Assessing Low Emission Zone and Demand Management policies using detailed traffic and vehicle emission measurements and coupled models.

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Abstract

This study has used detailed, coupled traffic and vehicle emission models to evaluate the environmental benefits of a range of Low Emission Zones (LEZs) and traffic demand management policies in the Fulford Air Quality Management Area (AQMA), City of York, UK. The movement of cars, vans, buses, coaches, commercial vehicles and the emissions they produce have been simulated as they negotiate traffic junctions, signals and interact with each other. The coupled models are: the S-Paramics traffic micro-simulator and the instantaneous emission model PHEM (Hausberger et al, 2011). As the vehicle movements through the well specified and calibrated urban network are simulated at a one-second time step; stop-start driving conditions, congestion effects and traffic demand changes can be assessed. The local, operational vehicle fleet was accurately specified in the model as vehicle registration numbers observed in the AQMA were cross-referenced with databases that contain information on individual vehicles so the share of cars, vans, buses, coaches and commercial vehicles; and their respective fuel type, engine size, weight and Euro standard proportions were known and accounted for. The UK and many EU member states are actively considering the wide-scale use of LEZs to accelerate the renewal of the vehicle fleet, particularly in areas where air quality limits are being exceeded. Sustainable travel modes and choices are also being actively promoted. As well as describing the modelling framework and configuration, this paper presents emission assessments of a range of notional Low Emission Zone and demand management policies in the Fulford AQMA.

Background

Despite the implementation of measures to reduce total PM and NO_X emissions from the transport sector, primarily motor vehicle emission standards, recent evidence suggests an unwanted side-effect of new diesel pollution abatement technologies to control particle emissions is an increase in emissions of Nitrogen Dioxide (NO_2) directly from vehicles (Grice et al, 2009). It is also now recognised there has been little change in the total NO_X (Oxides of Nitrogen) emission performance of light-duty diesel vehicles in “real-world” (or in-use) urban driving conditions in the past 15 years or so (Carslaw et al, 2011). Emissions of NO_X from diesel vehicles in urban environments are now considered to be higher than suggested by UK and EU emission inventories. UK and EU emission inventories have historically considered traffic flow volume and emission rates for different vehicle categories and sub-types (i.e. car, fuel type, engine size, Euro standard). The emission rates for a road section (or link) have also been based on the road type or the average speed. The data under-pinning such inventories (e.g. www.naei.org.uk) are mostly derived from laboratory dynamometer tests, where vehicles are driven over defined (artificial) speed-profiles (or drive-cycles) and their exhaust emissions analysed. Whether these drive-cycles are representative of on-road traffic flow conditions and behaviour is often debated. Indeed, there is mounting concern that such approaches do not adequately reflect emissions from congested networks. The detailed approach used in this study, coupling traffic microsimulations and an instantaneous emission model, allows the influence of vehicle accelerations, road gradient, vehicle and engine load to be considered. This is clearly highly desirable when attempting to understand vehicle emissions across congested networks, evaluate environmental traffic management and vehicle fleet renewal policies.

Clearly such higher resolution approaches are both information hungry and computationally intensive. Resources such as ANPR (Automatic Number Plate Recognition) data cross-referenced to the UK Motor Vehicle Registration Information database mean it is now feasible to develop a detailed understanding of the local vehicle fleet composition i.e. broken down by vehicle type (car, van, bus, coach, rigid- and articulated- HGV), fuel type, Euro standard, weight, etc. It is straight-forward for the coupled traffic-emission simulations to use this information. As individual vehicles enter the traffic microsimulation network, they are allocated a

vehicle type according to specified proportions. In the case of scheduled Bus services, these operate to set timetables and routes. This 'virtual' traffic-emission modelling environment is therefore not based on an average vehicle fleet; rather being a much closer representation of reality with individual vehicles having set attributes e.g. a Euro 4 diesel passenger car. Advances in desktop computing mean it is also now feasible to micro-simulate traffic movements at a detailed level as they negotiate traffic junctions, signals and interact with each other for complete City networks. Microscopic traffic simulation models are frequently used by transport engineers and planners to analyse traffic operations and evaluate management strategies. It is therefore likely that traffic microsimulation networks developed for transport planning purposes may be available for improved environmental assessments.

