NOx required

Whilst the aspiration to move from diesel to electric/hydrogen is widely shared, it is not logistically possible to replace this number of bus vehicles by 2020. Even if it were possible it couldn't be done without reducing the number of buses in operation, resulting in a lot more cars on the road, with the rise in congestion creating severe adverse consequences for city economies and their environment.

Modern diesel buses including retrofit of existing vehicles to Euro VI standard will deliver the reduction in NOx and other harmful emissions that is required in the time frame available. Retrofits for buses are reliable and proven to deliver Euro VI emission performance.

If retrofitting diesel buses to Euro VI standards is not supported the impact on bus passengers will be severe

It would be extremely harmful to the bus sector in what would be a perfect storm of declining patronage as a result of online shopping and relatively low motoring costs, coupled with the relentless increase in congestion which is pushing up bus costs and on its own is reducing patronage by 10% every decade[6]. Smaller operators and any operator unable to raise the capital for replacement vehicles would be particularly penalised.

If retrofit is not supported, and if bus operators try to recover the cost of replacing vehicles through the fare box, fares would increase by 40% resulting in a 20% fall in patronage. Fare increases of this magnitude will not happen because the market will not bear it. The more likely scenario is a combination of fare increases and service cuts.

Buses must be an integral part of the solution

CAZs present the opportunity not only to improve the health and well-being of UK citizens but also to support UK manufacturing, grow our local economies and tackle social deprivation.

If decision makers put buses at the centre of strategies to tackle air quality and congestion we will achieve a virtuous circle of falling costs, higher frequencies, lower fares and higher patronage. This will lead to improvements in local transport which will result in more people in work, fewer people suffering from income deprivation, more people with adult skills and more people in higher education.

To ensure the success of CAZs in our cities decisions at national and local level must be based on evidence rather than political expediency. This means including private cars in CAZs and much tougher action on diesel cars; ensuring the cleanest and most efficient bus operation across the country; and encouraging more use of public transport and other measures to tackle congestion.

[6] The Impact of Congestion on Bus Passengers, Begg 2016

1. ROAD TRANSPORT IS A MAJOR CAUSE OF AIR POLLUTION

1.1 We are facing a public health emergency

Concern over air quality is no longer just the preserve of environmental groups and it is now widely recognized that we are facing a public health emergency. With air pollution causing between 40,000 and 50,000 early deaths a year[7], the issue has attracted the attention of mainstream media, the business community, policy makers and the general public.

The Royal College of Physicians has linked air pollution to cancer, asthma, strokes, heart disease, diabetes, obesity and dementia. It has also estimated the cost of these health impacts to be £20 billion every year, and that these impacts fall most heavily on the poorest. Children, the elderly and the vulnerable in society are most at risk. In young children, air pollution can cause asthma and stunt lung growth by up to 10%[8].

1.2 Road transport is a major cause of poor air quality in our major cities

More than 50% of NOx in greater London is emitted by road transport. 24% of this road transport NOx comes from diesel cars; 12% from petrol cars; 21% heavy goods vehicles; 12% vans and mini buses; 20% from TfL buses; 6% non-TfL buses and coaches; and 4% from taxis[9].

The Mayor of London has announced that the most-polluting vehicles will have to pay a daily charge to drive within central London from 8 April 2019. He will expand this charge, the Ultra Low Emission Zone (ULEZ), across Greater London for heavy diesel vehicles, including buses, coaches and lorries, in 2020, and up to the North and South Circular roads for cars and vans in 2021.

The focus of this report is the CAZs outside of London, as this is what Government will announce imminently.

In cities outside London the proportion of public transport is lower, so the proportion of emissions from diesel and petrol cars is greater. In Manchester 43% of emissions come from cars and 11% of emissions come from buses.[10]

1.3 Congestion dramatically increases pollution from vehicles

Traffic congestion drastically worsens air quality. In nose-to-tail traffic, tailpipe emissions are four times greater than they are in free flow traffic[11]. Congestion has been steadily increasing in all our major cities. Tackling air quality is not just about getting rid of older, more polluting vehicles, it is about reducing the number of vehicles in congested urban areas where the air quality problem is most acute.

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[7] The EFRA Air Quality Select Committee Inquiry, 2016
[8] Every breath we take: the lifelong impact of air pollution, Royal College of Physicians, 2016
[9] London Atmospheric Emissions Inventory (LAEI) 2013 Update
[10] Greater Manchester Low-Emission Strategy, 2016
[11] Environmental Factors in Intelligent Transport Systems, IEE Proceedings, M.C. Bell 2006

We must tackle congestion if we are to improve air quality in our major cities. Reducing private car use through modal switch to public transport, cycling and walking is essential.

1.4 Those who produce the least emissions suffer the most

Research by the University of Surrey shows that drivers commuting in diesel cars produce six times as much pollution as the average bus passenger, yet bus passengers suffer far more from pollution in our cities than those travelling in cars[12].

The research from the University of Surrey shows that bus passengers are disproportionately affected by particulates (PMs), ultrafine particles (PNCs) and black carbon (BCs) compared with motorists, yet motorists are responsible for more of these pollutants per passenger journey than bus passengers.

This is a clear violation of the core principle of environmental justice: those who contribute the most to air pollution in our cities are the least likely to suffer. The imperative to tackle poor air quality isn't just a health issue, it is also a moral issue.

1.5 The onus must be put on the polluters

Unfortunately, the direction of policy so far has failed to address fundamental equity and social justice issues. The focus on emissions per vehicle rather than emissions per passenger presents a distorted picture and provides insufficient foundation for effective policy interventions.

Government policy so far has stopped short of tackling one of the biggest root causes of air pollution: increasing use of private diesel cars. Crucially, Government has **not** required the first five Clean Air Zones (Birmingham, Leeds, Nottingham, Derby and Southampton) to cover private cars[13].

[12] Environment International Today, University of Surrey 2017
[13] Draft Clean Air Zone Framework, DEFRA & DfT, 2016

2. BUS IS AN INTEGRAL PART OF THE SOLUTION

2.1 Bus must be put at the centre of strategy to tackle air quality

The quickest and most cost-effective solution to our air quality epidemic is to put the bus at the centre of the strategy. Policy interventions must be based on reducing emissions per passenger. This means tougher action on diesel cars; ensuring the cleanest and most efficient bus operation across the country; and, measures to encourage modal switch from car to bus.

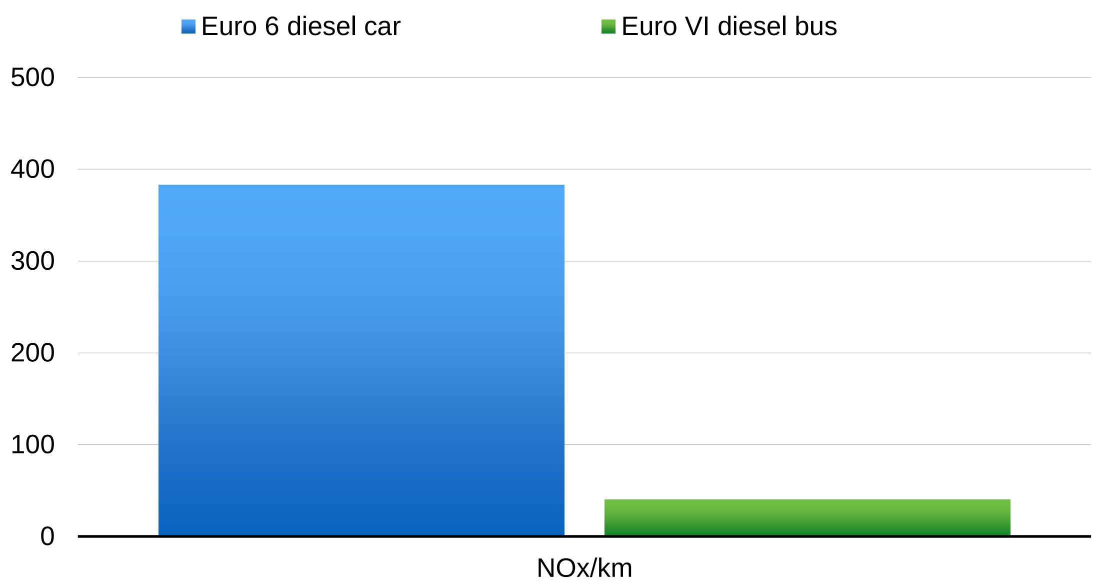
Government has been reluctant so far to take the necessary action on diesel cars, but eventually the onus will have to be put on the highest polluters. The Mayor of London, the EFRA Select Committee and many other leading voices have been calling for a national diesel scrappage scheme. Almost half of Britons would back restrictions on polluting cars, with only 18% opposed[14].

