Ricardo Energy & Environment

Additional evidence to M4 Smart Motorway specific issues hearing of November 17th, 2015

Dr Scott Hamilton, Ricardo Energy and Environment

Report for Slough Borough Council

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Table of contents

1 Introduction

This note provides additional evidence to the issue specific hearing pertaining to the Application by Highways England for an Order Granting Development Consent for the M4 Junctions 3 to 12 Smart Motorway (Case ref. TR010019).

In the text that follows I will make specific reference to the questions that arose at the hearing so that the textual evidence I provide can be placed in context and to aid the Inspectorate in their deliberations. I will highlight the references to the appropriate questions as they appear in the "Issue Specific Hearing Agenda" e.g. Section C Air Quality, Question 1.

1.1 Personal details

My name is Dr Scott Hamilton (BSc, PhD, CSci. MIAQM, MIEnvSc). I am an environmental scientist specialising in air pollution modelling, with a particular emphasis on road traffic emissions and dispersion. I am the technical lead on urban air quality modelling at Ricardo Energy and Environment (formerly AEA Technology). I have over 15 years of experience in modelling and measuring air pollution from all types of sources and have worked in the UK, Europe and Asia applying my skills to large air quality issues arising from road traffic. I am fully conversant in all modelling methods used by the applicant having applied the same tools in many instances in my own work at home and abroad.

1.2 Commission by Slough Borough Council

I have been commissioned by Slough Borough Council to offer expert advice to them with specific regard to the M4 Smart Motorway project and how it might affect the air pollution climate at sensitive receptors during the operational phase of the scheme. I represented Slough Borough Council at the "issues specific hearing" on November 17th and offered specific concerns and recommendations to the Inspector with regard to the potential impacts of the scheme, how future air pollution levels have been calculated and what options exist for mitigation of impacts at key hotspots in Slough near the M4.

1.3 Topics covered in this note

At the hearing we provided our thoughts on the questions as laid before us pertaining to air pollution effects of the scheme. Slough Borough Council is concerned not only about the effects of the scheme, but the effects of the M4 on air pollution in Slough now and in the future, with or without the scheme.

This note is not intended to replace the Local Impact Report already submitted and is mainly offered to provide additional evidence and discussion around key points that arose during the proceedings on the 17th of November. In addition I would like to take this opportunity to describe some additional concerns that I share with SBC with regard to the outcomes of the work undertaken for air quality given we have now had the opportunity to hear the methodology tested in the hearing.

I will provide full references to all quantitative data sources and will provide the source documents as well in a separate file submission to the Council, who will then submit these to the Inspectorate on or before November 26th 2015.

2 Characterisation of future NO_2 concentrations in Slough

2.1 Uncertainties

Relevant questions from the hearing:

Traffic growth forecasts- Question 9, Question 10, Question 12

All air quality questions pertaining to modelling are relevant to the evidence in this section (including the question 29 on the HIA).

We heard during the hearing that what would appear to be quite significant levels of uncertainty exist in the air quality baseline assessment. There a number of reasons for our concerns in this regard. Mainly these relate to uncertainties that compound as the modelling chain proceeds from traffic assessment, through emissions calculations, through dispersion modelling and finally future year forecasting.

The question of particular concern for Slough Borough Council is whether the future projections of compliance with air quality standards in Slough provided by Highways England are realistic and perhaps more importantly, conservative. In any modelling situation conservatism is used to effectively deal with uncertainty as we can never be absolutely sure of projections of air quality even into the quite near future. Our position is clear- when the future pollution climate along a road that is already causing air quality breaches is uncertain, mitigation should be explored.

The issue is further complicated by the fact that Slough's most exposed receptors are forecast in the ES) to experience levels of NO_2 very close to the annual mean UK air quality objective (and EU Limit Value which is numerically exactly the same being set at 40 micrograms per metre cubed as an annual mean). This means that even slight uncertainty in the projected levels in 2022 could cause exceedances of the standards where forecast levels are below the standard. If significant uncertainties exist in the work (say in the order of 10% of the standard being assessed- this equates to 4 μgm^3 of NO_2) then clearly the scheme will be operating in a quite different baseline air quality environment and should be viewed on that basis.

Some receptors in Slough are forecast to breach (albeit slightly) the NO_2 standard in the modelling as it stands, and their exposure could be higher if the uncertainty has resulted in underestimates of traffic generation or resulting emissions.

Slough Borough Council were encouraged by the comments from HM Inspectorate of Planning in opening statements that the scheme should promote "enhancement" of the environment. If the air quality modelling is accepted as being uncertain, we would prefer mitigation were provided to achieve the stated aspirations of the Inspector by seeking to reduce existing exposure to exceedances of NO_2 standards, whilst also providing mitigation against the increases projected for the scheme in 2022.

I would like to offer the following general comments about uncertainties I see in the "modelling chain" as outlined at the issues hearing.