Modelling

The modelling approach couples traffic microsimulations, which model the movement of individual vehicles through the well specified study area road network, with an instantaneous vehicle emission model that provides second-by second fuel consumption and tail-pipe emission predictions. The schematic in Figure 1 presents the modelling framework and flow of information. In this project the S-PARAMICS (www.sias.com) traffic micro-simulator has been coupled with the instantaneous emission model PHEM (Passenger car and Heavy Emission Model – Hausberger et al, 2011). The models are able to provide results for the complete network, selected road links or individual vehicles. Traffic surveys were conducted by www.nationwidedatacollection.co.uk on Fulford Main Street on Thursday the 19th of May 2011 between 07:00 and 19:00hrs. Two Automatic Number Plate Recognition (ANPR) camera systems were installed to survey the bi-directional flows on Fulford Main Street. The list of 16,422 registration plates (or Vehicle Registration Mark – VRM) was passed to the Department for Transport (DfT) to obtain detailed information for every observed vehicle. The data from the ANPR surveys, supplemented with additional traffic flow observation in the area, was used to specify and calibrate the traffic demand in the microsimulations. So the modelling could assess emissions in different traffic conditions throughout the day (24-hours) the S-PARAMICS model was setup to represent the four average week-day time periods:

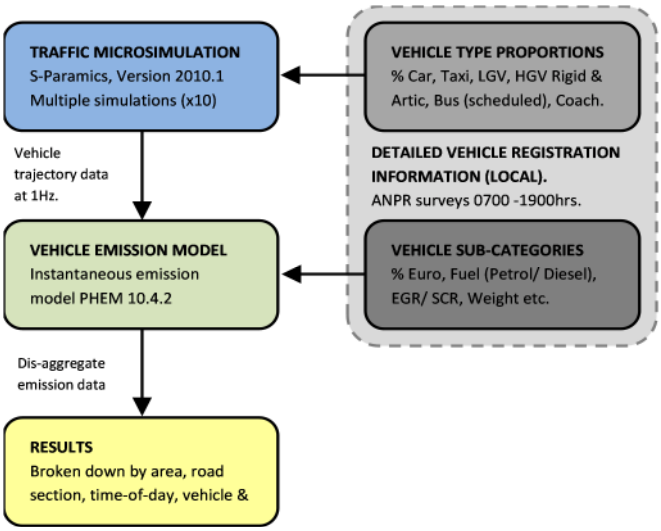

Figure 1. The coupled traffic-emission modelling framework

- AM (morning peak) period (07:30 - 09:30hrs);
- IP (inter-peak) period (09:30 – 16:30hrs and 18:30 – 19:30hrs);
- PM (evening peak) period (16:30 - 18:30hrs); and
- NIGHT-time period (00:00 – 07:30hrs and 19:30 – 23:59hrs).

The detailed local vehicle fleet information was analysed to firstly determine the vehicle type proportions (car, van, rigid- and articulated- HGV bus, coach) in the four average week-day time periods (Table 1). This was considered important as:

- HGVs are known to avoid urban areas in peak periods when congested stop-start driving conditions can significantly increase fuel consumption, journey times and operating costs; &
- Scheduled Bus services typically operate to fixed frequencies throughout the day, so whilst their flow level is broadly constant, their proportion is lower in AM and PM peak periods. In NIGHT-time periods there are usually no scheduled Bus services.

The detailed vehicle information resource also allows the local vehicle fleet to be characterised into fuel type (passenger cars) and Euro status sub-categories. The on-road passenger car fleet in Fulford village is dominated by Euro 3 classification or newer vehicles, which comprise 92.3% of the passenger car fleet. Passenger cars with a type approval after January 2005 (Euro 4 or

Table 1. Vehicle type proportions (%) in AM, IP, PM and NIGHT-time periods.

Vehicle type	Time period			
	AM (%)	IP (%)	PM (%)	NIGHT (%)
Car	84.0	81.6	88.6	83.6
Van	10.2	11.3	7.99	11.5
HGV (rigid)	2.90	4.27	1.31	4.37
HGV (artic)	0.75	0.37	0.30	0.37
Bus	1.96	2.36	1.58	0.00
Coach	0.24	0.12	0.27	0.12

newer) make up 59.5% of vehicles of this type. As observed at other sites in the UK (Carslaw et al, 2011), the share of diesel fuelled passenger cars has increased with time. For the latest Euro 5 standard, more diesel passenger cars were observed than those with petrol engines. In 2011 sales of diesel passengers overtook petrol fuelled vehicles for the first time in UK (SMMT, 2011).

