Air Quality Impacts of Low Emission Zones

Introduction

Transport is the cornerstone of modern society, yet contributes to poor air quality in many urban centres around the world. There are increasing concerns about the impact of traffic exhaust emissions on the health of citizens exposed to high concentrations of pollutants. European type approval legislation is helping to clean up vehicles and fuel, but there is a significant time-lag whilst the vehicle stock is being replaced. In the interim, mechanisms could be introduced to accelerate the replacement of vehicles or to reduce emissions from the existing stock.

A Low Emission Zone (LEZ) is a defined area in which controls are put in place to restrict access to vehicles that do not comply with set emission standards, so as to reduce exhaust emissions from road transport and thereby improve local air quality.

In Sweden, a similar concept has been in operation since 1996, whereby environmental standards are specified for heavy vehicles entering the central area of the main cities. Similar schemes are in place in Japan. In the UK, work has been carried on behalf of Transport for London and the ALG to investigate the impacts and practicalities of implementing a LEZ, and several other Local Authorities are carrying out feasibility studies to consider the implementation of a LEZ.

Environmental zones in Sweden

Environmental Zones have been in operation in the Swedish cities of Stockholm, Gothenburg and Malmo since July 1996 and Lund since January 1999. The zones have been created in central areas of the city that are particularly sensitive to exhaust emissions and noise from road traffic. The approach is easy to understand because it is based on vehicle age: all vehicles over 3.5 tonnes that are older than 8 years old are banned, including buses. Exceptions are made for vehicles between eight and twelve years old if they are retrofitted with new engines and/or particulate traps.

Enforcement is done by the police, via spot checks as well as an informal arrangement between carriers. Identification is through the vehicle number plate, with older vehicles being required to carry permits to prove they have been retrofitted with emission abatement technology. The environmental demands have also hastened the development of more environmentally friendly vehicles.

Particulate matter is the primary pollutant targeted using these zones. In Stockholm it is estimated that emissions of particulate matter have reduced by 30% and, to a lesser extent emissions of hydrocarbons and oxides of nitrogen have also fallen. Evidence also points to a drop in noise levels. Calculations made a year after the zones were introduced into Stockholm, Gothenburg and Malmo predicted the reductions in a range of key pollutants, as shown in Table 1. These reductions are a result of older vehicles being replaced earlier than they would otherwise have been and more retrofitting of vehicles.

Table 1: Percentage reduction in emissions from heavy vehicles (1 year after introduction)

Pollutant	Percentage reduction
Particulate matter	15 - 20%
HC emissions	5 - 9%
NO_x emissions	1 - 8%

The zone has reduced general accessibility to the city centres for many transport companies wanting to use their previous fleet vehicles. This has resulted in an increase in costs (estimated at 1-2%), due to vehicles needing to be replaced or retrofitted.

Gothenburg are currently looking to further develop the Environmental Zone, to increase the geographical extent of the zone, and to change the entry criteria to more stringent standards. Under the new standards, all vehicles will be allowed in the zone if they are less than 6 years old. Extensions are made to this age limit, based on euro-class. For example, Euro IV vehicles will be allowed for 9 years and Euro V for 10 years. The more stringent entry criteria will also be adopted for the Environmental Zones in Stockholm, Malmo and Lund.

The Automobile NO_x and PM Reduction Law in Japan

Many urban areas in Japan experience high concentrations of NO_2 and PM_{10}, and efforts to reduce emissions have been undermined by an increase in road transport use.

In response to this, 1992 Japan enacted the NO_x Reduction Law, which set permissible emission limits applicable to specified areas in Tokyo, Chiba, Saitama, Kanagawa, Osaka, and Hyogo. This law was revised and extended in 2001 to form the Automobile NO_x and PM Reduction Law, with the following conditions:

- An age limit for specified vehicles, as shown in Table 2;
- Challenging emissions standards for diesel vehicles after these age limits; and
- Businesses with more than 30 vehicles must provide an improvement plan, to include, for example, joint shipments, switching to lower polluting vehicles, appropriate driving practices, vehicle maintenance, etc.)