2.2 Progress in clean bus technology has exceeded car technology

The UK's bus sector has made very significant progress in introducing low emission, efficient technologies over the last decade. This progress has been detailed in a series of reports for Greener Journeys by the Low CVP*.

Currently a journey by diesel car, even a Euro 6 one, emits 10 times the per passenger NOx (383mg NOx/km) of a comparable journey by Euro VI bus (40mg NOx/km)[15].   The NOx emissions from a Euro VI bus passenger are even lower than a Euro 4 petrol car passenger (43mg NOx/km).

Euro 6 diesel car emits 10x more NOx pass/km as a Euro VI diesel bus



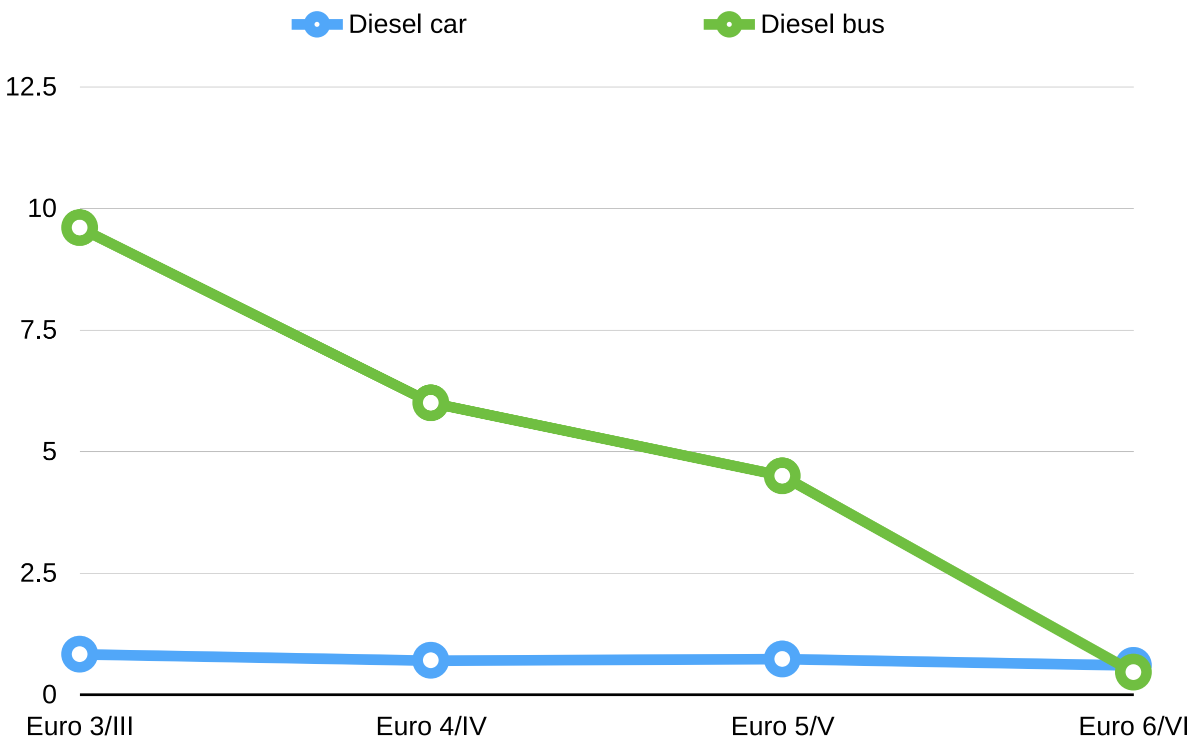
Source Low CVP Analysis based on COPERT Emissions Factors

[14] Friends of the Earth, 2017
[15] Low Carbon Vehicle Partnership 2017 analysis using COPERT Factors at 25km/h average speed, using average passenger loading (DfT)

Progress in clean diesel bus technology has dramatically exceeded progress in car technology. Since 2004, NOx emissions from diesel buses have been reduced by a factor of 20, but emissions for diesel cars have reduced by less than a third.

In 2016 emissions from a Euro VI diesel bus are <u>less</u> than from a Euro 6 diesel car, but a bus has 15 times the carrying capacity of a car.

NOx emissions at 25 kph for urban driving <u>NOTE</u> This is per vehicle <u>before</u> allowing for pass/ km



Source Low CVP Analysis based on COPERT Emissions Factors

Modern diesel buses are a major success story. Real world testing of the latest Euro VI diesel engines demonstrates a 95% reduction in NOx emissions compared with their older Euro V counterparts[16].   Moreover, the rigorous testing regime for bus manufacturing means that an equivalent of the Volkswagen emissions testing scandal would be inconceivable in the bus sector.

The public has lost faith in car manufacturers' claims. Tests of diesel cars last year found that almost all Britain's most popular diesel cars exceeded limits for safe levels of pollution during on-road driving, with toxic NOx emissions up to 14 times higher than claimed[17]. The Mayor of London will launch independent monitoring of vehicle emissions later this year.

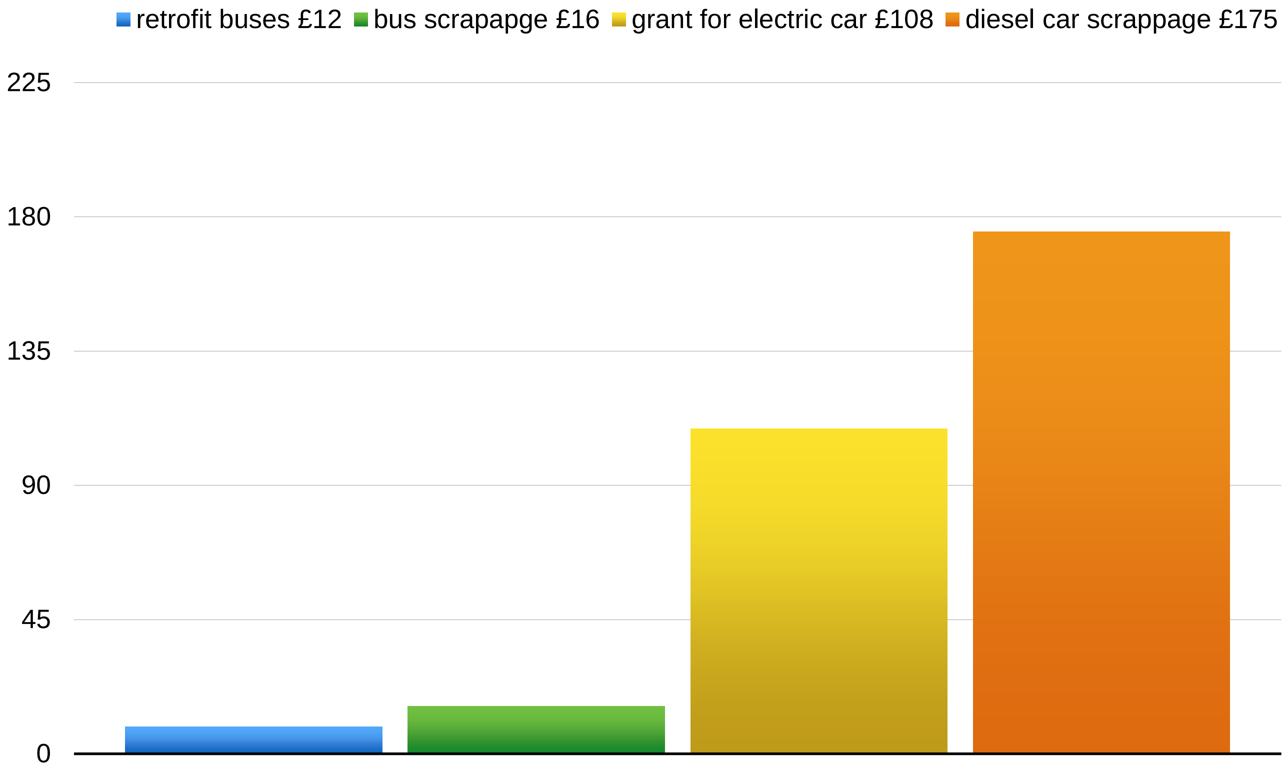
[16] The Journey of the Green Bus, Low CVP 2016
[17] Department for Transport, 2016

2.3 Investing in clean buses delivers the best value for money

Retrofits for buses are proven to deliver Euro VI emission performance and are reliable with direct monitoring already in place. Few retrofits exist for cars, they are unproven in the real world and very difficult to monitor in service. And if a scrappage scheme is justified for diesel cars the case is even more compelling for diesel buses.