1) The traffic model outlined at the hearing is underpinned by national traffic forecasts which will themselves carry some uncertainty.
2) The forecasts are then used in the trip end model which I understand can also carry uncertainty due to the spatial allocation of trips potentially not fully representing the fine detail of local conditions.
3) The road traffic model then provides speed and flows which can be passed to air and noise assessment methods. These are the two most fundamental variables in the emissions calculations (other than fleet mix and age) so any error in this step carries forward.
4) These flows and speed are then entered into emissions calculations, which even if the baseline traffic model was 100% certain, would add uncertainty by virtue of the emissions factors being average representations of vehicle emissions. The traffic model is not 100% certain.
5) The emissions data is then passed to a dispersion model (in this case ADMS Roads). ADMS Roads[1] is based on Gaussian dispersion algorithms that were empirically derived in the 1950s. These were primarily designed to describe plume dispersion from tall stacks, though parameterisations have since been developed to include line, area and volume sources. Traffic is treated as a series of line sources in the model. The mathematical treatment of the sources and how they affect very close receptors is still extremely basic (though this comment is not directed towards the applicant, ADMS Roads is the industry standard road traffic dispersion model in the UK). That said the use of flat topography in the model means that the

[1] http://www.cerc.co.uk/environmental-software/ADMS-Roads-model.html

model does not fully (or even attempt to) represent turbulent flow regimes that will exist around the motorway due to the interaction of winds and the surface topography. All told this means that the transport of the pollutants from the source to the receptors is quite uncertain though the use of model correction factors goes some way to deal with this empirically.

6) When concentrations have been calculated, Defra's NOx to NO_2 model[2] is used to convert annual average NOx (from the model) to annual average NO_2 (for comparing with standards). Again this process is derived from an empirical model which uses quite broad assumptions with regard to available ozone to titrate NOx to NO_2 and the reaction kinetics involved. This adds uncertainty in the ratio (or rate of formation) of NOx from road traffic to the NO_2 that is experienced by the receptor.

7) Also the tool relies on projections of the amount of "primary NO_2" that is released by the vehicles[3]- this is the proportion of NOx emissions released as NO_2 at the exhaust and is an important factor in NO_2 concentrations at receptors (more primary NO_2 = more total NO_2 at receptors). Nitrogen oxides (NOx) are emitted in the form of nitric oxide (NO) and nitrogen dioxide (NO_2). The fraction emitted directly as NO_2 (f-NO_2) is of particular interest for air quality modelling. Since NOx is not a regulated pollutant but NO_2 is, any uncertainty in this calculation means that the final estimate of NO_2 is subject to some uncertainty all other things being equal. There is actually no way to know how reliable the future levels of ozone assumed in the model are given the regulatory response to ozone (both in the UK and Europe) is extremely complex and involves regulation of volatile organic compounds, NOx and other precursor emissions.

8) There is a fundamental difference between model ***evaluation***, and assessing its power of ***prediction***. In this instance my understanding is that the model has been ***evaluated*** - that is to say its performance is checked against local measurements and adjustments made to account for any biases (usually under-prediction). This is not the same as to assess the model's predictive power which is important when considering whether the model can represent 2022 with the accuracy implied by providing results to three significant figures in the Environmental Statement - this would typically be done by assigning a training set of measurements (say 50% of the available NO_2 measurements, and asking the model to predict values at a validation set of measurements, the other 50% of measurements not included in the training set). In practice this is not commonly done in air quality assessments (probably due to the usual lack of AQ measurements) which may go some way to explain why model predictions of future conditions can be inaccurate.

   A recent review of modelling by Defra[4] stated that

   > *" **the ability of an air quality model to reproduce measured concentrations from the past does not guarantee its adequacy for the future** or for predicting the response to pollution control strategies. Agreement with observations is inherently partial. Models agree with some observations but not all. A model can certainly perform well against historic observations and the precision and accuracy of the fit can be quantified. The performance of models can be evaluated relative to past observations, relative to other models or against our own theoretical expectations, but **the performance of a model, especially for future projections of concentrations, cannot be ascertained precisely. Nevertheless, the comparison of model predictions against past observations is a good first step in the evaluation of model performance**".*

9) Model adjustment factors are calculated to account for some of the uncertainties, but these can only be considered reliable for the year of the measurements used to underpin the calculation. Projecting into the future assumes that the predictive power of the model is the same, which is difficult to ascertain.

10) The NO_2 modelling is then scaled forward to 2022 in tandem with the traffic models. Any time a model is projected forward uncertainty builds further. At the point of scheme opening in 2022, the modelling relies on several things being correct. These can be summarised thus:

[2] http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html
[3] http://naei.defra.gov.uk/resources/Primary_NO2_Emission_Factors_for_Road_Vehicles_NAEI_Base_2013_v1.pdf
[4] http://uk-air.defra.gov.uk/assets/documents/reports/cat05/1006241607_100608_MIP_Final_Version.pdf

a. The traffic model must be accurate when there is actually no way to know if this will be true or not.

b. Background concentrations of air pollution forecast by Defra[5,6] and used in the modelling must be accurate when in actual fact these carry significant uncertainty (See point 11 below).

c. Forecast emissions of NOx (and primary NO_2) from road traffic must be accurate whereas this is known from recent experience to be open to question. This reference (open access) written by my colleague Dr David Carslaw demonstrates the lack of NOx reduction from diesel vehicles in recent years in the UK[7].

d. The NOx to NO_2 conversion calculation relies on values for ozone concentration and levels of primary NO_2 emissions that may not be accurate in 2022 so the calculated ratios of NOx to NO_2 may be uncertain. This relates back to the item above pertaining to accuracy of future background forecasts.