As the emission characteristics of Euro 4 and 5 heavy-duty vehicles are dependent on the exhaust after-treatment system employed, best endeavours were made to quantify the split of heavy-duty vehicles equipped with Exhaust Gas Recirculation (EGR) or Selective Catalytic Reduction (SCR) systems. Unfortunately the http://www.dvla.gov.uk detailed vehicle registration database does not currently hold details of exhaust after-treatment systems. Instead the list of Heavy-duty vehicles was reviewed by Dr Martin Rexeis, a Heavy-duty vehicle emission researcher at the Technical University of Graz (TUG, Austria). For each manufacturer and heavy-duty vehicle sub-category Rexeis (2011) estimated the type of exhaust after-treatment technology employed. This expert assessment provided the estimated split of Euro 4 and 5 heavy-duty vehicles equipped with EGR/ SCR systems in the study area.

The S-PARAMICS (version 2010.1) traffic microsimulation software was used to simulate and track vehicles as they negotiate the traffic junctions, signals and interact with each other through the Fulford Road corridor. The S-PARAMICS model of the network developed by Halcrow Group Limited for City of York Council in July 2009 (Preater, 2009) was edited to better reflect the 2011 network and traffic flow levels, vehicle fleet proportions, scheduled Bus services, Bus stop locations and vehicle dynamics behaviour (acceleration and deceleration rates). In-line with 'best practice' (Dowling et al, 2004), ten simulations of each time period/ scenario were run with different initiating 'number seeds'. The traffic demand was calibrated using available traffic monitoring information from six sites in the study area. The model was calibrated by comparing:

- observed/ modelled flows; and
- observed/ modelled vehicle fleet proportions.

The GEH statistic, as recommended by the UK DMRB (http://www.dft.gov.uk/ha/standards/dmrb/index.htm) was used to compare the observed/ modelled traffic volumes. For traffic models a GEH of less than '5.0' is considered a good match between the modelled and observed hourly volumes. According to the UK DMRB, 85% of the volumes in a traffic model should have a GEH less than '5.0'. To account for the variability (stochastic modelling) in microsimulation processes multiple (ten) simulations of the AM, PM, IP and NIGHTtime period networks were run. The GEH statistics for all the "BASE" model time periods and monitoring sites were less than the specified 'measure of performance' value of '5.0'. The observed fleet proportions were also compared with the modelled results (vehicle kilometres in the AQMA – average of 10 simulations). The vehicle fleet in the NIGHTtime period was assumed to be the same as that operating during the Inter-Peak (IP), with the exception that there were no scheduled Bus services. The observed and modelled vehicle fleet proportions were well matched for all the day-time periods, with the difference between observed and modelled always being less than 1%.

The S-PARAMICS facility to track all vehicles on selected links during each simulation time-step (2Hz) was used to record: individual vehicle ID, road section/ junction code, vehicle type (Car, Van, HGV-rigid, HGV-articulated, Bus, Coach), co-ordinates, speed ($km \cdot h^{-1}$) etc. Detailed vehicle traces were collected for all road sections (or links) in the Fulford AQMA. The open-source software 'R' (R.Team, 2008) was used to process, sample and manipulate the large data files (~1Gb) into the 1Hz format required by the emission model PHEM.

PHEM is a comprehensive power-instantaneous emission model that is able to simulate fuel consumption and NO_X, NO_2, HCs, Particulate Mass (PM_{10}), Particle Number (PN), Carbon Monoxide (CO) and Hydrocarbons (HC) tail-pipe emissions of the whole vehicle fleet of Euro 0 to Euro 5, petrol/ diesel/ CNG and bio-gas fuels, heavy-duty vehicles, passenger cars and light commercial vehicles second-by-second. The model is based on light- and heavy-duty vehicle engine speed – power emission maps established from engine and chassis dynamometer