Government financial support for bus retrofitting provides more than 15 times as much value as scrappage allowances for diesel cars to convert to Euro 6 or electric, and 11 times as much value from a bus scrappage scheme compared with diesel car scrappage. The table below shows how much it would cost the Treasury to save 1kg of NOx per annum from different policies. The bus options of retrofit and scrappage allowance offer much better value for money than a diesel car scrappage scheme or grants for electric cars.

Cost (£) to Treasury for saving 1kg of NOx



Assumptions: Retrofit costs £17,000 and lasts 5 years the cost is £12 kg of NOx saved.

Scrapping a Euro III bus and replacing with Euro VI saves 600kg NOx per year. If the Euro III bus is 13 years old and has two year life expectancy its book value would be around £20,000. I'm assuming it was purchased for around £150,000 in 2004 which means it depreciates at £10,000 p.a. over its 15 year life span. Assume the bus scrappage allowance is equal to book value cost per kg of NOx saved = £10,000/600 = £16.

Grant for electrics car is £4,500 and has a 10 year life at a cost of £108/kg saved.

If a Euro 3 diesel car is scrapped at £2000 and replaced with a new Euro 6 model and lasts 10 years the cost is £175/kg.

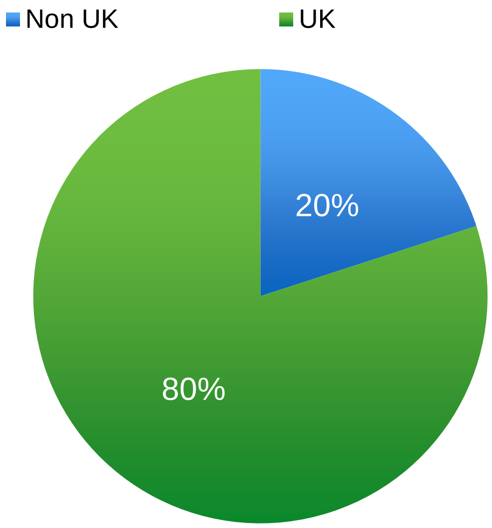
So the cost to the Treasury in terms of NOx saved is 15 times more expensive for diesel car scrappage than retrofitting buses, and 11 times more expensive than a bus scrappage scheme. The bus options offer much better value for money. Source: Low Carbon Vehicle Partnership 2017

2.4 Investing in bus supports UK manufacturing

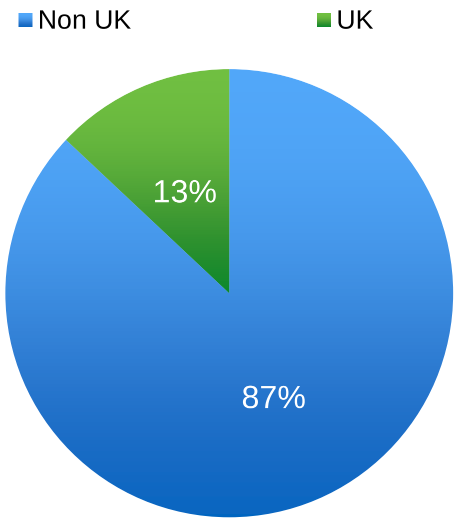
Bus manufacturing is adopting new clean and ultra-low emissions technology much quicker than car manufacturing. Ultra-Low Emissions Vehicles (ULEVs) account for twice the proportion of the bus fleet as they do for the car fleet[18].

Putting buses at the centre of our air quality strategy would also support UK manufacturing. At least 80% of urban buses sold in the UK are built in the UK, but only 13% of the 2.6 million cars sold in the UK are built in the UK[19].

80% of buses sold in the UK are built in the UK



13% of car sold in the UK are built in the UK



[18] Low Carbon Vehicle Partnership, 2017
[19] Society of Motor Manufacturers & Traders, 2016

2.5 Bus priority measures reduce emissions and congestion

Measures to encourage modal switch from car to bus can be transformative. Bus priority measures can deliver 75% fewer emissions per bus passenger km than for car passengers[20].

Bus priority is not only a successful measure to improve air quality but it also effectively tackles congestion, with one bus moving 10 times as many people as a car (based on average vehicle occupancy for both). A fully loaded double decker bus could take up to 75 cars off the road.

Bus priority measures also enable more effective management of road space and speed up journeys offering high value for the taxpayer. Effective investment in bus infrastructure can generate up to £7 of net economic benefit for every £1 invested[21].

*****For Further Reading**:**

The Journey of the Green Bus: A revolution in the introduction of greener, cleaner buses in the UK is helping deliver on climate change and air quality targets

Low CVP, February 2016

A Green Bus for Every Journey: Case studies showing the range of low emission bus technologies in use throughout the UK

Low CVP, November 2016

Any Journeys is Greener by Bus: Passenger experiences of modern bus services

Low CVP, February 2017

[20] Professor Peter White, University of Westminster 2015
[21] An Economic Evaluation of Local Bus Infrastructure Schemes, KPMG 2015

3. CLEAN AIR ZONES AND BUS ECONOMICS

3.1 Purpose of bus economic analysis

The purpose of the bus economic analysis is to estimate the impact on bus passengers resulting from two different scenarios: replacing the non-compliant fleet with new Euro VI vehicles; and, retrofitting vehicles to the new Euro VI standard.

The cost impacts for one bus are estimated; then the cost impacts for bus operations in a whole metropolitan region are estimated (the impact on the balance sheet is modelled over a 5-year period). A forecast is then produced on the increase in fares and/or decline in service frequencies that would be required, and the resulting decline in patronage, assuming the extra costs are recovered through the fare box.

<u>For detailed assumptions and calculations please refer to the Appendices:</u>

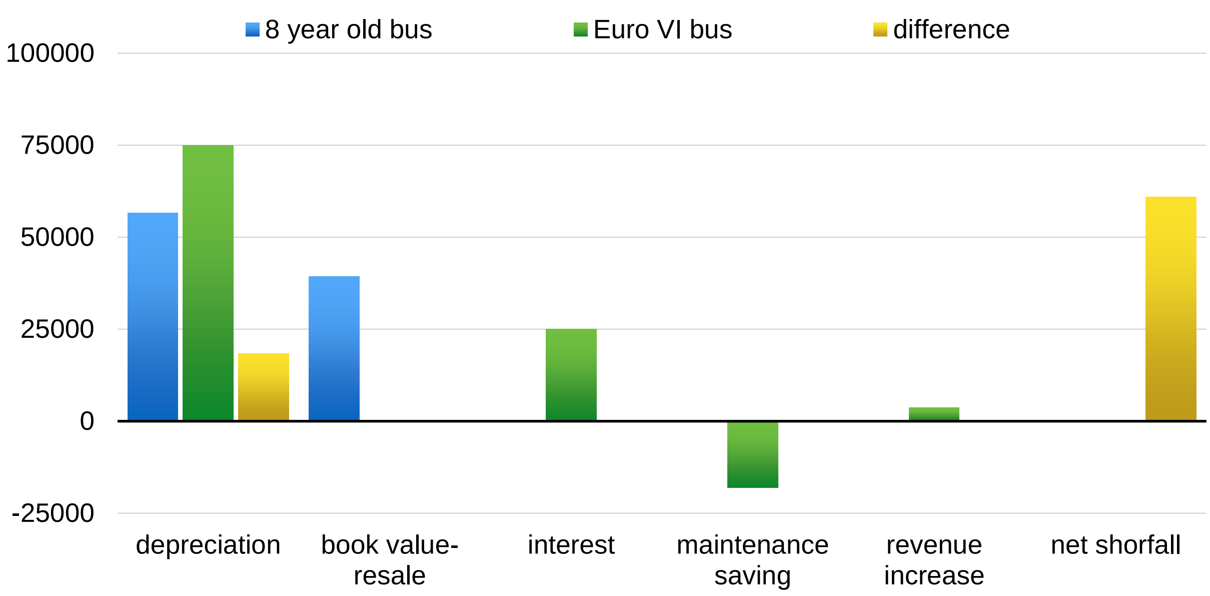
- **i) CAZs and bus economics: technical summary**
- **ii) Arc price elasticity of demand**