11) It is instructive to note the levels of uncertainty (also called "data quality") that are achieved in monitoring and modelling prescribed by the European Commission for assessing against the European Limit Values[8]. The below is a quote from their "Position Paper on Air Quality: Nitrogen Dioxide" as referenced in the footnotes of this document:

> *"The following data quality objectives that can be achieved through the implementation of this QA/QC programme are:*
>
> - *Continuous or semi-continuous measurements: 15% (individual measurements)*
> - ***Indicative measurements: 25% (individual measurements)***
> - ***Modelling 30 - 50% (may be different for daily, monthly or yearly averages)***
> - *Objective estimation: 50 to 100%*

The NO_2 modelling can be viewed in the light of these for the following reasons:

- The indicative measurements referenced above are usually taken using diffusion tubes, as has been done for the ES modelling - so these have up to 25% uncertainty even for current conditions
- The modelling done in the UK by Defra to provide the background maps used in the air quality models in the ES have the same data quality as the modelling standard above. This is because they are derived from the same model (usually referred to as the PCM model[9]) which is designed firstly to meet the data quality standards prescribed by the EC, and then secondly to provide the background maps. Therefore the background maps can be considered to carry error of a similar magnitude for any given 1km grid square in the UK, including Slough.

Given these uncertainties it does not seem reasonable that Slough Borough Council should accept the implied accuracy of the air quality modelling assessment. Representing the modelled values to three significant figures implies a high level of precision and accuracy in the results, which we would argue cannot be guaranteed here.

However, Slough Borough Council and I agree that some pragmatism is required here. We agree that the modelling has been done largely following accepted guidance but we would like the applicant to accept that the modelling nevertheless carries potentially significant uncertainty (equal to at least 10% of the NO_2 standard, or 4 μgm^3 of NO_2 as an annual average) and explore mitigation options that are based on conservatism of future NO_2 concentrations. As a safety measure, perhaps mitigation should be targeted at locations in Slough where the projected NO_2 concentrations are 36 $\mu g/m^3$ (or higher) of NO_2 as an annual average - this would offer some protection to human health at compromised areas, but still allow for progression of the scheme.

Perhaps mitigation should also provide for HM Inspectorate of Planning stated aims (at the hearing of November 17th) of environmental "enhancement" as well. This would represent a significant step

[5] http://laqm.defra.gov.uk/documents/Background-maps-user-guide-v1.0.pdf
[6] http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html
[7] Carslaw, D.C. and Rhys-Tyler, G. (2013). New insights from comprehensive on-road measurements of NOx, NO2 and NH3 from vehicle emission remote sensing in London, UK. Atmospheric Environment, Vol. 81 339-347
[8] http://ec.europa.eu/environment/archives/air/pdf/pp_no2.pdf
[9] http://uk-air.defra.gov.uk/research/air-quality-modelling?view=modelling

towards Slough Borough Council achieving its aims of removing all exceedances of the annual mean NO_2 standards within the Borough and show Highways England's commitment to improving air quality.

I now turn to providing additional documentary evidence which backs up my oral evidence from the hearing.

3 Barriers for air quality mitigation

Relevant questions from the hearing

Air Quality Mitigation measures- Questions 25, 26, 27, 28

I have already provided evidence to the Inspectorate on the potential impacts on air quality of roadside barriers - this was included in Appendix 1 of Slough Borough Council's Local Impacts Report[10]. It is our considered view that Slough Borough Council should, in light of the obvious uncertainties in future projected NO_2 concentrations in 2022, seek a thorough investigation by the applicant of barriers as a potential mitigation strategy at locations along the M4 where values of greater than 36 $\mu g/m^3$ of NO_2 as an annual average are predicted in the ES air quality modelling.

The Council cannot realistically be expected to impact on the emissions from the road traffic on the M4 as it has little or no control over this source - yet it must try under the LAQM legislation. This appears a quite futile exercise without the help of key partners like Highways England.

The Council also cannot affect the location of receptors close to the road (and which are in effect brought closer by virtue of using the hard shoulder). It can however seek mitigation with regard to modification of the source/receptor pathway as a means to reduce exposure to air pollution. Again we would reiterate that we were grateful to hear that HM Inspectorate of Planning seek "enhancement" of existing conditions, and not merely mitigation of added pollution from the scheme.

The potential scale of effectiveness of roadside barriers for mitigating high NO_2 concentrations in Slough's exposed receptors is still a somewhat open question, although a quite significant body of scientific evidence is emerging that barriers could be effective. During the hearing I committed to providing documentary evidence as to the potential effects of barriers. To assist HM Inspectorate of Planning in their deliberations I have provided these papers as a separate submission, but I also paraphrase the conclusions of these papers in the bullet points below.

