**16th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
8-11 September 2014, Varna, Bulgaria**

INVESTIGATION OF THE EMISSION AND AIR QUALITY IMPACTS OF LOW EMISSION ZONE SCENARIOS IN NEWCASTLE AND GATESHEAD, UK.

Paul Goodman[1], Anil Namdeo[1], Fabio Galatioto[1], Margaret C. Bell[1], Edwin Foster[2], Caroline Shield[3]*

[1]Transport Operations Research Group, School of Civil Engineering and Geosciences, Newcastle University, Newcastle-upon-Tyne, NE1 7RU, United Kingdom,
[2]Newcastle City Council, Civic Centre, Newcastle-upon-Tyne, NE1 8QH, UK,
[3]Gateshead Council, Civic Centre, Regent Street, Gateshead, NE8 1HH, UK

[*]*Corresponding author: Anil Namdeo, anil.namdeo@newcastle.ac.uk*

Abstract: Many cities in the UK and EU are failing to meet standards for NO_2. In the UK, 63% of UK Local Authorities out of a total of 403 Local Authorities have declared one or more Air Quality Management Areas (AQMAs) in 2011, which is a significant increase compared to the corresponding figure of 29% in 2003. The number of AQMAs declared for NO_2 has risen by nearly 350% from 160 to 549 AQMAs, during the same period. This has prompted local authorities to develop local transport plans to manage traffic levels and also explore ways to reduce vehicular emissions in the areas which are failing to meet NO_2 standards. Low Emission Zones (LEZ) have been designed in many European cities to achieve the latter. As the aim of an LEZ is to reduce concentrations of air-pollutants within its boundaries, generally those vehicles with the largest gross contribution to emissions are targeted initially. This study presents the results of a joint Low Emission Zone investigative study proposed by Newcastle and Gateshead local authorities in the UK. A base year of 2010 was set up and then seven scenarios, for the year 2021, were investigated with varying degrees of penetration of new technology vehicles. The seven scenarios for 2021 included a business as usual scenario and six others with different mix of vehicle fleet (all vehicles Euro 5/V compliant; all vehicle Euro 6/VI compliant; only goods vehicles Euro V compliant; only goods vehicles Euro VI compliant; all buses Euro VI compliant; and all cars Euro 6 compliant). For scenarios where the Euro 6/VI regulations were assumed effective it was found that general fleet turnover and renewal over the 2010 to 2021 period, coupled with emissions improvements in other sectors, lead to an approximate 45% reduction (equivalent to 10 – 15 $\mu g/m^3$) in mean NO_2 concentrations for receptor points in Newcastle City and Gateshead Air Quality Management Areas. This reduction by itself is sufficient to significantly reduce the chances of exceedence of the National Air Quality Standard for annual mean NO_2 (currently 40 $\mu g/m^3$) in those areas, though the potential for 'hot-spot areas' with excessively high concentrations may remain.

INTRODUCTION

Newcastle is a city with approximately 280,000 inhabitants, situated on the northern banks of the River Tyne in north-east England. Opposite, on the southern side of the river lies Gateshead, home to 200,000 people. Both are inextricably linked; physically by numerous bridges over the Tyne, as well as historically, culturally and economically. Unfortunately both, like over 250 other local authorities in the UK, are also linked through the problem of exceedence of the UK National Standard limit values for annual mean NO_2 (set at 40 $\mu g/m^3$) in their centres, with both having declared Air Quality Management Areas (AQMAs) (DEFRA, 2014).

Over the past decade, throughout Europe, the concept of a Low Emission Zone (LEZ) has received much attention as a potential solution to mitigate exceedence problems in urban areas (EC, 2014). Many existent LEZ schemes are focused on the abatement of issues with particulate matter (e.g. PM_{10} and $PM_{2.5}$) arising primarily from heavy vehicle (both freight and public transport) usage. Such schemes have involved regulation on the use of earlier Euro emissions standards (i.e. Euro 2/II, 3/III and 4/IV), and the uptake of particle traps or filters within the vehicle fleet.