measurements (Zallinger et al. 2005). PHEM has a time alignment and correction sub-model to relate engine speed – power events to predicted engine-out emissions. These methods make PHEM capable of simulating the instantaneous fuel consumption and emissions for any speed profile or driving cycle. As input, PHEM requires 1Hz speed data, road gradient and the vehicle specification including: fuel type, Euro emission standard, engine size, exhaust after-treatment systems, vehicle weight, frontal area, drag coefficients and transmission ratios. Although the PHEM model has default EU average values available, as this study had a detailed understanding of the local vehicle fleet, the known distribution of fuel types, Euro standard proportions and vehicle weight information was used to parameterise the emission model. The gradient of road sections was also considered, derived from the Google Earth (2011) terrain model. All the PHEM simulation results assumed vehicles were in a 'hot-running' condition.

Scenarios

Low Emission Zones (LEZs) are areas or roads where the most polluting vehicles are restricted from entering. Restrictions are usually applied according to the vehicle type and Euro standard. There are currently around 200 LEZs in operation in 11 European countries (Sadler, 2010). As heavy-duty vehicles, due to their larger diesel engines and higher power demands make a disproportionate contribution to total road transport emissions, LEZs are often targeted at the Bus and HGV vehicle categories e.g. The Greater London LEZ. Transport for London (TfL) introduced the Greater London LEZ in 2008 to encourage the most polluting heavy diesel vehicles to use newer, cleaner vehicles. The LEZ covers most of Greater London within the M25 and is therefore a large scheme. To drive within the LEZ without paying a daily charge, heavy-duty vehicles must meet specified emission standards that limit the amount of particulate matter coming from their exhausts. In 2011 Lorries, Buses and Coaches were required to meet the Euro 3 standard for Particulate Matter (PM). From 2012 vehicles need to meet the Euro 4 standards for PM. Whilst LEZs have been found in many countries to be an effective strategy to move towards meeting the health-based EU PM10 limit values, it is un-certain whether LEZs reduce NO_X and NO_2 emissions and consequently ambient concentrations, unless of course there has been a reduction in traffic demand and congestion within the zone. In this study a range of LEZ policies have been assessed targeted at:

- Buses (scheduled);
- Heavy-duty vehicles (Bus, Coach and HGVs); and
- Light- and Heavy- duty vehicles.

A Bus LEZ has been considered as a separate option as there is a compelling need to develop a sustainable public transport system that delivers reductions in CO_2 and local air quality pollutant emissions. Buses are intensively operated heavy-duty vehicles that frequently stop and start in normal traffic operations, but also as they service Bus stops. These demanding operating conditions are fuel intensive and elevate the exhaust emissions per kilometre travelled. As Buses make repeated scheduled journeys each day there is also a greater opportunity to reduce emissions in a sensitive area by renewing a small number of vehicles with cleaner technology than with any other category of vehicle. Local Authorities may also influence Bus operators through Quality Bus Partnerships and other Local Transport initiatives. In the Bus LEZ scenarios, Buses were required to meet certain minimum emission standards: Euro 3, Euro 4 and Euro 5. LEZ policies to encourage the renewal of all heavy diesel vehicles driving in the Fulford AQMA were also evaluated. For these scenarios, all heavy-duty vehicles had to meet minimum emission standards, namely: Euro 3, Euro 4 and Euro 5.

In attempt to give greater impact, a number of LEZs in Europe also restrict access to light-duty vehicles (Sadler, 2010). It was assumed access restrictions for light-duty vehicles would only be applied in addition to a comprehensive LEZ scheme for heavy vehicles. In this study the impact of restricting access to light-duty vehicles were therefore applied in addition to the Heavy vehicle Euro 4 scenario. The comprehensive (light- and heavy-duty) LEZ policies assessed are:

- Light-duty vehicles required as a minimum to meet the Euro 1 emission standard (Heavy-diesel vehicle Euro 4); and
- Light-duty vehicles required as a minimum to meet the Euro 2 emission standard (Heavy-diesel vehicle Euro 4).

As the modelling framework has the capability to consider the influence of changes in traffic demand on congestion and tail-pipe emissions, a range of notional demand management

scenarios were also considered. Reductions in road traffic demand of -5% and -10%, excluding scheduled Bus services, were simulated so the potential benefit of successful sustainable travel measures could be evaluated. Conversely the impact of growths in road transport demand of +5% and +10% (again excluding scheduled Bus services) were also assessed.