3.2 Replacing non-compliant buses

Whilst the aspiration to move from diesel to electric/hydrogen is widely shared, it is not logistically possible to replace this number of vehicles within such a short time frame. Even if it were logistically possible it couldn't be done without severe adverse consequences for city economies and their environment.

In the immediate term, Euro VI buses will deliver the seismic reduction in NOx and other harmful emissions that is required. This can be achieved by investing in new vehicles or retrofitting existing vehicles to Euro VI standard. The chart below shows the cost implications of replacing a vehicle.

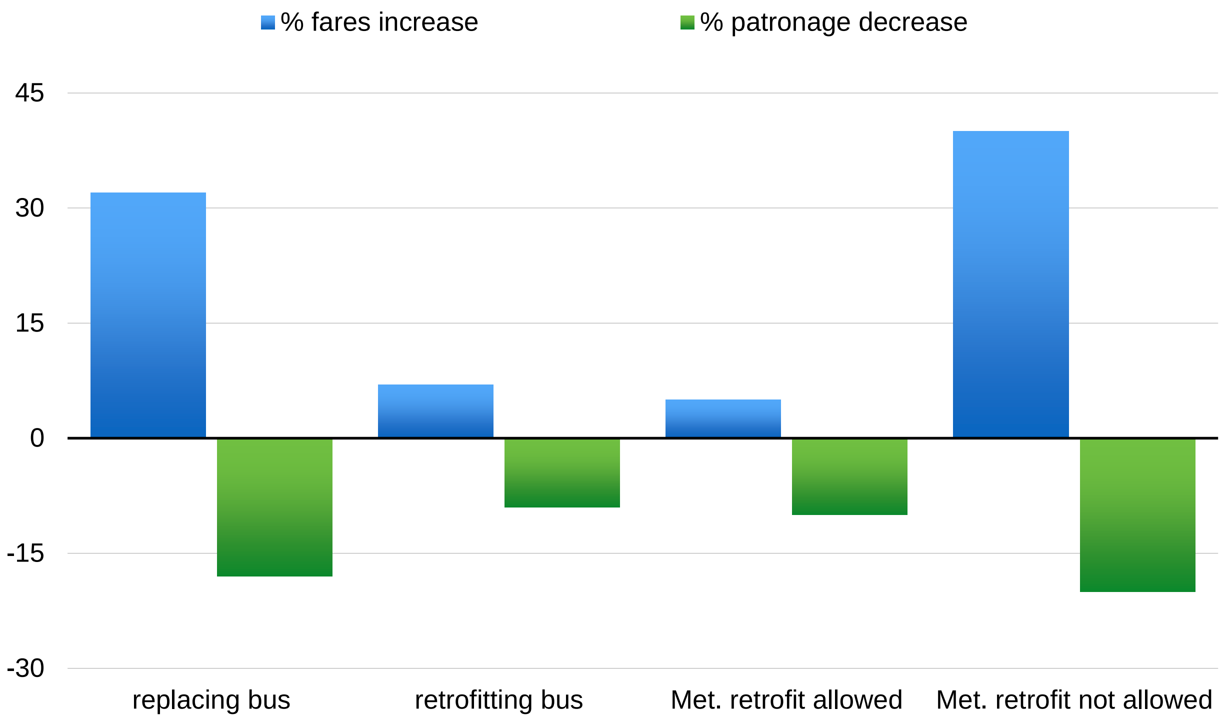
Five-year financial impact (£) from replacing 8-year old bus with new Euro VI



3.3 Why retrofitting is essential

If retrofitting diesel buses so that they meet the very clean Euro VI standards is not permitted, then the impact on the bus sector and bus passengers will be dramatic.

Impact on fares and patronage from the One Bus Model and Metropolitan Region Case Study



Even fare increases of much less magnitude than the high end 40% shown in the table above are not a realistic commercial proposition. A more likely response from bus operators would be to cut service levels and reduce the number of buses they operate.

Our metropolitan case study is based on real data. It is based on a business as usual scenario and takes cognizance of the number of new vehicles and retrofits that are planned between now and 2020.

In our metropolitan case study area 50% of the bus fleet, in the wider city region, travel into the city centre where the CAZ is located. Of these buses 50% are non-compliant. Rather than replace this number of buses, and incur unsustainable cost increases in such a short space of time, operators would be more inclined to reduce service levels.

If they don't replace any of the non-complaint vehicles and cut service levels by 50% this would result in a 25% decline in patronage (frequency elasticity of demand = -0.5). They won't cut service levels by 50% to avoid having to purchase this volume of new vehicles required, more likely a combination of fares increase, service level cuts and the purchase of new vehicles.

While fare increases and service level cuts normally lower the barrier to entry for new operators coming into the market, and for this reason are often rejected by the incumbent operators as a viable commercial proposition, a CAZ significantly increases the barrier to entry by imposing a high capital cost for entry to the market. It will penalise the smaller operators in particular but also any operator who will find it difficult to raise the capital.

It could potentially destroy the bus sector in what will be a perfect storm of declining patronage as a result of online shopping and relatively low motoring costs, coupled with relentless increase in congestion which is pushing up bus costs and on its own is reducing patronage by 10% every decade.[22]

A CAZ which does not permit retrofitting will damage the bus sector. A CAZ which bans diesel would severely damage the sector.

[22] The Impact of Congestion on Bus Passengers, Begg 2016

4. FUTURE SCENARIOS

There is an optimistic and a pessimistic scenario for the future health and prosperity of our cities resulting from the introduction of Clean Air Zones (CAZs). The outcome depends on the framework set by Government and how CAZs are implemented by local authorities.

4.1 Optimistic Scenario

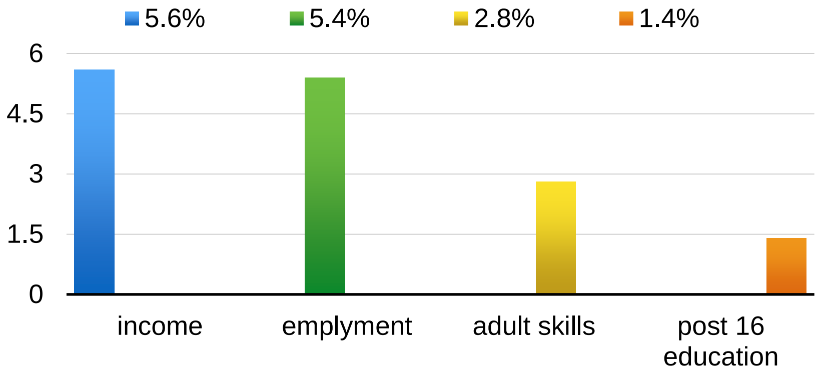
Our town and city centres become more pleasant places to shop, work and socialise, with clean air, safe streets, priority for pedestrians and cyclists, and fast, efficient and affordable bus services.