The papers provided (and paraphrased are as follows)

1) *"Dutch Air Quality Innovation Programme concluded"* Rijkswaterstaat Center for Transport and Navigation (2010) : accessed via http://laqm.defra.gov.uk/documents/Dutch_Air_Quality_Innovation_Programme.pdf
2) "*Examples of air quality measures near roads within Europe, National measures of the international CEDR air quality group*", P.B. van Breugel et al (2005) : accessed via https://www.hoevelakenbereikbaar.nl/www2/MilieuZaken/luchtkwaliteit/Examples-air-quality-measures-near-roads-in-europe-200507.pdf
3) "*Passive methods for improving air quality in the built environment: A review of porous and solid barriers*", John Gallagher et al, Atmospheric Environment 120 (2015) 61-70 : accessed via http://www.sciencedirect.com/science/article/pii/S1352231015303204
4) *"Model evaluation of roadside barrier impact on near-road air pollution",* Gayle S.W. Hagler, Atmospheric Environment 45 (2011) 2522- 2530 : accessed via http://www.sciencedirect.com/science/article/pii/S1352231011001646
5) *"Field investigation of roadside vegetative and structural barrier impact on near-road ultrafine particle concentrations under a variety of wind conditions",* Gayle S.W. Hagler et al, Science of the Total Environment 419 (2012) 7–15: accessed via http://www.sciencedirect.com/science/article/pii/S0048969711014070

[10] Appendix 1: Local Impact Report for Slough Borough Council Development Consent Order Application for M4 Smart Motorway Junctions 3 to 12, 8th October 2015

6) *"Sound wall barriers: Near roadway dispersion under neutrally stratified boundary layer",* Sam Pournazeri et al, Transportation Research Part D 41 (2015) 386–400 : accessed via http://www.sciencedirect.com/science/article/pii/S1361920915001492

3.1 Conclusions of research literature on barriers

3.1.1 "Dutch Air Quality Innovation Programme concluded" Rijkswaterstaat Center for Transport and Navigation (2010)

"Noise barriers reduce concentrations of nitrogen oxides and airborne particulates along motorways. That is the conclusion drawn by (international) air quality experts based on the measurements obtained during two years of large-scale practical trials. The data were recorded at the Barrier Test Site, the experimental station set up by the Air Quality Innovation Programme, IPL, along the A28 at Putten.

From literature and wind tunnel studies it had already been concluded that noise barriers might make a significant contribution to improving air quality. In May 2007, IPL therefore organised a competition challenging companies to come up with innovative barrier designs having an additional impact on air quality compared with conventional barriers. This led to a large number of innovative noise barriers. Some of these were tested in a practical setting, others in the laboratory. Nowhere in the world had such large-scale practical trials previously been conducted in the context of air quality."

"At three distances behind the barriers the concentrations of nitrogen oxides and particulates were measured. At the locations behind the barriers this led to a reduction in levels of nitrogen dioxide, nitrogen oxides and particulates. The impact of noise barriers on air quality has thus been demonstrated."

3.1.2 "Examples of air quality measures near roads within Europe, National measures of the international CEDR air quality group", P.B. van Breugel et al (2005)

"The pollution is reduced by 20 to 10% depending on the distance from the barrier." (for upwind receptors and 45 degree winds in relation to the barrier)

"The pollution is reduced by 20 to 10% depending on the distance from the barrier, as shown by the following curves." (for upwind receptors and winds perpendicular to the barrier)

90° Wind (perpendicular)

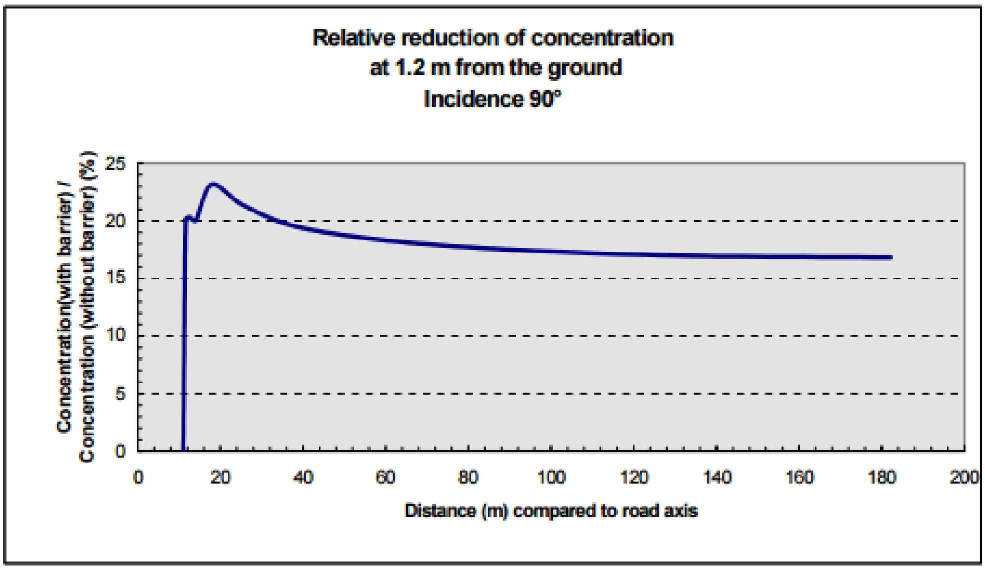


Figure 3 Relative reduction of concentration at 1.2 m from the ground.

Source: Examples of air quality measures near roads within Europe, National measures of the international CEDR air quality group", P.B. van Breugel et al (2005)

3.1.3 *"Passive methods for improving air quality in the built environment: A review of porous and solid barriers", John Gallagher et al, Atmospheric Environment 120 (2015) 61-70*

"Noise barriers are commonly placed on major high-speed highways to reduce noise pollution for populated areas, but these barriers can also influence localised dispersion and have been shown to improve downwind air quality".