This paper examines the potential for NO_x and NO_2 reductions (alongside PM and CO_2), through the implementation of LEZ affecting later Euro classes (5/V and 6/VI) throughout the combined core areas of Newcastle and Gateshead (Goodman *et. al.*, 2013).

METHODOLOGY

The methodology adopted in the study leveraged existing model and data resources from both local authorities, as well as Newcastle University itself. The backbone of the methodology was based on taking traffic information from three primary sources:

1. Flow information for private (i.e. cars) and freight transport (i.e. light goods vehicles [LGVs] and heavy goods vehicles [HGVs]) from the Tyne and Wear strategic Transport Planning Model (TPM) (Jacobs, 2008);
2. Flow information for public-transport operations, based on publically available route and timetable information;
3. Speed information from GPS-enabled vehicles, collected by a third-party, and licensed to Newcastle City Council.

These data were fed into Newcastle University's bespoke PITHEM (Platform for Integrated Traffic, Health and Environmental Modelling) (Namdeo and Goodman, 2012) software to produce a link-based emissions inventory for the baseline year of 2010. Iterations of the inventory also included further information of local vehicle fleets, obtained from the UK Driver and Vehicle Licensing Agency (DVLA) and regional public transport bodies (notably the Tyne and Wear Passenger Transport Executive: NEXUS, and local bus operators) (see Goodman *et. al.*, 2014). Speed-based emissions factors for the inventory were derived from those published by the UK Department for Environment Food and Rural Affairs (DEFRA) in the Emissions Factor Toolkit (version 5.1.3) (DEFRA, 2012a). It is worth noting that these emissions are derived from assumptions about real-world vehicle emissions from test cycle data.
Outputs from PITHEM (primarily NO_x, PM_{10} and $PM_{2.5}$ emissions plus vehicle primary NO_2 estimates) were then utilised in the ADMS-Urban Gaussian pollution dispersion model (CERC, 2011), to produce concentrations (i.e. annual average values) across the two urban areas. Final concentrations also incorporated non-traffic source emissions from DEFRA's background maps (DEFRA, 2012b), and NO_x to NO_2 conversion using DEFRA's spreadsheet tool (DEFRA, 2012c). Greenhouse gas estimates, in the form of CO_2 emissions were also produced. Based on discussions within the project advisory group, a target year for LEZ implementation was set for 2021, and eight further scenarios were developed. These scenarios were:

- A 'do-minimum' scenario, with assumed fleet turnover based on the UK NAEI;
- An 'all goods vehicles (light and heavy) Euro 5/V compliant' LEZ scenario;
- An 'all vehicle classes Euro 5/V compliant' LEZ scenario;
- A 'cars-only Euro 6 compliant' LEZ scenario;
- A 'all goods vehicles (light and heavy) Euro 6/VI compliant' LEZ scenario;
- A 'buses-only Euro VI compliant' LEZ scenario;
- An 'all vehicles Euro 6/VI compliant' LEZ scenario, and;
- Two 'Euro 6/VI fail' scenarios - based on the assumption that future Euro 6/VI vehicles do not meet the expected emissions targets, and are more akin to existing Euro 5/V vehicles in their NO_x performance.

Baseline fleet turnover over the decade 2021 was extrapolated from the 2010 data using the UK National Atmospheric Emissions Inventory (NAEI). This was coupled to projected traffic growth information (+10% car, +24% LGV, +12% HGV and +0% Bus) within PITHEM, and resultant concentrations re-calculated using ADMS-Urban.

RESULTS FOR EMISSIONS

Figure 1 shows modelled emissions for NO_x within the central Newcastle AQMA, apportioned by vehicle type. Within the 2010 base year, buses are identified as the largest single contributor (47%) to traffic NO_x emissions, but by 2021, the effect of light diesel vehicles becomes more dominant.