Results

The traffic-emission NO_X, NO_2 and PM modelling results are analysed to:

- illustrate the emission performance of the modelled vehicles per kilometre travelled;
- predict the contribution of each vehicle sub-category to the emission totals; and
- evaluate the impact of the proposed Low Emission Zone (LEZ) policies and traffic demand management scenarios.

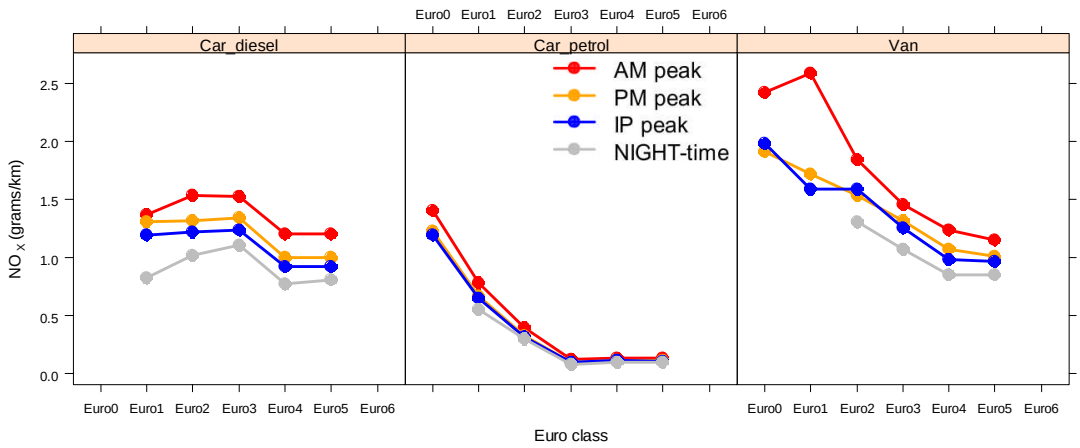

Figure 2. Light-duty NO_X emission factors for each time period (a) diesel passenger cars, (b) petrol passenger cars, (c) vans.

The average emissions per kilometre travelled for each vehicle sub-type have been calculated from the traffic-emission modelling outputs of the current or "baseline" conditions (May 2011). Figure 2 presents the modelled NO_X emission factors for the light-duty vehicle types in the AM, PM, IP and NIGHT-time periods. The results for each light-duty vehicle type are presented in a separate panel. The NO_X emission factors are presented for each Euro category where available. Results are not available if the combination of fleet proportion and demand level for a given time period do not lead to a vehicle of that sub-type being simulated.

The modelled emission factors for diesel passenger cars (left panel, Figure 2) are broadly similar through all Euro generations. During AM and PM peak periods, emission factors are elevated as the simulated vehicles perform more polluting stop-start motions as they negotiate a busier network with longer traffic queues. The modelled emission factors for petrol passenger cars (middle panel, Figure 2) decrease substantially through the Euro standards. Older pre-catalyst (Euro 0) petrol vehicles are modelled as having high NO_X emissions, similar to the levels from diesel passenger cars. The modelled emission factors for petrol vehicles suggest Euro standards have successful delivered improvements in the NO_X emission controls on petrol cars. The NO_X emission factors for Euro 3 and newer vans are similar to those of diesel passenger cars. This is expected as diesel cars and vans share engine and exhaust after-treatment technologies. The modelled emission factors for Euro 2 and older diesel vans are however higher than those of comparable diesel passenger cars. This maybe because the model considers the emission performance of vans has degraded quicker than a comparable diesel passenger car, as they are likely to have higher annual mileages and have a lower quality maintenance history. There is however more uncertainty with these results as the number and length of journeys simulated completed by older vans is substantially lower than for the other vehicle sub-types.