"The measurements reported by (Baldauf et al., 2008) for PM and CO demonstrated that the introduction of a noise barrier reduced pollutant concentrations behind the barrier by approximately 15% but at times reached 50%. With the inclusion of a barrier, the modelling results suggested that a reduction in pollutant concentrations would be achieved further downwind (Bowker et al., 2007)".

"The work by Ning et al. (2010) measured the size distribution of particulate concentrations and several other pollutants in two case studies of urban freeways. Very similar results were noted in this study for PM number concentrations, with reductions in the 45-50% range downwind of the barrier. Tracer pollutant investigations reported by Finn et al. (2010) demonstrated the potential for noise barriers to improve air quality by over 50% downwind of the barrier during certain meteorological conditions such as stable atmospheres.

The results of another tracer (C_2H_6) modelling investigation by Hagler et al. (2011) ranging from 15 to 61% and dependent on the height of the barrier (higher the barrier, the greater the downwind pollutant reduction)".

"The potential of noise barriers to affect pollutant transport and dispersion is influenced by the size and layout of the barrier, wind direction and turbulence conditions (Finn et al., 2010; Hagler et al., 2011; Jeong, 2014; Schulte et al., 2014; Steffens et al., 2014, 2013). As previously noted, results measured by Hagler et al. (2011) showed reductions in pollutant concentrations of up to 61%, with improved air quality conditions associated with an increase in the barrier height".

"The findings demonstrate that a reduction in pollutant concentrations occurs downwind of the barrier. In some cases, this downwind location may be a densely populated area, therefore implementing this type of barrier may help improve air quality conditions for urban inhabitants. Studies have also demonstrated the potential negative impact of increased concentrations of pollutant on the roadside of the barrier if vehicle turbulence does not increase mixing and dilution. Noise barriers can reduce downwind pollutant concentrations and further investigations can provide transferable results to ensure these solid barriers provide simultaneous air and noise quality benefits".

"Yet, it has to be recognised that their effectiveness is dependent on local geometrical and meteorological conditions, as this is what affects localised dispersion and turbulence in the built environment".

3.1.4 *"Model evaluation of roadside barrier impact on near-road air pollution", Gayle S.W. Hagler, Atmospheric Environment 45 (2011) 2522- 2530*

"Under winds perpendicular to the road, CFD model simulations show that roadside barriers reduce the concentration of an inert gaseous tracer (c), relative to a no-barrier situation, vertically up to approximately half the barrier height and at all horizontal distances from the road. At 20 m (3.3H, where H = 6 m) from the road, barriers of heights ranging from 0.5H to 3.0H reduce the maximum concentrations by 15-61% relative to a no-barrier case, with the location of the maximum shifted to occur near the top of the barrier".

"These results imply that roadside barriers may mitigate near-road air pollution, although local meteorology, the barrier structure, and the degree of lee-side emission sources are critical factors determining the outcome".

"If roadside structural and/or vegetative barriers are shown to improve air quality, the added air quality benefit may justify the addition of barriers to existing roadside developments or the preservation of existing roadside barriers".

3.1.5 "Field investigation of roadside vegetative and structural barrier impact on near-road ultrafine particle concentrations under a variety of wind conditions", Gayle S.W. Hagler et al, Science of the Total Environment 419 (2012)

"If roadside noise barriers or tree stands are found to consistently lower ground-level air pollution concentrations in the near-road environment, this may be a practical strategy for reducing exposures to air contaminants along populated traffic corridors. This study measured ultrafine particle (UFP) concentrations using an instrumented mobile measurement approach, collecting data on major roadways and in near-road locations for more than forty sampling sessions at three locations in central North Carolina, USA. Two of the sampling sites had relatively thin tree stands, one evergreen and one deciduous, along a portion of the roadway. The third sampling site had a brick noisewall along a portion of the road".

"At 10m from the road, UFPs measured using a mobile sampling platform were lower by approximately 50% behind the brick noise wall relative to a nearby location without a barrier for multiple meteorological conditions".

3.1.6 "Sound wall barriers: Near roadway dispersion under neutrally stratified boundary layer", Sam Pournazeri et al, Transportation Research Part D 41 (2015) 386–400

"In conclusion, results from this study show that roadside structure such as sound barriers, reduce both on-road as well as downwind ground level concentrations by enhancing the mixing of the pollutants and elevating the plume by a length scape proportional to the barrier heights.

"It is anticipated that diesel $PM_{2.5}$ emissions will be reduced by 50% from anticipated levels between 2015 and 2023 as compared to a scenario without the rule in place. Although the implementation of this regulation can significantly reduce near-roadway exposure to diesel exhaust PM, more health protection strategies are required. This paper supports the deployment of sound walls as a strategy to reduce the exposures to emissions from cars; however, it does not provide any insight on impact of the roadside structures on emissions released at 3–4 m above the roadway".

4 Evidence on potentially failing Euro 6 standards from Europe

4.1 Reason for submission of this evidence

At the hearing I committed to providing some literature on the issue of Euro 6 standards potentially not providing anticipated benefits in NOx emission reduction. This is summarised below and provided as a separate document submission.