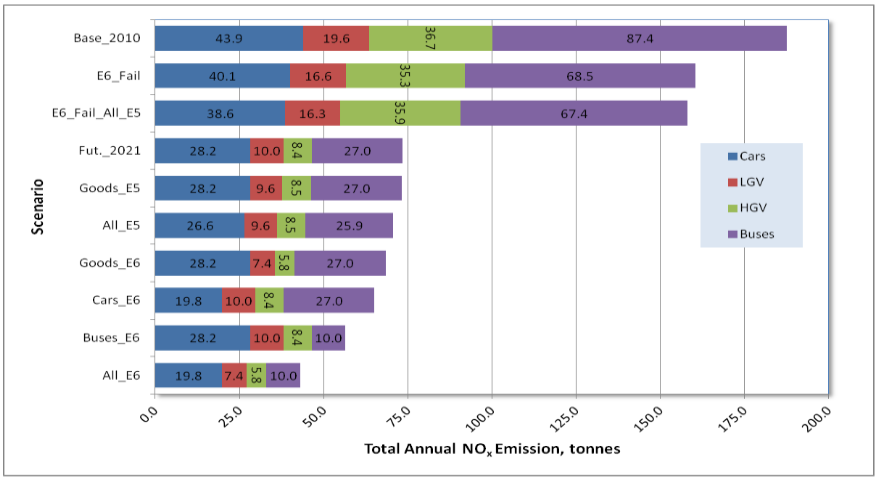

Figure: 1. Emissions of Oxides of Nitrogen in Newcastle Centre AQMA, for different scenarios

Even before any LEZ strategy is applied, simple fleet turnover, with increasing proportions of Euro 6/VI vehicles accounts for a 60% reduction in NO_x emissions. Further LEZ scenarios involving transition of vehicle classes to at least Euro 5/V were found to be relatively ineffective, providing only a further 2.4% reduction over the 2021 'do minimum' case. LEZ strategies based on compliance to Euro 6/VI standards within the city centre fared better, with up to a 77% reduction on the 2010 baseline. Similar reductions were modelled for the centre of Gateshead. The scenarios assuming no improvement of emissions through the introduction of Euro 6/VI, resulted in emissions that were only 16% lower than the 2010 baseline.
For other pollutants, total primary NO_2 emissions were modelled to decrease by 45% through general fleet turnover by 2021, with LEZ scenarios increasing the reduction to a maximum of 65%. Worryingly, the 'Euro 6/VI fail' scenarios produced 2021 primary NO_2 emissions that were comparable, if not higher than the baseline 2010 values, accepting the projected increase in traffic. Impacts of the LEZ scenarios on PM_{10} or $PM_{2.5}$ emissions were found to be relatively negligible compared to the 2021 'do minimum' scenario. For CO_2 emissions, there were small dis-benefits (+8%) calculated for the LEZ scenarios, given the fuel penalties suggested in the EFT data associated with additional particulate filter and catalyst use on public transport vehicles, coupled with general traffic growth.

Results for Concentrations

The left-hand side of Figure 2 shows the modelled concentrations for both Newcastle and Gateshead in the baseline 2010 scenario. The blue contour lines represent modelled areas were annual-NO_2 concentrations were considered 'high' (>35 $\mu g/m^3$), whilst the red contours show areas in exceedence of the 40 $\mu g/m^3$ limit. The right hand side of the figure shows the proportion of total NO_x emissions associated with each vehicle class. Figure 3 shows the same data, but for the 2021 'do-minimum' scenario.