Table 2: Grace period for application of the special emission standards to vehicles in us

Vehicle category	Grace period (years from initial registration date *1)
Ordinary-sized trucks	9
Small-sized trucks	unknown
Large-sized buses	12
Microbuses	10
Diesel passenger cars	9
Special-purpose motor vehicles *2	10

Notes: *1. The initial registration date is the date on the vehicle registration file under article 4 of the Road Vehicles Act.

*2. For special-purpose motor vehicles with special design, equipment, or usage as designated by the Minister of the Environment, the grace period shall be 15 or 20 years.

A study carried out in 2000 suggested that these restrictions, together with other measures such as traffic demand management, will mean that the environmental standards for NO_x and PM in Japan will be met by the year 2010.

Emission impacts of UK LEZ scenarios

In a 1999 study of strategies for meeting National Air Quality Standards in London it was concluded that emission control strategies could be more effective than demand management strategies, such as workplace parking controls. Table 3 identifies the predicted percentage reduction in emissions compared to a 2005 'business as usual' scenario for London (WS Atkins, 1999). The table shows that emission control strategies are judged to have a greater impact than demand management measures.

Table 3: Comparison of Demand Management and Emission Control strategies compared to a 2005 'Business as Usual' scenario for London

	Central London		City-wide	
	NO_x	PM_{10}	NO_x	PM_{10}
Demand management	4% to 17%	5% to 20%	1% to 10%	1% to 11%
Emission controls *Alternative fuels*	14% to 44%	11% to 44%	4% to 37%	4% to 37%
Low Emission Zones	18% to 26%	14% to 23%	8% to 18%	6% to 17%

Later work carried out by CERC used the Emissions Inventory Toolkit (EMIT) to calculate the emissions benefits of implementing a LEZ in central London. The calculation of road traffic emissions in EMIT is based on the 'Route-type' concept, which describes the distribution of engine technology (e.g. EURO I, EURO II etc) across the vehicle fleet components that the user has available for the roads in their area (e.g. Light / Heavy). The emission factors used for the engine technologies are obtained from the UK Emission Factors Database and default route-types are based on the latest National Atmospheric Emissions Inventory figures.

Vehicle restrictions were applied to the Central area of London, corresponding to the Congestion Charging zone, and the emissions from that area for 2005 were calculated without and with the restrictions in place. The following vehicle restrictions were applied:

- Motorcycles, Cars, Taxis: No restriction
- LGVs: EURO IV minimum
- Buses: EURO II with retro-fit particulate traps, or EURO III
- HGVs: EURO III minimum

The calculations indicated that these vehicle restrictions would give a 16% decrease in emissions of NO_x and a 25% decrease in emissions of PM_{10}.

Another study, on behalf of Westminster City County (TRL, 1999) investigated the emissions reductions that would result from a London wide LEZ for 2005, restricting access to goods vehicles and buses over 3.5 tonnes, as well as taxis. For the preferred scenario (HGV, bus and taxi to meet Euro III, or Euro II plus trap) emissions calculations indicated that these vehicle restrictions would give an overall 18% decrease in emissions of NO_x and a 47% decrease in emissions of PM_{10}.

Subsequent revisions of the Defra vehicle emission factors in 2002, reported under the National Atmospheric Emissions Inventory, have resulted in marked changes to emissions estimates. New factors were adopted for Euro I and II vehicles, and some changes made to the Euro III and IV emission reduction factors. The focus of a LEZ is to target emissions from the most polluting vehicles, and to accelerate the shift towards cleaner vehicles; therefore the revision of the emission factors has had a significant effect on the emissions estimates for LEZ scenarios.

A feasibility study carried out on behalf of Transport for London (TfL) to investigate the implementation of a LEZ in London found that the early calculations of the emissions benefits of implementing an LEZ in London, described above, were likely to be overestimates and the emission reductions likely to be lower than previously calculated (AEAT, 2003).