Relevant questions from the hearing

Air Quality Assessment of effects Question 10, Question 11, and Question 15

4.1.1 "Real-world exhaust emissions from modern diesel cars, a meta-analysis of PEMS emissions data from EU (EURO 6) and US (Tier 2 Bin 5/ULEVII) diesel passenger cars", Vincente Franco et al, ICCT, 2014

In a significant research programme[11] conducted by the International Council on Clean Transportation (ICCT) there is strong evidence to suggest existing Euro 6 diesel vehicles in Europe greatly exceed their NOx emissions standards. Passages from the document are provided below.

"This study analyzed the on-road emissions performance of fifteen new diesel passenger cars, twelve certified to the Euro 6 standard and three to the US equivalent (Tier 2 Bin 5), using portable emissions measurement systems (PEMS), which provide a continuous stream of vehicle data signals including emission rates, velocity, acceleration, road gradient and exhaust temperature.

[11] http://www.theicct.org/real-world-exhaust-emissions-modern-diesel-cars

Emissions were measured over 97 trips, totalling more than 140 hours of operation and 6,400 kilometres driven. The high temporal and spatial resolution of PEMS datasets permitted the analysis to link elevated NOx mass emission rates to the driving conditions that caused them.

This is the first systematic analysis of the real-world performance of modern diesel passenger cars, and the most comprehensive profile available of the on-road behaviour of the latest generation of diesel passenger cars".

On average, real-world NOx emissions from the tested vehicles were about seven times higher than the limits set by the Euro 6 standard. If applied to the entire new vehicle fleet, this would correspond to an on-road level of about 560 mg/km of NOx (compared to the regulatory limit under Euro 6 of 80 mg/km). *This is compelling evidence of a real-world NOx compliance issue for recent-technology diesel passenger cars, for both the EU and US test vehicles."*

The figure below is taken from the ICCT report and shows graphically the scale of the NOx over emissions from the Euro 6 diesel cars. Almost all of the vehicles exceeded the standard set for Euro 5 as well.

The acronyms in the diagram pertain to the NOx abatement system employed which is supposed to reduce emissions in the diesel vehicles to Euro 6 levels - the two main abatement systems employ Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR). There is actually no such thing as a "no-abatement required" Euro 6 engine, all require abatement as part of their design to attempt to achieve the standard.

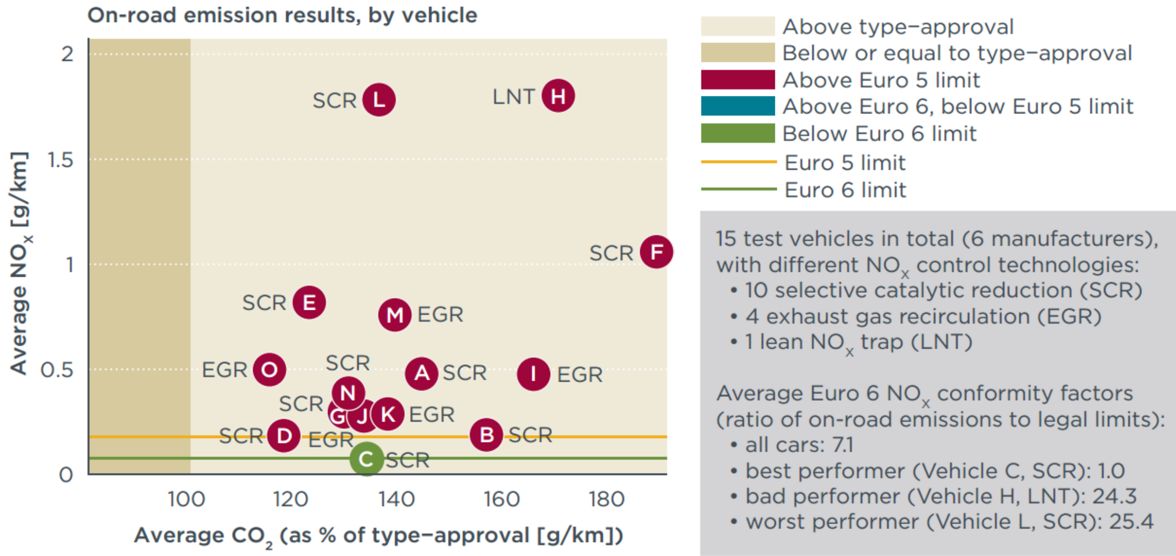
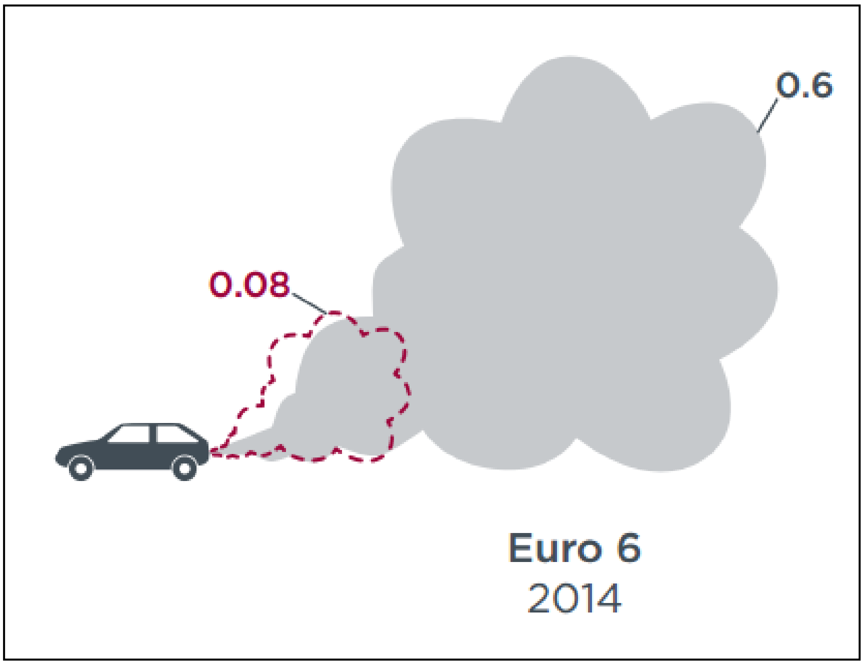


