

used to develop large-scale emissions inventories are not a suitable method by which to represent emissions for specific driving characteristics (idling, acceleration/deceleration), which are unique to each junction separately.

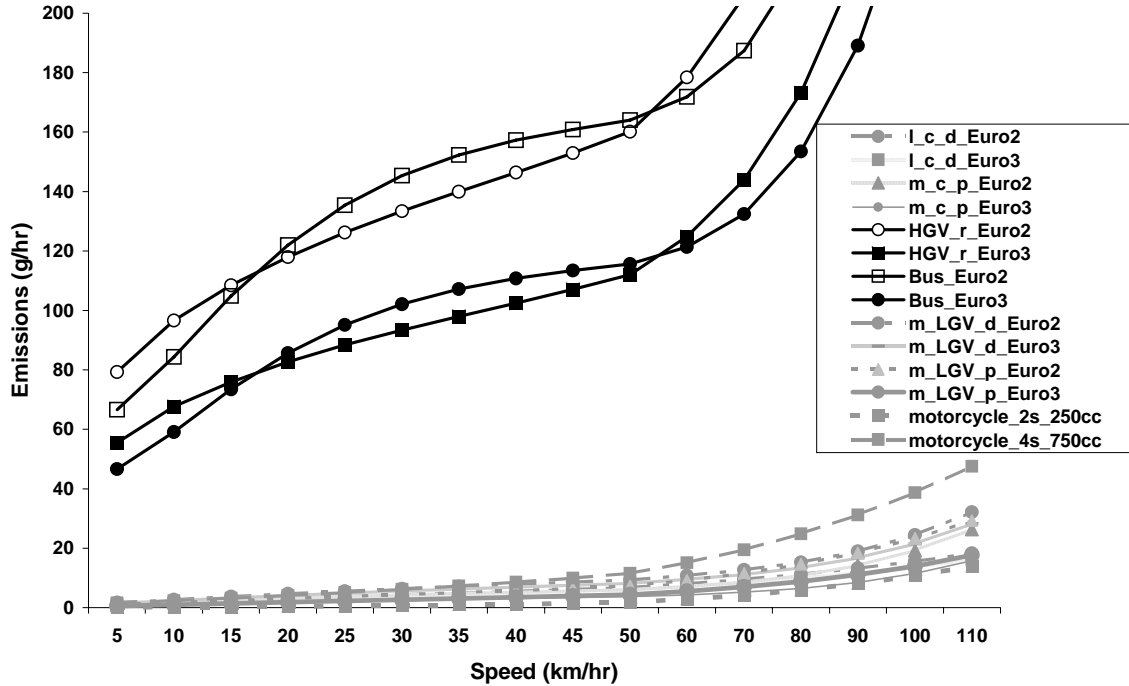


Figure 13 Emissions NO_x (g/hr) for Euro 2 and 3 Vehicles at different Average Speeds (km/hr)

The detailed DMRB emission factors are applicable down to a speed of 5 km/hr, although factors at this speed are highly uncertain. These data were employed in the redistribution of junction emissions described above. It is worth therefore investigating the effect of low speeds on the emissions of, in this case NO_x, from different vehicle types. By multiplying the g/km results for different average speeds by the speed the emissions may be expressed in g/hr. A sample of the g/hr vehicle emissions for Euro 2 and 3 vehicles is summarised in Figure 13 above. It shows that as LGV (petrol and diesel), cars (petrol and diesel) and motorcycles increase their speed so the emissions increase steadily and are at a maximum at 110 km/hr. This increase in emissions is related to the additional work, which is being done by the engine. It is important to note however, that for these vehicle types the g/hr emissions approaches zero at 5 km/hr. Also plotted in black are rigid HGVs, and buses in the Euro 2 and 3 technology categories. These vehicles contrast significantly with the cars, LGVs and motorcycles by showing emissions up to a factor 40 times greater than for smaller vehicles at very slow speeds. It is therefore these specific vehicle types, which provide the majority of the emissions close to road junctions. Since comparatively little work has been carried out on emissions from heavy vehicles, the emission factors derived at such slow speeds should be treated with considerable caution. It is important to considered these effects when considering the results from the modelling.