Buses are recognised as an integral part of the solution and not put at a competitive disadvantage compared with cars, especially diesel cars which emit 10 times as much NOx per passenger km using the latest technology. This means if buses are charged to enter the CAZ for non-compliance with emissions standards, then so are diesel cars. If there is a scrappage scheme for diesel cars there is also a scrappage scheme for diesel buses and grants for retrofit.

CAZs are part of a wider urban and national strategy to tackle both air quality and congestion. Bus priority is encouraged as a successful measure to tackle both.

There is a modal shift away from the car to more sustainable forms of transport: walking, cycling, bus and rail (where available). Cars use roads more inefficiently than other modes of transport and limit the number of people who can move in a city with a fixed amount of movement space available. The more vibrant, healthy, prosperous cities are those which have a higher percentage of people travelling by sustainable modes.

We achieve a virtuous circle of falling costs, higher bus frequencies, lower fares and higher patronage. If we can improve bus accessibility 20% from this scenario this would result in a **7.2% reduction in social deprivation**, a 5.6% increase in people with increased income, a 5.4% increase in employment, a 2.4% increase in adult skills and a 1.4% increase in students attending post 16 education[23].



[23] Professor David Begg analysis of University of Leeds, ITS 2016 Report

4.2 Pessimistic Scenario

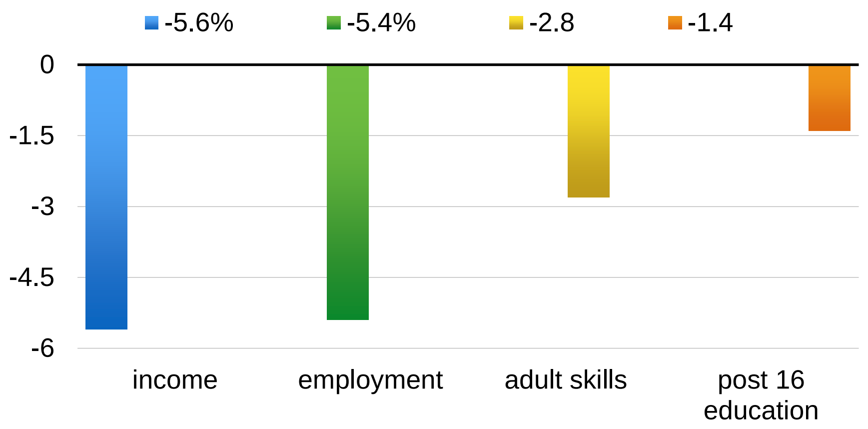
Air quality targets are not met and our towns and cities suffer from increasing levels of congestion. The downward spiral caused by congestion which has already resulted in 10% fewer bus passengers every decade[24] accelerates.

Buses are viewed as a problem and not part of the solution. Buses which don't meet the CAZ standards are charged and diesel cars which don't are not. There is no scrappage scheme for buses and a limited grant for retrofitting. Some local authorities don't allow retrofitting which significantly increases the cost of bus operations, leading to high fare increases and service reductions to pay for the new vehicle fleet.

This leads to a vicious downward spiral of rising costs, higher fares, service cuts and lower patronage. This in turn results in more cars on the road, more congestion and more pollution.

This creates a perfect storm for the bus sector on top of the loss of passengers to online shopping, and to the car with relatively low motoring costs. Those without a car, many on low income, are severely disadvantaged and marginalised.

If we assume bus accessibility declines by 20%[25] this would result in a **7.2% increase in social deprivation**, a 5.8% decrease in income, a 5.4% decrease in employment, a 2.8% decrease in adult skills, and a 1.4% decrease in students attending post 16 education[26].



This pessimistic scenario will only unfold if policy makers at national and local levels base decisions on political expediency rather than evidence; if they fail to address head on the issue of diesel cars; and if they fail to appreciate the importance of the bus to society and maximise its role in reducing emissions.

[24] The Impact of Congestion on Bus Passengers, Professor David Begg 2016
[25] This is a conservative estimate based on the modelling in the pessimistic scenario
[26] Professor David Begg analysis of University of Leeds, ITS Report 2016

5. CONCLUSION

CAZs will not be successful if their scope does not also apply to diesel cars.

Buses must be an integral part of the solution in CAZs, if they are to be successful in dramatically cutting harmful emissions, reducing congestion and stimulating economic growth.

If buses are seen as a problem, and not part of the solution, CAZs will be less successful in tackling harmful emissions and congestion will rise to even more intolerable levels in our urban conurbations with an adverse impact on the economy, the environment and society as a whole.

Buses are becoming incredibly green. Since 2004, NOx emissions from diesel buses have been reduced by a factor of 20, but emissions for diesel cars have only reduced by less than a third. The Treasury would get 15 times more value from investing in bus retrofitting than they would from a diesel car scrappage scheme (measure in kg of NOx saved).

If retrofitting is not permitted we face the prospect of fares rising by 40% in our urban conurbations and bus patronage falling by 20%.

To ensure the success of CAZs in our cities decisions at national and local levels must be based on evidence rather than political expediency, and we must also tackle congestion.

RECOMMENDATIONS

1. **Diesel cars must comply with CAZ standards. The focus should not just be on buses, taxis, lorries and vans**

2. **Government should provide maximum support to green the bus fleet, including support for retrofit to Euro VI standard**

3. **Demand management measures to tackle the volume of traffic in our urban conurbations, and measures to encourage modal switch from car to sustainable transport, must be introduced**

APPENDICES

i) CAZs and bus economics: technical summary
ii) Arc price elasticity of demand

In writing this report I have been helped by many people. There are too many to mention, but I would like to single out three people.

Dr Gerard Whelan for guiding me through complex transport economics. It's a long time since I have used " Arc" Price elasticity of Demand. I needed to use some complex equations to calculate the fare changes required to generate different amounts of revenue. The detail is contained in appendix i

Martin Dean for giving me an invaluable insight into bus finances. We had long discussions on how the balance sheet would be impacted by the resale value of a bus falling well below its book value. His influence can be seen in Appendix I.

And finally, Chris Cheek, from "Passenger Transport Monitor", who kindly took the time to capture my numbers on a spreadsheet and offer some unique insights of his own.

Any errors are mine and mine alone.

APPENDIX i – CAZs and bus economics: technical summary

There are still many uncertainties surrounding the detail of CAZs, so it is difficult to be precise about their impact on bus finances. The geographical size of the zones are as yet unknown, whether a bus depot is located within a zone, what the charges will be for non-compliant vehicles and whether retrofitting vehicles will be supported.

In order to make some estimates of likely financial impacts the following assumptions have been made after a long iterative process with operators, local authorities, TfL and industry experts:

- Revenue per vehicle £150,000 p.a. (urban bus)
- Pre-tax margin 8.5% equates to pre-tax profit of £12,750, which means operating costs are £137.250 p.a.
- The capital cost of a Euro VI double decker is £225,000. Operators have purchasing arrangements with manufacturers which are often kept confidential for commercial reasons. The consensus was that this was an accurate figure.
- The cost of retrofitting is around £13,000. This is the figure which has been assumed by the West Midlands Bus Alliance and is based on the cost that their main operator, National Express, has agreed with the supply chain.
- The resale value of a mid-life bus (eight years old based on a 15-year life cycle) falls to £40,000 compared with a book value of £85,000. The latter is based on a purchase price when new of £170,000.
- Straight line depreciation is used over the lifetime of the vehicle.
- The impact of the differential between resale value and book value will hit the profit and loss account (P&L). Whether or not the loss is classified by the companies' auditors as "exceptional", the loss will hit the P&L account through accelerated depreciation. If the operator sells the bus, they recognise the loss in the P&L.
- The extra revenue generation from a new vehicle is 0.5% p.a. Some operators thought it could be as high as 2% p.a. however the consensus was 0.5%. It depends on how old the bus that is being replaced is.
- The warranty on the purchase of a new bus is 3 years. This is negotiable with the manufacturer, but again this was the consensus figure. This eliminates maintenance costs of around £6000 p.a. for these 3 years.
- The assumption is that on current investment trends 20% of the fleet will be compliant by 2019: Euro VI, electric or hydrogen. This is based on detailed figures from the West Midlands Bus Alliance and the consensus from the responses received from operators.
- In the retrofitting estimates the assumption is that Euro III, IV and V diesel buses can all be retrofitted but that Euro II or earlier cannot.
- No changes have been made to running costs from a new vehicle or from retrofitting. The changes to mpg were marginal in both cases so they could be discounted. The UK bus manufacturers: Alexander Dennis, Wrights and Optare have all successfully reduced the weight of their new vehicles which does reduce mpg but it was not felt to be significant by the operators consulted with. There

was a slight deterioration in mpg after retrofitting but again it was too marginal to include.