Figure 1. On-road emissions of nitrogen oxides (NO_x) from 15 Euro 6-equivalent diesel passenger cars, as measured by portable emissions measurement systems (PEMS)

Source: http://www.theicct.org/sites/default/files/ICCT_PEMS-study_diesel-cars_2014_factsheet_EN.pdf

This diagram shows the difference between the anticipated Euro 6 emission levels, and the average measured value during the ICCT study.



Source: http://www.theicct.org/sites/default/files/ICCT_PEMS-study_diesel-cars_2014_factsheet_EN.pdf

This evidence would suggest that a cautious approach is warranted when trying to estimate future NOx emissions from diesel vehicles, which are forecast to make up over half of the fleet in the UK at the time of the scheme opening. **In fact for motorways the expected split between petrol and diesel in the road fleet in 2022 is 33% and 67% respectively[12].** This makes issues with Euro 6 performance in future years particularly pressing when attempting to characterise future NO_2 concentrations in Slough near the M4.

5 Results based on application of previous Long Term Trends (LTT) methodology

Relevant questions from the hearing

Air Quality Question 9, Question 11, Question 15

My calculations using the previous LTT method suggest much higher concentrations for 2022 in Slough for the base case. The calculations below are based on scaling the values reported in the ES but using the methodology outlined in the *"Interim Advice Note 174/13- Updated advice for evaluating significant local air quality effects for users of DMRB Volume 11, Section 3, Part 1 'Air Quality (HA207/07)".* I understand this document is already included in evidence to the Inspectorate.

To show the effect of the rescaling according to this methodology I have used receptors in Slough presented in "Results for All Receptors, Appendix 6.6, Page 14" of the ES. The results of the new analysis add about 11 $\mu g/m^3$ of NO_2 as an annual average to the 2022 results with some receptors seeing concentrations well above 50 $\mu g/m^3$. I argued at the hearing that Highways England should be seeking to mitigate existing high concentrations along the M4 regardless of the scheme progression and should not rely on engine standards delivering the required reductions in NO_2 concentrations.

If the concentrations in the order of 50 $\mu g/m^3$ are indeed realised in 2022, but say where mitigation has been ruled out by the Inspectorate during these proceedings, Slough Borough Council will seek

[12] Proportion of VKM by Fuel, Road Type and Devolved Administration IN rtp_fleet_projection_Base2013_v3.0_final, National Atmospheric Emissions Inventory, 17.6.14, accessed via http://naei.defra.gov.uk/resources/rtp_fleet_projection_Base2013_v3.0_final.xlsx

assurances from Highways England that mitigation will be installed post-scheme as their evidence base will have been proven to be too optimistic about future NO_2 concentrations falling with time. Otherwise Slough Borough Council will be in a position of taking on a regulatory burden of trying to reduce emissions on a road they have no control over, but were assured that would not cause future exceedances of the NO_2 standard during these proceedings.

A useful comparison could be made with regulation of industrial pollution - if an operator of an industrial process proposed levels of any air pollutant that turned out through the passage of time to be false and limits were exceeded, they would be mandated to mitigate those effects (through process engineering) by environmental regulators. NO_2 from an industrial source is no different to NO_2 from a road source and receptors will see the same effects, so I would argue that similar guarantees are appropriate to a scheme of this nature.

The table in the Appendices provides the results of the rescaled receptors in Slough.

6 Barrier locations

Relevant questions from the hearing

Air Quality Mitigation measures- Questions 25, 26, 27, 28

Slough Borough Council will seek mitigation wherever the projected concentrations of NO_2 exceed 36 $\mu g/m^3$ as an annual average. We expect that the applicant will conduct their own analysis and advise Slough Borough Council as to the locations and necessary barrier heights and designs. Slough Borough Council do not have the resources to make these detailed technical investigations.

7 Continuous monitoring location

Relevant questions from the hearing:

Air quality Question 30

Slough Borough Council would like an automatic monitoring station for both NOx/NO_2 and $PM_{10}/_{2.5}$. This should be placed near our station at Chalvey but at a distance from the road more representative of the worst case receptor concentrations. Slough Borough Council will offer advice on siting of the monitoring station when the applicant accepts the request to install one.