Appendix C

3 Model Validation and Verification

3.1 Model validation

A comprehensive validation exercise has been undertaken for the ERG NO_x-NO₂ model at measurement sites in London. A very extensive data set exists for the years 1996, 1997, 1998 and 1999 and these were used in the exercise. Comparisons were made with sites located at roadside and kerbside in both open locations and street canyons, as well as in background locations. All sites were not available for every year and for NO_x and NO₂.

To ensure the validity of the exercise care was taken to locate the site locations as accurately as possible, particularly in relation to roadside sites, where a steep concentration gradient exists and poor site locations may lead to significant changes to the model performance.

Overall the model performed very well with the average modelled and measured predictions showing close agreement. A summary of the overall performance of the model gives the standard deviation of the measured minus the predicted NO₂ concentrations as 12 % (1996), 9 % (1997), 11 % (1998), and 11 % (1999). The percentages were calculated by dividing the standard deviation by the all site average measured NO₂ concentration.

This level of accuracy does not apply to all sites and certain roadside sites are not as well predicted, this might be a result of the very low vehicle speeds at this site (approximately 10 km/hr throughout the day) and the uncertainty in emission factors at this speed, as described in Appendix E.

Further details on the methodology developed can be found on the GLA website (see http://www.london.gov.uk/mayor/environment/air_quality/docs/modelling.pdf)

3.2 Model verification

The TG03 guidance suggests where there is disparity between predicted and measured results an appropriate adjustment factor should be determined.

To determine applicability of the ERG model to Lewes a series of model tests were run for 2005. A comparison of the measured to final model test results for 2005 at the Lewes 2 continuous site is given below.

	Total	Background NO₂	Roads	Factor
Lewes 2 Measured NO ₂	35.4	17.1	18.3	
Modelled NO ₂	26.1	17.1	9	2.033

Based on this comparison the above verification factor was used with the modelled results in the Lewes AQMA.

Separate verification was used for the A26 Malling Street site, which is away from the congested conditions in Lewes town centre. This verification was based on the bias adjusted diffusion tube results in this area.

		Total	Background NO₂	Roads	Factor
Malling Street	Measured NO ₂	35	17.1	17.9	
	Modelled NO ₂	30.6	17.1	13.5	1.33

Appendix D

4 Emissions from Road Transport in Lewes

4.1 Major Road Flows

The Lewes District Council obtained recent traffic counts from the East Sussex County Council (ESCC) for the identified roads in the AQMA and surrounding roads. The counts were undertaken in 2005 and were 12-hour counts. The ESCC also kindly provided a factor (1.096) to convert these flows into daily average flows.

4.2 Vehicle Classification, Age and Speed

The above counts provided some details of vehicle classification for the roads, see Table 9. The breakdown of vehicle ages was based on the national model.

Table 9 AADT Road traffic flows and stock used for 2005

2005 base case	M/cycles	Cars	Bus and coaches	LGV	Rigid 2 axle	Rigid 3 axle	Artic	Speed kph
FISHER STREET	42	4343	102	822	94	21	0	8
STATION STREET	52	4465	122	964	114	23	0	8
HIGH STREET W	90	6845	285	1143	190	62	1	16
HIGH STREET E	76	5694	253	963	163	53	0	16
WEST STREET	114	9484	328	1729	249	84	0	8
MOUNT PLEASANT	83	6619	227	1207	173	59	0	16
MALLING STREET	128	16678	277	2925	473	703	149	48

Vehicle speeds in the AQMA were not available and therefore assumptions were made of average speeds along links in the area, as above.