As part of the London feasibility study a detailed analysis of emissions and air quality impacts was carried out for three scenarios:
1) Euro 2 + RPC LEZ for heavy vehicles in 2007;
2) Euro 3 + RPC LEZ for heavy vehicles in 2010;
2) Euro 3 + RPC LEZ for heavy vehicles in 2010 plus a 10 year age limit for vans and taxis.

All schemes are implemented within Greater London and include an assessment of the potential benefits from the recommended scheme, including traffic up to and around the M25.

The percentage reduction in emissions from the base case for each scenario is shown in Table 4.

Table 4: Summary percentage reduction in emissions from the base case for each scenario

Pollutant	**Reduction in Emissions (relative to baseline)**		
	Scenario 1	**Scenario 2**	**Scenario 3**
NO_x (NO_2)	1.5%	2.7%	3.8%
PM_{10}	9.0%	19%	23%

The base case emissions calculations have been performed assuming that, due to the impacts of the Mayor's Air Quality Strategy, all TfL buses are fitted with particulate traps and are at least Euro 2. If the base case were calculated reflecting the national fleet mix, PM_{10} emissions, and to a lesser extent NO_x emissions, would be considerably higher. Therefore a LEZ implemented outside of London is likely to give greater emissions reductions that those presented above.

Potential air quality impacts of LEZ scenarios

It should be noted that there is often no direct linear relationship between changes in emissions and changes in pollutant concentrations in the air. This is due to the contribution from other sources, the effect of meteorology and the complex chemistry behind, for example, the formation of oxides of nitrogen. It is therefore important to examine the evidence for a reduction in transport emissions leading to an improvement in air quality.

Detailed air quality modelling was carried out for the London LEZ feasibility study, to investigate the air quality impacts of each of the three preferred scenarios (AEAT, 2003). To account for the uncertainty in estimating the air quality impacts, modelling was carried out by both ERG and CERC. The predicted concentrations, and predicted percentage change in concentrations as a result of the LEZ scenarios, are given in Tables 5 and 6.

Table 5: Summary of ERG and CERC modelling results for annual mean NO_2

Scenario	Annual mean NO_2 (μgm^{-3})		% difference from base case	
	ERG	CERC	ERG	CERC
Base case 2007	36.42	40.40	-	-
Scenario 1	36.20	40.24	-0.60	-0.40
Base case 2010	32.47	39.25	-	-
Scenario 2	32.06	38.96	-1.26	-0.74
Scenario 3	31.84	38.81	-1.94	-1.12

Table 6: Summary of ERG and CERC modelling results for annual mean PM_{10}

Scenario	Annual mean PM_{10} (μgm^{-3})		% difference from base case	
	ERG	CERC	ERG	CERC
Base case 2007	21.36	22.78	-	-
Scenario 1	21.11	22.61	-1.17	-0.75
Base case 2010	19.47	20.93	-	-
Scenario 2	19.16	20.70	-1.59	-1.10
Scenario 3	19.07	20.63	-2.05	-1.43

Tables 5 and 6 show that the absolute reduction in the concentrations of NO_2 and PM_{10} are predicted to be small for all scenarios. For all scenarios the predicted reduction in PM_{10} is significantly greater than the predicted reduction in NO_2. The CERC results predict that the LEZ scenarios will be less effective than is predicted by the ERG results.

The study also looked at the impact of the LEZ in reducing the area over which the objective values are exceeded, as shown in Table 7.

Table 7: Summary percentage reduction in emissions from the base case for each scenario

Pollutant	Reduction in Area Exceeding Targets (relative to baseline)		
	Scenario 1	Scenario 2	Scenario 3
NO_x (NO_2)	4.7%	12%	18.9%
PM_{10}	0%*	32.6%**	42.9%**

* London should meet the relevant air quality for PM_{10} in this year without any additional action, for an average year's weather.
** Exceedence of the annual mean PM_{10} objective.

Table 7 shows that although the reduction in absolute concentrations is small, the reduction in the area of exceedence is much more significant.

The feasibility study concludes that 'A London low emission zone would have modest benefits in improving overall emission levels and absolute air quality concentrations in London, but it would make a larger contribution to reducing exceedences of the air quality targets.'