8 SBC concerns over impacts on their AQMAs

Relevant questions from the hearing:

Air quality Question 3, Question 4, Question 5, Question 16

Specific to Q3 there has been no attempt to characterise the effects of the scheme on Slough Borough Council's existing AQMAs. This should be rectified by additional modelling by the applicant which Slough Borough Council will be happy to support with air quality monitoring data where available. If the Inspectorate accepts the need for the applicant to undertake this additional modelling Slough Borough Council will fully engage with the methodological discussions that would have to take place. We would advise that Slough Borough Council seek a conservative assessment given their Low Emission Strategy is currently being prepared and the scheme could negate some of that effort (which is supported by Defra funding and policy) - any negative air quality impact on their AQMAs would contradict the stated aims of the Low Emission Strategy which could call its potential effectiveness into doubt.

Specific to Q4, Slough Borough Council have no evidence before them to comment on this hence the recommendation under Question 3.

Specific to Q5 Slough Borough Council recommend that their AQMAs are modelled by the applicant in order to better understand the effect on their AQMAs. This requires an obvious expansion in study area.

Specific to question 16 - Slough Borough Council are concerned that the location of a construction phase depot in the Brands Hill AQMA will compromise their efforts in their Low Emission Strategy and would suggest it is re-sited to an area where air quality is less of a sensitivity. Slough Borough Council prefer the screening criteria for additional traffic set out in the EPUK/IAQM guidance in any event.

9 Feedback on Health Impact Assessment

Relevant questions from the hearing

Air Quality Question 29

I have no feedback to provide on the HIA as I did not review the document during my deliberations on behalf of Slough Borough Council. That said, my discussions around uncertainty has raised several sources of potential error in the future NO_2 projections. Any error in these NO_2 concentrations will have carried forward into the HIA.

10 Other matters

10.1 Typical barrier designs

Relevant questions from the hearing

Air Quality Mitigation measures- Questions 25, 26, 27, 28

To assist the Inspectorate in their deliberations I have sourced some typical designs for roadside barriers that are of the height that the scientific evidence suggests could reduce off road concentrations of air pollution. These are provided below.

10.2 Image showing Spackman's Way existing barriers and view from the street to M4

Relevant questions from the hearing

Air quality Question 27

The purpose of this image is to show the existing roadside barriers at the Spackmans Way site in Slough. In addition I have provided a view looking back to the motorway from the street - this is shown in the inset of the image below. There are quite significant obstacles between the street and the view to the motorway which would potentially offset some of the visual impacts of roadside barriers (at least from the street).

Existing barriers- Spackmans Way

APPENDIX 1 – Results of application of the previous LTT projection method on NO_2 concentrations in 2022

Environmental Statement version

Receptor ID	Drawing	x	y	2013 Base NO2 (ugm3)	Projected 2022 Base NO2 (ugm3)	2022- Do Min NO2 (ugm3)	2022- Do Som NO2 (ugm3)	LTT 2022 Do-Min NO2 (ugm3)	LTT 2022 Do-Som NO2 (ugm3)
A247	6.11c	496222	179222	51.6	32.2	33.5	34.5	39.4	**40.7**
A248	6.11c	496225	179218	51.5	32.2	33.4	34.5	39.3	**40.6**
A249	6.11c	496229	179209	51.6	32.3	33.5	34.6	39.4	**40.8**
A250	6.11c	496231	179205	51.9	32.4	33.7	34.8	39.6	**41**
A251	6.11c	496234	179201	52.2	32.6	33.9	35.1	39.9	**41.2**
A252	6.11c	496236	179196	52.6	32.9	34.1	35.3	40.2	**41.6**
A253	6.11c	496238	179192	53.1	33.2	34.4	35.6	40.6	**42**
A254	6.11c	496227	179213	51.5	32.2	33.4	34.5	39.3	**40.6**

The columns in red can be compared to show the difference in NO_2 concentrations from applying the more conservative LTT projection methodology. The difference is consistent across all the receptors in the table at 11% or so.

New analysis using Previous LTT method

Receptor ID	Drawing	x	y	2013 Base NO2 (ugm3)	Projected 2022 Base NO2 (ugm3)	2022- Do Min NO2 (ugm3)	2022- Do Som NO2 (ugm3)	Ratio A (=2013 base/ 2022 base)	Ratio B (=2022 factor/ 2013 factor)	Gap Factor	LTT 2022 Do-Min NO2 (ugm3)	LTT 2022 Do-Som NO2 (ugm3)	Difference between ES values and these values
A247	6.11c	496222	179222	51.6	32.2	33.5	34.5	0.62	0.94	1.50	50.3	**51.8**	11.1
A248	6.11c	496225	179218	51.5	32.2	33.4	34.5	0.63	0.94	1.50	50.0	**51.7**	11.1
A249	6.11c	496229	179209	51.6	32.3	33.5	34.6	0.63	0.94	1.50	50.1	**51.8**	11.0
A250	6.11c	496231	179205	51.9	32.4	33.7	34.8	0.62	0.94	1.50	50.6	**52.2**	11.2
A251	6.11c	496234	179201	52.2	32.6	33.9	35.1	0.62	0.94	1.50	50.9	**52.7**	11.5
A252	6.11c	496236	179196	52.6	32.9	34.1	35.3	0.63	0.94	1.50	51.1	**52.9**	11.3
A253	6.11c	496238	179192	53.1	33.2	34.4	35.6	0.63	0.94	1.50	51.5	**53.3**	11.3
A254	6.11c	496227	179213	51.5	32.2	33.4	34.5	0.63	0.94	1.50	50.0	**51.7**	11.1

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