Appendix E

5 Model Uncertainty Assessment

5.1 Introduction

This appendix describes the application of Bayesian Monte Carlo (BMC) analysis to the ERG model developed to predict present and future concentrations of annual average NO₂ in London. Model uncertainties arise because of limited scientific knowledge, limited ability to assess the uncertainty of model inputs, for example, emissions from vehicles, poor understanding of the interaction between model and/or emissions inventory parameters, sampling and measurement error associated with NO_x sites in London and whether the model itself completely describes all the necessary atmospheric processes. The application of the BMC technique here results in the reduction in uncertainties predicted through the additional information provided by the measurements themselves.

5.2 Uncertainty Assumption in Model Input Parameters

Selection of the uncertainty of input variables are obtained through access to published literature, the opinions of experts in the field, and through the assessment of relationships used within the model. A summary of the assumptions made for the model are given in the table below:

Table 10 Uncertainty Assumptions (1 σ) use for the Uncertainty Predictions

	(%)
Road Traffic Emissions	30
Other Emissions	50
London + Rural NO _x Contribution	10
Pollution Climate Mapping (NO _x)	11
NO _x -NO ₂ Relationship	10
Roadside Dispersion	20

5.3 Bayesian Monte Carlo Analysis

In Monte Carlo analysis, the model is run with the input variables varied simultaneously and independently of each other and a resulting probability distribution of the output information, obtained. Bayes' theorem is then applied to derive a final uncertainty estimate, by assigning a high probability to those predictions that agree with the measurements and a low or zero probability to those, which do not. The application of probabilities to the model prediction uses the likelihood function (Equation 1) and results in the best estimate of overall model uncertainty.

$$L(Y_k | O) = \frac{1}{\sqrt{2\pi}\sigma_e} \exp\left(-\frac{1}{2} \left[\frac{O - Y_k}{\sigma_e}\right]^2\right) \quad (1)$$

A mathematical summary of BMC is given below. From Bayes' theorem the final probability of model output is defined by equation 2 as

$$p(Y_k | O) = \frac{L(Y_k | O)p(Y_k)}{\sum_{j=1}^N L(Y_j | O)p(Y_j)} \quad (2)$$

5.4 Results at Background

A BMC uncertainty analysis was carried out for annual average NO₂ concentration throughout London. The application of BMC analysis reduces the final uncertainty giving a standard deviations in this case are 2.0 ppb (8.5 %).

The BMC analysis was then applied for 5 sites individually and the results summarised in Table 12. Again BMC analysis results in a significant reduction in σ providing a reduction in uncertainty. The average σ for the 5 sites was 1.8 ppb.

Table 11 Final uncertainty and measured annual mean NO₂ concentrations (ppb) at all sites in London for 1998

Average Model Prediction (ppb)	σ (ppb)	Uncertainty %	Measured Result (ppb)
23.6	2.0	8.5	23.2

Table 12 Final uncertainty and measured annual mean NO₂ Concentrations for separate Sites in London for 1998

Site Location	Final Model Prediction (ppb)	σ (ppb)	Uncertainty %	Measured Results (ppb)
Bridge Place	30.6	2.2	7.2	30.2
Bexley 2	19.1	1.5	7.8	18
Tower Hamlets 1	24.1	1.8	7.5	24.6
West London	26.8	2.0	7.5	26.8
Sutton 2	18.6	1.4	7.5	19.8

5.5 Results at Roadside

Predictions of the concentration of NO₂ at roadsides throughout London have shown a high sensitivity to the pass/fail standard. These predictions are crucial to the development of air pollution control, through local authority action plans, and it is therefore essential to completely understand the uncertainty associated with them. Only then will the strengths and weaknesses of the predictive process be understood enough for decision-makers to make informed policy judgements. It is

the uncertainties associated with these predictions, which are the subject of this appendix.

Monte Carlo modelling techniques have been used to calculate the uncertainties associated with roadside NO₂ predictions. It also includes a full sensitivity analysis to determine the most important input variables to the model. Specific tests include the uncertainties associated with flows and emissions from LGVs, HGVs and buses, vehicle speed, the dispersion model, and the pollution climate mapping technique, used for calculating background concentrations.