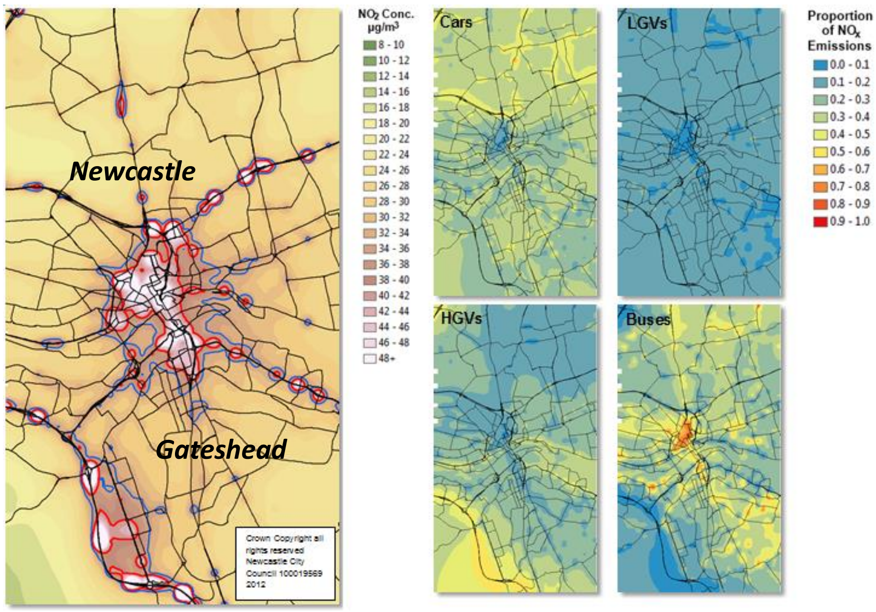

Figure 2. Concentrations of NO_2 and source apportionment of NO_x in the 2010 base case

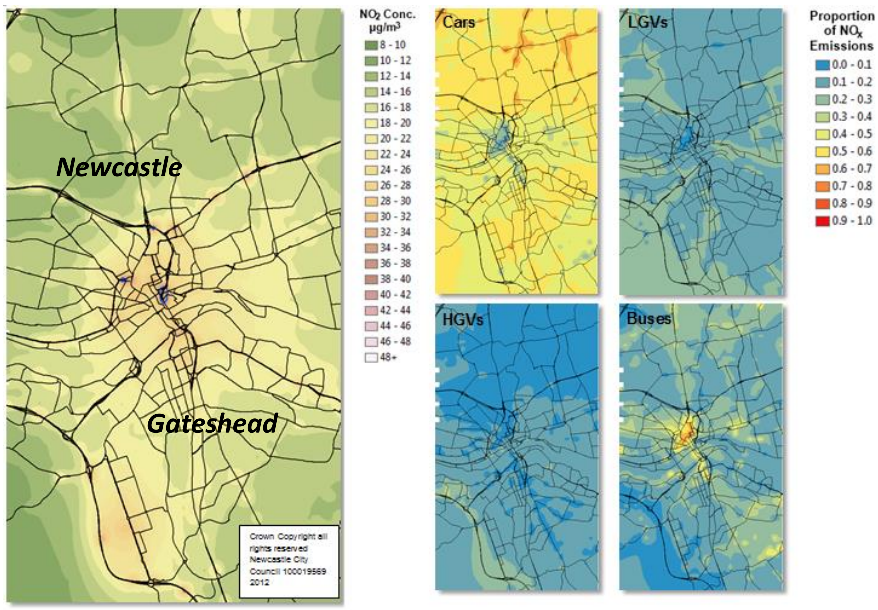

Figure 3. Concentrations of NO_2 and source apportionment of NO_x in the 2021 'do-minimum' case

Two things are immediately apparent from Figures 2 and 3: firstly, that in the 2010 baseline scenario there is clear evidence of air quality issues in both urban centres, and secondly, assuming the expected fleet turnover rates, improvements due to Euro 6/VI technologies and decreases in emissions from the sectors, problems with NO_2 disappear by 2021. Indeed, the general reduction across the city centres over the 2010 to 2021 period was approximately 15 $\mu g/m^3$. LEZ scenarios involving compliance to Euro 5/V standards achieved further mean reductions of the order of 0.0 – 0.3 $\mu g/m^3$, whilst those concentrating on Euro 6/VI achieved 0.3 to 2.0 $\mu g/m^3$ reductions. LEZ strategies affecting buses were associated with large reductions in the very central areas (i.e. adjacent to the major bus termini), whereas strategies affecting cars and goods vehicles had benefits spread more widely, especially on the periphery of the centres, dominated by strategic routes. Under the 'Euro 6 fail' options, however, mean reductions on 2010 levels were far more modest overall (around 4 – 5 $\mu g/m^3$ improvement), with technical exceedences of the limit value still occurring in the Newcastle AQMA.