- The financial impact over a 5-year period has been examined. This enables a more accurate assessment to be made of a combination of one off costs which hit the balance sheet: impairment of value for example, and annual impacts from depreciation changes, interest cost and revenue generation.
- The assumption is that when operators are able to cascade vehicles to other parts of the country that the transfer is done at market/replacement value rather than book value. This practice is not uniform but again it was the consensus.
- In estimating the impact on patronage from higher fares to recover the cost increase, the DfT fares elasticity of -0.7 has been used.
- In assessing the impact on patronage of service reductions a frequency elasticity of -0.5 has been used. (Begg; Impact of Congestion on Bus passengers, 2016)

Replacing 8-year old bus with Euro VI

Depreciation

8-year old bus: £170,000/15 = £11,333 p.a.

Euro VI bus: £225,000/15= £ 15,000 p.a.

One year deprecation increase = £15000 - £11,333 = £3667 p.a.

So, over the next 5 years (the bus has 7 year life expectancy left however the model is the analysis is on a 5 year balance sheet impact) there is a £18,335 hit to the P&L account from the extra depreciation by replacing the vehicle.

Resale value

The resale or market value of our 8-year old bus will be substantially less than its book value in a buyers' market, with a surplus of second hand buses. The more CAZs that are established the more profound this differential will be. This will have a big hit on the bus sector and it's not unreasonable to assume that the resale value of our bus will fall to £40,000. In many cases where a buyer can't be found the vehicle would be scrapped.

8-year old bus Book value: £ 170,000/15 x 7		£79,331
Market value		£40,000
Difference	=	£39,331

As soon as the bus is sold this could have an immediate P&L hit of almost £40,000. Recovering this through the fare box immediately would be impracticable given that it represents one third of annual operating costs.

Interest rate impact

If the operator buys a new bus there is a real cash impact. A new bus costs £225k, and it is partly offset with £40k of income by selling the old bus. Therefore, each new bus requires £185k of capital:

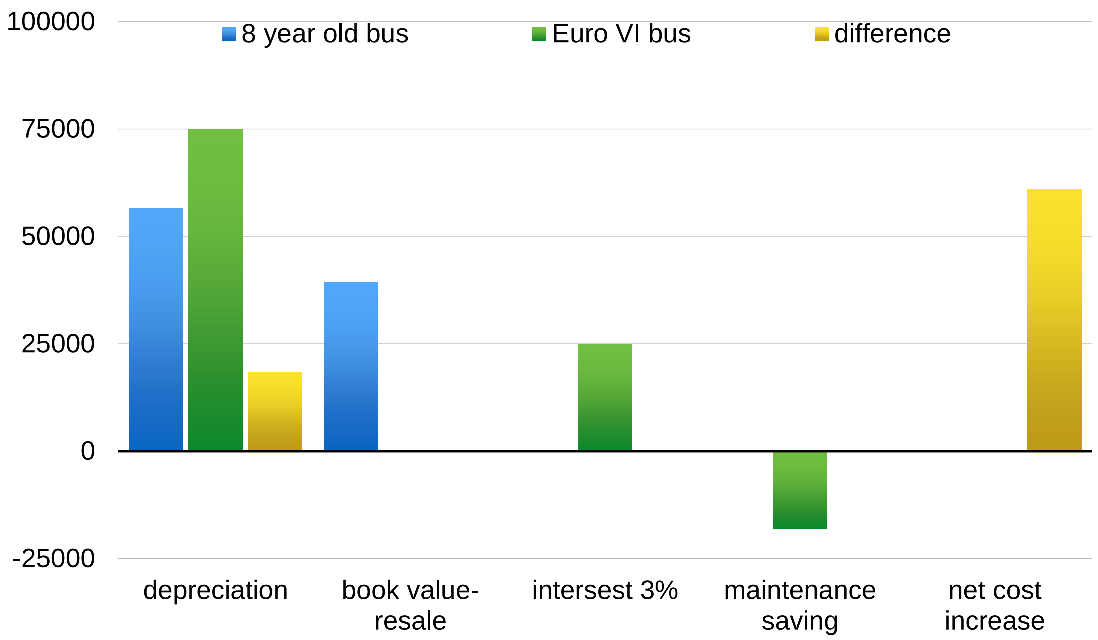
Assuming this is debt financed, the impact on the P&L is additional interest (even at current low rates, 3% interest equates to an additional £5k p.a. interest cost per bus).

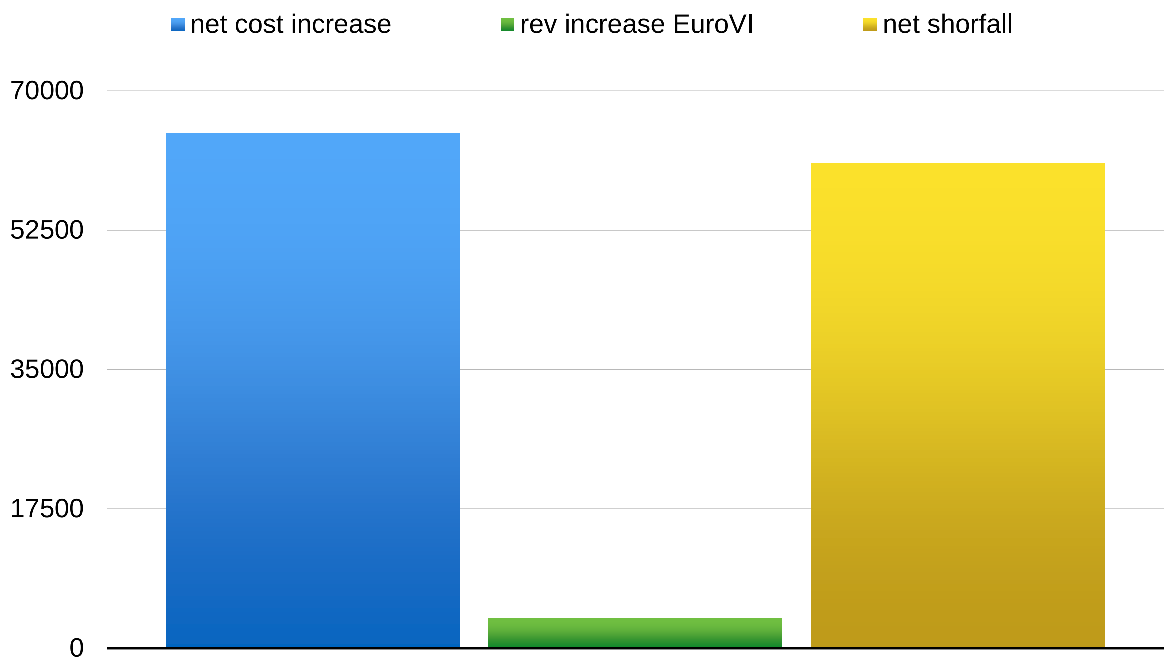
Cost increase

Depreciation: £3677 x 5		£18,385
Book value write off		£39,331
Interest (3%) 5000 x 5		£25,000
Total	=	£82,716
Less saving in maintenance. 3 x 6000	-	£18,000
Net cost increase	=	£64,716
Less revenue uplift. £150,000x0.005x5	-	£3,750
Net shortfall.	=	£60,966

New vehicle generates 0.5% extra revenue p.a. (depends what vehicle it is replacing). Obviously replacing a 10 year old bus with a new Euro VI will have a bigger passenger uplift than if it is a modern Euro V that is being replaced.