In *Monte Carlo* analysis, the input variables are varied simultaneously and independently of each other, and the effect on important outputs assessed. The model uncertainty, relating to the input parameters, is calculated by treating them as random variables. By studying the resulting probability distribution of the output (i.e. the concentration or emission estimate), information is obtained regarding the model uncertainty.

The original study has focused on Marylebone Road for a base year of 1997 for meteorology and atmospheric chemistry and uses the London Transportation Studies (LTS) traffic model. Further uncertainty assessments have also been undertaken for an “average road” in central and outer London, as well as a ‘Motorway’ in outer London.

The sensitivity analysis revealed that roadside NO_x predictions are mostly sensitive to the assumptions regarding HGV emissions and flows and the dispersion model used to predict roadside concentrations. For the prediction of NO₂, the NO_x-NO₂ relationship used is the most important factor. Table 13 below shows how each input data or modelling method affects the final concentration, for the Marylebone road example.

Table 13 The Relative Importance of Model Parameters in Predicting NO₂ at Marylebone Road

Model Parameter	Relative Importance 2005 (% of mean at 2σ)	Relative Importance 1997 (% of mean at 2σ)
NO _x -NO ₂ relationship	13.9	11.9
HGV emissions	7.9	8.1
Dispersion model	7.3	6.8
HGV flow	5.5	5.5
LGV emissions	4.2	4.7
LGV flow	4.2	4.7
Vehicle speed	3.6	2.1
Background mapping	1.8	1.7
Bus emissions	1.2	0.9
Bus flow	0.6	0.4

For 1997, NO_x was predicted to be 258 +/- 83 ppb and NO₂ 47 +/- 10 ppb, at two standard deviations – equivalent to the 95 % confidence interval. These statistics assume that the resultant distribution is normal.

The overall uncertainty of NO₂, which corresponds to 22 %, is less than that for NO_x (32 %). This feature is a result of the non-linear NO₂ relationship, which is quite insensitive to NO_x concentrations, implying that a stated NO_x uncertainty is a better indication of the quality of a prediction.

Measurements for the Marylebone Road site for NO_x and NO₂ are within the uncertainty limits calculated here. NO_x was between 213 and 229 ppb and NO₂ between 44 and 48 ppb for 1997. The range reflects the two different monitoring techniques used at the Marylebone site.

Similarly, for 2005, NO_x is estimated to be 117 +/- 35 ppb and NO₂ 33 +/- 7 ppb, at two standard deviations – equivalent to the 95 % confidence interval. It can therefore be concluded that with a probability of 95 % the true value lies within the ranges given above. This would indicate that, despite the calculation of uncertainty associated with the 2005 predictions, the NO₂ concentration always exceeds 21 ppb and therefore Marylebone Road will exceed the AQS objective. This may not always be the case however and with a prediction whose range straddles 21 ppb, a decision must be made concerning the approach to be taken. For example, a prediction of 20 +/- 2 ppb could be considered a pass or a fail.

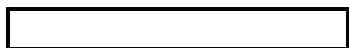
It is further concluded that the prediction of NO₂ concentrations in London depend most on the NO_x-NO₂ relationship used and the traffic data for HGVs. It is flows of, and emissions from, HGVs and buses that become more important in the future, as emissions from these vehicles will make up a greater proportion of the total.

The results from the analysis of a further three roads is given in Table 14. These represent an average road at a central and outer location and an average motorway in outer London. The flow and percent HGV for the average road was derived from all 10,000 roads in the LTS 91 network.

Table 14 NO₂ Uncertainty Estimates for Typical Roads in London in 2005

Road Type/Location	Total vehicle flow	Percent HGV	Uncertainty (% of mean at 2σ)
Average road (central London)	17,000	9	16
Average road (outer London)	17,000	9	18
Motorway (outer London)	80,000	9	21

Our best estimate of the uncertainty in annual mean NO₂ predictions is therefore +/- 16-21 % at two standard deviations.



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