The emission factors from this coupled traffic microsimulation and instantaneous modelling approach have been compared with recent, local UK vehicle emission Remote Sensing Device (RSD) measurements (Carslaw et al, 2011). Daily average (weighted mean) emission factors from the traffic-emission modelling are compared with RSD emission factors estimates based on measurements in the study area in September 2011. Considering the significant differences

between the approaches, the NO_X emission factors from the PHEM simulations and those from the RSD measurements for diesel passenger cars were found to be in close agreement. Diesel passenger cars are an increasingly important vehicle category with respect to NO_X emissions as:

- Their fleet share continues to increase. In the "baseline" simulations diesel passenger cars completed 33.8% of the vehicle kilometres in the average weekday simulations; and
- NO_X emission controls under-perform in urban driving conditions. Recent evidence and research is suggesting that diesel exhaust NO_X after-treatment technologies are in-effective in urban driving conditions, with their lower power demands, exhaust flow rates, exhaust gas temperatures and consequently catalyst temperatures.

The emission factor estimates for petrol passenger cars all suggest NO_X emissions from each successive Euro generation have fallen. Carslaw et al (2011) propose the higher estimates from the RSD measurements indicate the models are not fully capturing the emission performance degradation of petrol cars. The PHEM emission estimates for older passenger cars are therefore considered to be optimistic. As the fleet share of Euro 1 and older petrol cars for example is only ≈1% of the observed passenger cars, this is not considered to be a serious limitation. For vans, all the modelled emission factor estimates suggest NO_X emissions decline through the Euro 0 to Euro 5 emission standards. The magnitude of the PHEM and RSD van emission factors are however similar, especially for the more recent and more common Euro 3 and 4 vehicles (that comprise ≈85% of the observed van fleet).

Although the DEFRA (2009) source apportionment methods do not currently consider the primary (direct) NO_2 emissions explicitly, the PHEM modelling results for NO_2 have been analysed. The addition of Diesel Oxidisation Catalysts (DOCs) on light-duty diesel vehicles from Euro 3 onwards has led to a dramatic increase in emissions of NO_2 directly from vehicles. The peak NO_2 fraction is for Euro 4 light-duty diesels. The PHEM f-NO_2 for Euro 5 light-duty diesels is lower than that of Euro 4 vehicles. This is because Euro 5 DOCs have a higher palladium content that are known to have better f-NO_2 characteristics. Heavy diesel f-NO_2 are significantly lower than those reported for light-duty diesels.

Emission contributions

In this section the NO_X, NO_2 and PM emission contributions for the current (May, 2011) or "baseline" conditions are presented. The results are presented as a weekday (24-hour) average (weighted mean of the AM, IP, PM and NIGHT-time periods). The Figure 3 bar chart presents the predicted NO_X emission contributions from each vehicle type over an average weekday. The breadth of the bar is proportional to the share of total (simulated) vehicle kilometres completed by that vehicle type in the Fulford AQMA (i.e. CAR-petrol 49.5%, CAR-diesel 33.8%, VAN 10.5%, HGV 4.1%, BUS 1.9%, COACH 0.2%). Approximately a third of the road transport NO_X emissions in the Fulford AQMA are estimated to be emitted from diesel cars. HGVs contribute another third. In relation to the vehicle kilometres travelled the heavy diesel categories make a dis-proportional contribution. For example although Buses (scheduled) only comprise 1.9% of the modelled fleet, they contribute nearly 20% of the NO_X.

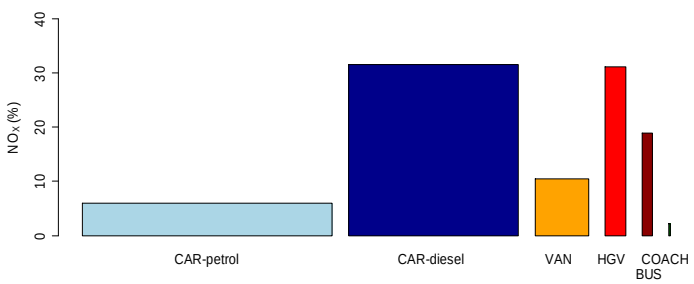

Figure 3. The NO_X emission contributions from each vehicle type.

The modelling suggests the majority (≈60%) of primary NO_2 emissions are generated by diesel cars. The predicted NO_2 contribution from light-duty diesels, i.e. diesel cars and vans, is ≈80%. The source of PM emissions in the Fulford AQMA is mainly generated by the stock of light- and heavy-duty diesel vehicles. Although these vehicles only complete approximately half of the vehicle kilometres travelled in the area, they emit ≈85% of the PM. Roughly half of these PM emissions are generated by light-duty diesels (diesel cars and vans), the other half from the heavy-duty diesel vehicle types.