While the latter has an environmental uplift feedback from operators suggests that it is unlikely that this would result in more passengers in the way that air conditioning, WIFI and new upholstery would.





This £60,966 shortfall equates to £12,193 (no compounding) and represents 8.9% of annual operating costs (12,193/137,000 x 100) and 8.1% of annual revenue (12,193/150,000)

If a price elasticity of demand of 0.7 is applied this would mean that fares would have to rise by around 32% and patronage would fall by 18% to generate this amount of extra revenue.

This is an increase in fares which the market would not be able to bear.

The concern is that this is not sustainable as the sector is facing the perfect storm with CAZs on top of fewer passengers caused by congestion (Ref: "Impact of congestion on bus passengers", Begg 2016), growth in online shopping and low fuel prices making motoring less expensive.

Retrofitting an 8-year old bus to Euro VI standard

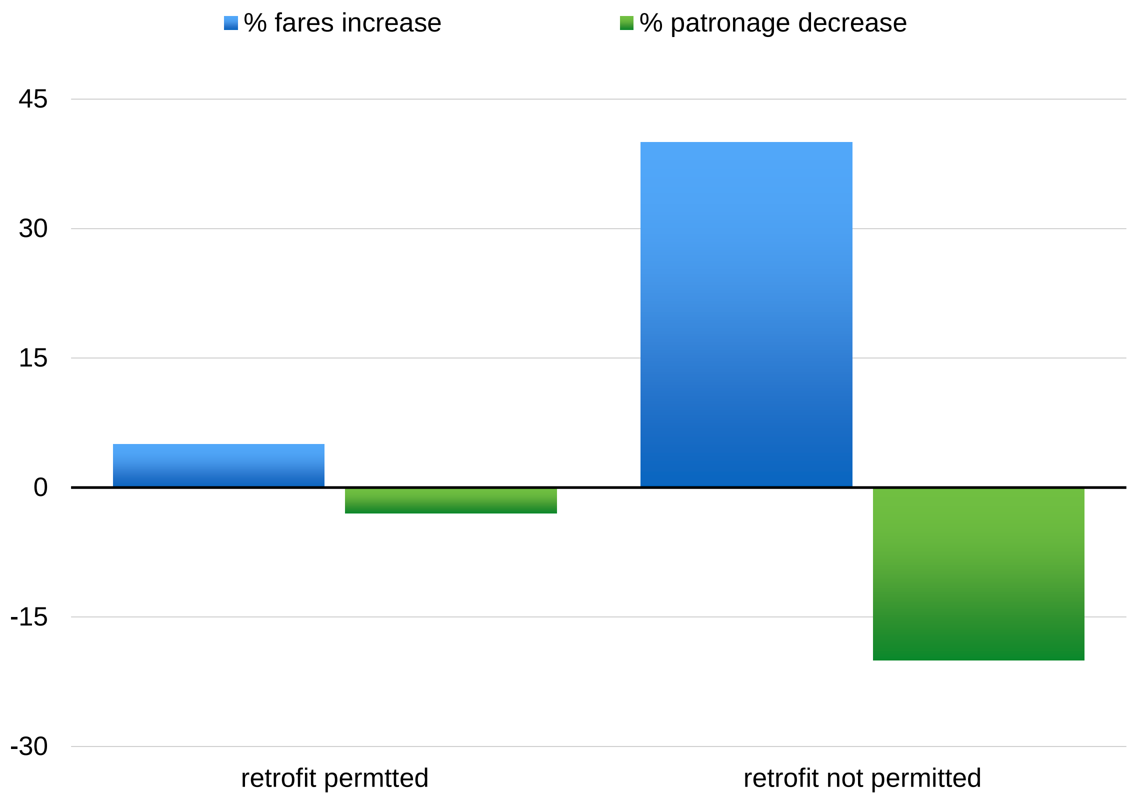
Cost of retrofitting	£13,000	
Extra depreciation 13000/7 x5	=	£9,285
Interest at 3%: 13,000 x 0.03 x 5	=	£1950
Cost increase	=	£11,235

If total operating costs are £685,000 over 5 years this represents a 1.6% in costs (11,235/685000 x 100) and a 1.5% increase in revenue (11,235/150,000 x 5 x 100).

If the operator decided to generate this additional revenue from a fares increase, fares would have to increase by 5% resulting in a 3% decline in patronage (Appendix iii – Arc price elasticity of demand).

It's manageable to run with a 10% fares increase over 5 years but it must be remembered that this is on top of annual inflationary increases which have been running at 2%.

Fares and patronage impact from replacement and retrofit. Assumes no grant



The danger is that even with the more modest cost impact from retrofitting it would occur at a time when the sector is facing a perfect storm with online shopping hitting patronage, motoring costs at historically low levels, and traffic congestion pushing up costs and resulting in a 10% loss of passengers every decade (Ref: Begg "Impact of congestion on bus passengers" 2016)

It is important that grant funding is made available from Government to assist with the cost of retrofitting. At present £120 million is available from the Clean Bus Technology fund. If all of this was allocated for retrofitting this would only pay for just over 9,000 buses.

The key challenge for central Government is setting the right guidelines for CAZs, and the challenge for local authorities in implementing them, is how to improve air quality without having unintended consequences for the city-region economy and on equity.

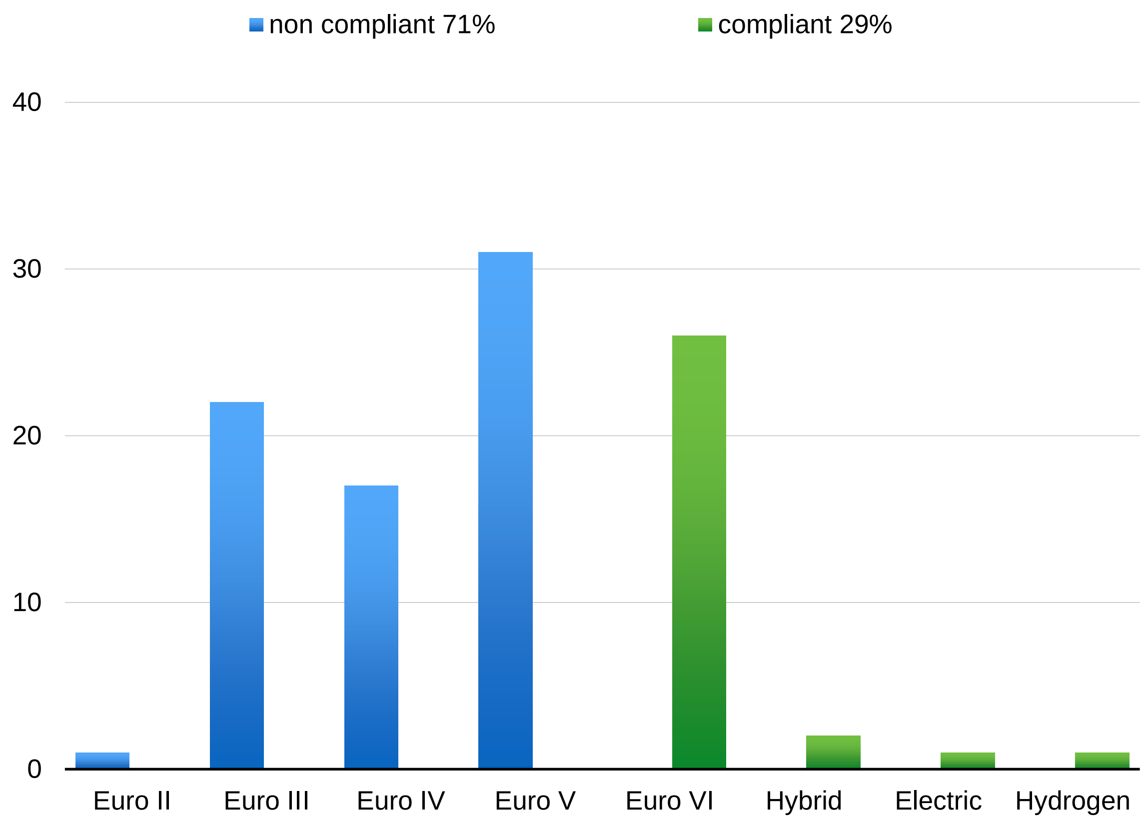
While the impact on costs and potentially fares from replacing vehicles to become compliant with CAZs is something to watch, perhaps the biggest challenge is logistical.