CONCLUSIONS AND FURTHER WORK

Based on the initial results, further sensitivity analysis was undertaken, examining the effects of background contributions from other sources, and changes in primary fraction of NO_2 emissions (f-NO_2). The model was found to be far more sensitive to background NOx and O_3 assumptions, than to those for f-NO_2. Under any combination of background level or f-NO_2 assumptions, the rank ordering of LEZ options was fairly invariant – with Euro 5/V options performing poorly and Euro 6/VI options more robustly. The relative failure of the Euro 5/V options is in part due to assumptions on the lack of performance of Selective Catalytic Reduction (SCR) as a de-NOx technique in congested urban areas, present in the EFT factors. As would be expected, the 'all vehicles Euro 6/VI compliant' was consistently the best option. The 'Euro 6/VI' fail options raise the spectre of air quality problems potentially still existing into the next decade, and demonstrate the crucial requirement of Euro 6/VI meeting expectations, both within the model, and in reality. Additionally, the results showed deterioration in future GHG emissions within the city centres. At present, further work is being undertaken by the University to improve the spatial resolution of results, and the definition of street canyon environments within the central areas of both cities.

ACKNOWLEDGEMENTS:

The authors wish to acknowledge the support of both Newcastle City Council and Gateshead Council, alongside contributions from Capita Symonds, NEXUS, regional bus operators (Arriva, Go North East and Stagecoach) and colleagues at Newcastle University. The work was funded through a DEFRA Air Quality Grants scheme.

References:

CERC (2011) *ADMS-Urban, An Air-Quality Management System, User Guide Version 3.1, September 2011*. Cambridge Environmental Research Consultants Ltd. Cambridge, UK.

DEFRA (2012a) *Emission Factors Toolkit for Vehicle Emissions (Version 5.1.3. August 2012 Update).* (Online resource) Department for Environment, Food and Rural Affairs. http://laqm.defra.gov.uk/documents/EFT_Version_5_1_3.zip (Accessed: 29/5/14).

DEFRA (2012b) *2010-Based Background Maps for NO_x, NO_2, PM_{10} and $PM_{2.5}$*. (Online resource) Department of Environment, Food and Rural Affairs. http://laqm.defra.gov.uk/maps/maps2010.html (Accessed: 29/5/14)

DEFRA (2012c) *NO_x to NO_2 Calculator. Version 3.2. September 2012.* (Online resource) Department of Environment, Food and Rural Affairs. http://laqm.defra.gov.uk/documents/NOx-NO2-Calculator-v3.2.xls (Accessed: 29/5/14)

DEFRA (2014) *Air Quality Management Areas (AQMAs)* (Online resource). Department of Environment, Food and Rural Affairs. http://uk-air.defra.gov.uk/aqma/ (accessed: 29/05/14).

EC (2014) *Low Emission Zones (LEZs)* (Online resource). Provided for the European Commission by CLARS (Charging, *Low Emission Zones*, other Access Regulation Schemes). http://www.lowemissionzones.eu/ (accessed: 29/05/14).

Goodman P, Galatioto F, Namdeo A and Bell, Margaret C. (2014). *Newcastle/Gateshead Low-Emission Zone Feasibility Study: Vehicle Emissions and Air-quality Modelling*. Report to DEFRA by Newcastle University on behalf of Newcastle City Council, Gateshead Borough Council.

Jacobs (2008). *Tyne and Wear Transport Planning Model (TPM). Technical Note Submitted to the Joint Transport Working Group of the Tyne and Wear Authorities. TN1: TPM Overview and Completion Report.* Jacobs Consultancy Report Published: May 2008.

Namdeo A and Goodman P (2012) *Platform for Integrated Traffic, Health and Environmental Modelling (PITHEM).* Better Air Quality 2012 Conference, Hong Kong, 5-6th December 2012.