LEZ policies

For the LEZ scenario evaluations the demand levels of all vehicle types are un-changed from the current or "baseline" conditions. Instead only the distribution (proportions) of vehicles' Euro standards is adapted for each of the LEZ scenarios. Vehicles that did not meet a minimum LEZ standard in the current fleet (May 2011), were redistributed to the Euro categories that did achieve the criteria. It was not assumed that older vehicles that did not meet the criteria were simply replaced with new vehicles, as this was not considered realistic. Instead vehicles were assumed to be replaced in proportion with the Euro standard distribution of vehicles that did meet the minimum LEZ standard in the current "baseline" fleet.

The observed Bus fleet operating in the AQMA is dominated by Euro 4 vehicles (≈50%). The majority of the Euro 4/ 5 Buses were considered to be equipped with SCR exhaust after-treatment technology. The Bus LEZ policy restricting access to vehicles that did not comply with the Euro 3 emission standards, would only require about a quarter of the Buses to be up-graded. These vehicles complete a very small proportion of the total vehicle kilometres (≈0.45%) in the study area over a typical week-day. Although the Bus LEZ policies would only affect a small number of vehicles, the models predict they would lead to modest reductions in the total road transport NO_X emissions across the study area. The Bus Euro 3 LEZ is estimated to reduce total NO_X emissions by 4.3%. If the LEZ policy was extended to only allow Euro 4 and newer Buses to drive in the AQMA, the reduction in total NO_X emissions is estimated to be 5.8%. Restricting access to Buses that comply with the latest (Euro 5) emission standards has further benefits. There are however greater uncertainties with the validity of the emission factors for the latest heavy-duty vehicles. This is because the performance of their emission control technologies are considered to be more sensitive to the operating conditions (Velders et al, 2011). A Euro 5 Bus LEZ policy would also demand most (≈84%) of the vehicle fleet was renewed, which would be expensive and therefore unpopular with Public Transport operators.

As the modelled Heavy-Vehicle (HV) LEZ scenarios restrict access to a larger population of older more polluting vehicles, the benefits are greater than for the Bus LEZs. The HV LEZ scenarios extend the restrictions to Coaches, rigid- and articulated HGVs. In the AM and IP periods there are roughly two Coaches/ HGVs for every simulated scheduled Bus. In the PM peak the proportion of Coaches/ HGVs and scheduled Buses are roughly equivalent. Coaches, rigid- and articulated HGVs are also assumed to operate and contribute to the total NO_X emissions in the NIGHT-time period. The Euro 3, 4 and 5 HV LEZ policies were predicted to reduce total NO_X emissions by 5.8%, 13.8 and 21.7% respectively.

Extending the LEZ restrictions to older passenger cars and vans were only predicted to lead to further nominal reductions in NO_X emission totals. This is because:

- older Euro 0 and 1 passenger cars and vans only comprise ≈1% of the vehicle fleet;
- the modelling assumed the LEZ policies would not deter any vehicle journeys from taking place. Instead the journeys completed by older vehicles were replaced with trips by newer vehicles that met the LEZ requirements;
- the majority of older passenger cars have a petrol engine. If for example a Euro 0 petrol car is replaced with:
    - a newer petrol car, then there is a predicted NO_X emissions benefit;
    - a newer diesel car there is predicted to be no NO_X emissions benefit as the two vehicles have comparable NO_X emissions performance (factors);
- replacing a Euro 1 petrol car journey with a newer diesel car is likely to cause the amount of NO_X emitted to increase;
- the Euro 1 to 5 emission standards for vans are only considered to have delivered small incremental improvements in NO_X performance. Therefore replacing an older van journey with a trip completed by a newer equivalent vehicle is only projected to lead to a small reduction in the NO_X emitted.

The increasingly stringent emission standards Euro 1 to 5, have led to consistent improvements in the Particle Mass (PM) emission performance of both light- and heavy- duty vehicles. The simulated LEZ policies are therefore predicted to deliver significant PM benefits. The Euro 4 Bus LEZ policy for example is forecast to reduce the total (exhaust) PM emissions by ≈10%. By also restricting access to older HGVs and Coaches the policy is projected to deliver an additional ≈10% reduction in PM emissions.