At the time of writing this report it is not clear how many cities will become CAZs. It is also not clear what geographical area will be covered by CAZs. If a bus depot is located in a CAZ then the whole fleet located at that depot would have to become compliant or pay a charge, which is still unspecified, for entering the zone. It would be surprising if it was restricted to the original five outlined in the initial DEFRA Plan: Birmingham, Derby, Leeds, Nottingham and Southampton. There has been speculation that between 20 and 25 cities could be designated CAZs. This represents a massive logistical challenge for the supply chain to supply the new fleet of compliant Euro VI buses and/or retrofitting thousands of new vehicles.

<u>How will this impact on a typical metropolitan area?</u>

Data from metropolitan areas in England outside London varies in terms of the percentage of the bus fleet that will be compliant by 2020 on a business as usual scenario. An optimistic scenario would give the following breakdown between compliant and non-compliant vehicles:

% Breakdown in fleet by vehicle type



The assumption is that 60% of the bus fleet in the wider city region travel into the CAZ.

It is also assumed in the retrofitting scenario that all vehicles Euro III or better can be retrofitted to Euro VI standard and made compliant. The model would estimate the following % increases in costs and revenue:

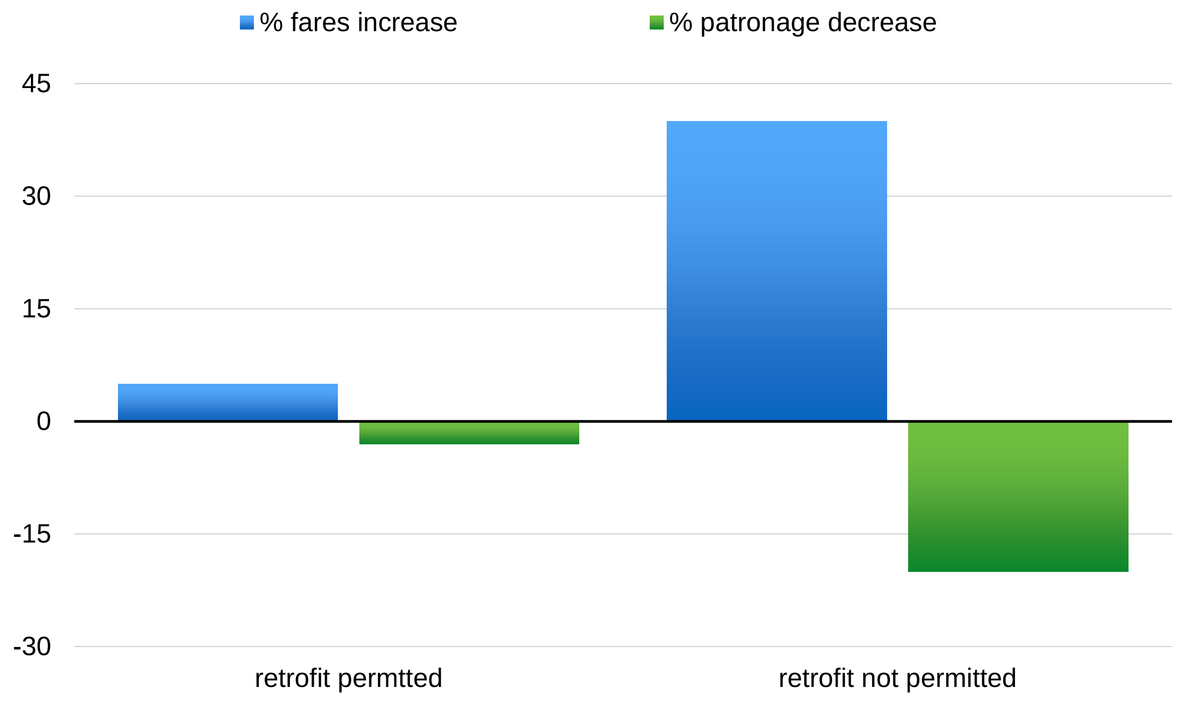
The extra cost incurred from retrofitting (assuming no further government funding) equates to a 1.6% increase in costs. This would require an increase in revenue of 1.5% to cover the extra cost. If operators attempted to generate this extra revenue form the fare box they would have to increase fares by 5% leading to a 3% fall in patronage (see Appendix ii: Arc price elasticity of demand).

If retrofitting id not supported and a vehicles replacement strategy is pursued this would result in a 12.8% increase in costs and a 11.7% increase in revenue required to cover this cost increase.

To generate this amount of revenue through the fare box would require a fare increase of 40% resulting in a fall in patronage of 20% (see Appendix ii).

If retrofitting diesel buses - so that they meet the very clean Euro VI standards- is not permitted to ensure that they are compliant with CAZ's, then the impact on the bus sector and their passengers will be severe, leading to a perfect storm of declining patronage as a result of online shopping and relatively low motoring costs, coupled with relentless increase in congestion which is pushing up bus costs and on its own is reducing patronage by 10% every decade (The impact of Congestion on Bus Passengers, Begg 2016).

Fares and patronage impact from replacement and retrofit for Met area. Assumes no grant



APPENDIX iii – Arc price elasticity of demand

We need to think about this in terms of the change in revenue to cover the increase in costs. This change in revenue needs to include both the change in demand and the change in price.

As we put up fares to increase revenue, at the same time the price elasticity suppresses demand. Solving this is not straightforward as we need to simultaneously solve price and demand to generate a given increase in revenue.

In the illustration below we start with price=1 and demand=1, yielding revenue=1. On the next row in the table we increase price by 1% to 1.01, demand falls to 0.9931 ((1.01/1.00)^-0.7) and revenue increases to 1.003. On each subsequent row, we keep increasing prices by 1% supressing demand via the elasticity until we hit our increase in revenue of 8.7%.

Revenue	Price	Demand
1.0000	1.0000	1.0000
1.0030	1.0100	0.9931
1.0060	1.0201	0.9862
1.0090	1.0303	0.9793
1.0120	1.0406	0.9725
1.0150	1.0510	0.9658
1.0181	1.0615	0.9591
1.0211	1.0721	0.9524
1.0242	1.0829	0.9458
1.0272	1.0937	0.9392
1.0303	1.1046	0.9327
1.0334	1.1157	0.9262
1.0365	1.1268	0.9198
1.0396	1.1381	0.9134
1.0427	1.1495	0.9071
1.0458	1.1610	0.9008
1.0489	1.1726	0.8945
1.0521	1.1843	0.8883
1.0552	1.1961	0.8822
1.0584	1.2081	0.8760
1.0615	1.2202	0.8700
1.0647	1.2324	0.8639
1.0679	1.2447	0.8579
1.0711	1.2572	0.8520
1.0743	1.2697	0.8461
1.0775	1.2824	0.8402
1.0807	1.2953	0.8344
1.0839	1.3082	0.8286
1.0872	1.3213	0.8228
1.0904	1.3345	0.8171
1.0937	1.3478	0.8114

1.0970	1.3613	0.8058
1.1002	1.3749	0.8002
1.1035	1.3887	0.7947
1.1068	1.4026	0.7891

As we are dealing with non-marginal changes in fares we can't simply define a point elasticity (% change in demand / % change in fare), we need to define an arc elasticity (https://en.wikipedia.org/wiki/Arc_elasticity). This gives the arc elasticity at -0.7.

As a sense check it is useful to think about the relationship between the fare elasticity and revenue. Where markets are inelastic, an increase in price leads to an increase in revenue. Where markets are elastic, an increase in price leads to a reduction in revenue. Where markets are unit elastic (-1.0), an increase in price is revenue neutral – the increase in revenue from customers paying more is exactly offset by the loss of revenue from those priced off.

With a price elasticity of -0.7, as in the example, it would require substantial fare increases to raise the revenue required, given the significant fall in patronage.