As noted in the discussion of emissions, if the base case were calculated reflecting the national fleet mix, PM_{10} emissions, and to a lesser extent NO_x emissions, would be considerably higher and therefore a LEZ implemented outside of London is likely to give greater emissions reductions that those presented above. This is likely to mean that the reduction in air quality impact will also be greater for an LEZ implemented outside of London, although to a lesser extent.

Another study of the impact of LEZ (and traffic reduction) strategies was carried out with particular regard to the effect on NO_2 concentrations at roadside locations (Carslaw et al, 2002). The research compared scenarios which involved traffic reductions of 10% and 20% with vehicle emission reduction strategies. The first of these involved removing all pre-Euro I vehicles (including cars and light goods) and the second removed all pre-Euro III trucks and buses in addition to pre-Euro I cars. In both scenarios the total vehicle numbers stayed the same, and direct replacement by cleaner models was assumed.

It was found that the most effective scenario was the one with higher vehicle emission standards (post Euro I cars and Euro III for trucks and buses), which was significantly more effective than any other scenario tested. However, none of the scenarios as modelled on vehicles in central London were sufficient to meet the NAQS.

Instead, it is suggested that a much wider LEZ would be required, to combat the accumulative effect of background emissions. When this is examined it appears that the removal of pre-Euro III vehicle is roughly equivalent to a 30% reduction in overall traffic. The study makes the point that the same improvement brought about by the LEZ scenario would occur in time, as cleaner vehicles are bought to replace older ones. It is calculated that similar air quality improvements might take place within 5 years of the 2005 NAQS. However, the NAQS would still not be met in London.

From the study it can be concluded that LEZ scenarios could bring forward the impact of cleaner vehicles on air quality by a number of years, and compare well to major traffic reduction strategies. A progressive LEZ policy could continue the accelerated take-up of cleaner vehicles ahead of otherwise predicted rates of renewal, to the benefit of air quality.

Conclusions

The results of emission inventory models indicate that changing parts of the vehicle fleet towards more recently manufactured vehicles can produce a marked reduction in total emissions from road transport. This compares very well with traffic reduction measures, which would have to be very severe to produce similar effects.

Recent work carried in London on the feasibility of a LEZ has concluded that the scale of emission reductions probable through a LEZ is sufficient to have an impact on air quality, though not as great as that indicated by earlier studies. Work is continuing to progress the London LEZ, and several other UK city Authorities are carrying out feasibility studies to consider the implementation of a LEZ for their area.

Finally, operating zones in Sweden are calculated to have reduced emissions and to be a practicable policy for reducing the impact of vehicles in urban areas. Similar schemes are in place on a larger scale in Japan, although the impact of these is not yet known.

References

- ANAS (Lund, Sweden). Environmental Zones Report. www.ils.nrw.de/netz/leda/pdf/dv3-an10.pdf
- Carslaw, D.C., Beevers, S.D., 2002. The efficacy of low emission zones in central London as a means of reducing nitrogen dioxide concentrations, Environmental Research Group, King's College London, Transport Research Part D 7 (2002) 49 – 64.
- CERC, EMIT. www.cerc.co.uk
- Civitas Factsheet, Environmental Zone for Heavy Duty Vehicles, Goteborg 2005, Demonstrator 5.7
- Cloke, J., et al, 2000. A low emission zone for London. TRL.
- Environmental Management Bureau, Ministry of the Environment (Japan), Kazumi YOSHIKAWA, Motor Vehicle Emission Control in Urban Areas
- NSCA, 1999. LEZ Toolkit and Calculation Tool. www.nsca.org.uk/lez.htm
- Roth, A. (City of Gothenburg), 2001. Clear Zones Conference Papers.
- AEA Technology plc, 2003. London Low Emission Zone Feasibility Study Phase II. Final Report to the London Low Emission Zone Steering Group.
- WS Atkins, 1999. An evaluation of transport measures to meet NAQS objectives, Stage 2 Report