Demand management scenarios

Reductions in general road traffic demand (cars, van, coaches, HGVs) of -10% and -5% in all the time periods, excluding scheduled Bus services, were simulated to predict the potential benefit of a range of sustainable transport measures that either initiated a mode shift to walking/ cycling/ public transport or negated the need for the journey. The traffic microsimulation model is able to simulate congestion (i.e. the growth and dissipation of traffic queues), and coupled with PHEM can be used to predict the impact on vehicle emissions. As expected, by removing a proportion of the traffic demand the severity of congestion and delays on the modelled network were lessened. A 5% reduction in general traffic demand was predicted to increase the average vehicle speed in the AM peak network from 16.7km•h^{-1} in the BASE situation to 21.9km•h^{-1}. A reduction in the general traffic demand of 10% in the AM peak was predicted to raise the average speed further to 25.4km•h^{-1}, which is similar to the level in the current (BASE) IP situation. These modelling results suggest that modest reductions in general traffic demand can significantly relieve congestion on over-capacity networks. Conversely increases in general traffic demand in the AM peak network were predicted to worsen delays and congestion. Additional traffic demand of +5% and +10% in the AM peak were projected to lower the average network speed to 14.6km•h^{-1} and 13.8km•h^{-1} respectively. Congestion was simulated to be more severe in the calibrated AM peak network than was modelled in the other time periods. Therefore the impacts of the demand changes in this time period are more pronounced.

The impact of the changes in general traffic demand on the total NO_X emitted in each time period (AM, IP, PM and NIGHT-time) are higher in the more congested AM peak. The results indicate that a change in traffic demand will effect a greater change in vehicle emissions, whether the change is positive or negative. Reducing the general traffic demand in all time periods by 10% was predicted to lower the average NO_X emissions over a typical weekday by 18.4%. In the more congested AM peak period, the change was more evident as the NO_X emissions were predicted to fall by 26.5%. The traffic-emission modelling results indicate that a modest 5% increase in general traffic flows would lead to a ≈10% rise in the emissions of the local air quality pollutants NO_X, NO_2 and PM. This is encouraging and supportive evidence for policy makers wishing to promote sustainable travel modes and choices. It is however acknowledged that whilst delivering and maintaining a reduction in general traffic demand is challenging because of the level of suppressed demand, the potential environmental benefits are significant. Conversely the penalties for not managing traffic demand effectively are also great. A 10% increase in traffic demand was shown to lower average network speeds further, with the higher traffic flow in more polluting congested driving conditions predicted to generate ≈17% more NOX emissions.

Acknowledgements

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References

Carslaw, D., Beevers, S., Tate, J., Westmoreland, E., Williams, M. (2011). Recent evidence concerning higher NO_X emissions from passenger cars and light duty vehicles. Atmos. Environment, 45, 7053-7063.

Grice, S., Stedman, J., Kent, A., Hobson, M., Norris, J., Abbott, J., Cooke, S. (2009). Recent trends and projections of primary NO2 emissions in Europe. Atmospheric Env. 43, pp. 2154 – 2167.

Dowling, R., Skabardonis, A., Halkias, J., McHale, G., Zammit, G. (2004). Guidelines for Calibration of Microsimulation Models. Transportation Research Record, 1876, 1-9

Hausberger, S., Rexeis, M., Zallinger, M., Luz, R. (2011). User Guide to the PHEM Emission Model. Version 10. Technical University of Graz, Austria, January 2011.

Preater, D. (2009). South of Fulford Main Street S-PARAMICS model. Technical Note 1, Model Development, Construction & Validation. Reference CTD-ALI-001.

Rexeis, M. (2011). Expert assessment of the exhaust after-treatment technology used by the heavy duty vehicles observed in York. Personal communication. 20th September 2011.

Sadler, L. (2010). LEZs in Europe. Report for the UK Department for Transport. Sadler Consultants. February 2010. http://www.dft.gov.uk/pgr/scienceresearch/orresearch/lez/pdf/lowemissionzones.pdf

Zallinger, M., Le Anh T., Hausberger S. (2005). Improving an instantaneous emission model for passenger cars. Transport and Air Pollution Conference, ISBN 3-902465-16-6