

## Comparison of ADMS-Roads, CALINE4 and UK DMRB Model Predictions for Roads

Kate Ellis, David Carruthers, Christine McHugh<sup>1</sup>, & Stephanie Dyster

*Cambridge Environmental Research Consultants Ltd*

<sup>1</sup>*Corresponding author*

### 1 Introduction

Three systems commonly used to assess the impact of road traffic on air quality are compared and validated against some available data.

ADMS-Roads is based on ADMS-Urban (McHugh C.A., Carruthers D.J. and Edmunds H.A., 1997, [www.cerc.co.uk](http://www.cerc.co.uk)), it is suitable for local scale studies of the impact of road traffic on air. It includes chemistry algorithms for calculating NO<sub>2</sub> concentrations and allows the user to model explicitly defined roads, several point sources and other emissions as volume sources. CALINE4 was developed by the California Department of Transport and the US Federal Highways Agency. An earlier version CALINE3 is recommended for use by the US EPA (Benson 1979). It is a Gaussian model that can model junctions, parking lots, street canyons, bridges and underpasses. It includes the "Discrete Parcel Model" for NO<sub>x</sub> chemistry. DMRB (the Design Manual for Roads and Bridges 1999) is a screening method based on tables and algorithms formulated by the UK Department of Transport to give a preliminary indication of air quality near roads.

Three sets of calculations are presented. Firstly comparisons of ADMS-Roads and CALINE4 with the Caltrans Highway 99 dataset; secondly comparisons of ADMS-Roads with data from a continuous monitoring site adjacent to the M4 motorway in South East England. Thirdly ADMS and DMRB are compared for a typical road.

### ADMS-Roads and CALINE4 using the Caltrans Highway 99 dataset

The Caltrans highway 99 experiment has been used for validating the road dispersion model CALINE4. The experiment is repeated here using ADMS-Roads and compared to the CALINE4 results.

Highway 99 is a dual carriageway, each carriageway is 7.3 m wide and there is a 14m central reservation between the carriageways. Four monitors were placed along the central reservation at intervals of half a mile, a further 3 monitors were placed perpendicularly above and below the road, to a distance of 200m, giving 10 monitors in total. Eight equally spaced vehicles emitted the tracer chemical SF<sub>6</sub> during sampling periods. The experiments were in California during December to March 1981/82 between 6am and 9am and 4pm to 7pm. Scatter plots of the calculated and monitored concentrations have been used to give a straight line equation of best fit for each model, these are shown in Figure 1 with statistics for the ADMS-Roads calculated concentrations in Table 1.

The raw data results for the CALINE4 results are unavailable although the correlation is given as 0.51. The results using ADMS Roads consider all 549 observations, whereas only results for downwind locations, 163 observations, are considered with CALINE4. The ADMS Roads results show a higher correlation than the CALINE4 results, 0.84 compared to 0.51. Figure 1 shows that for most observed concentrations the calculated concentrations will be within the factor of two envelope for both models. The ADMS Roads line of best fit is closer to the target line,  $y=x$ , than the CALINE4 line of best fit. Both models show a tendency to over predict low concentrations and under predict high concentrations.

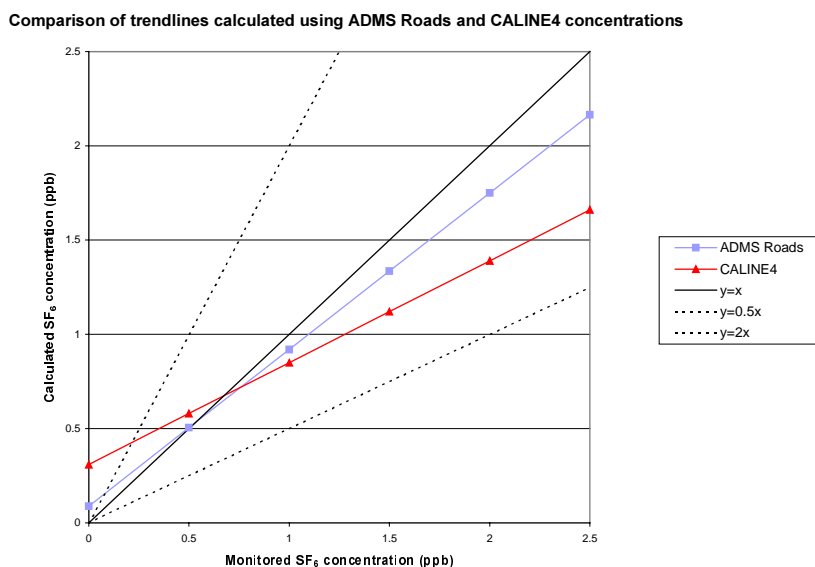


Figure 1

Table 1 SF<sub>6</sub> (ppt) concentration statistics (549 observations).

Model	Mean	Sigma	bias	nmse	correlation	fa2	fb	fs
Observed	1059	1023	0	0	1	1	0	0
ADMS-Roads	964	1002	95.68	0.33	0.842	0.62	0.095	0.02

### Calculating concentrations on the M4 using ADMS Roads

ADMS Roads has been used to compare calculated and monitored concentrations of NO<sub>x</sub>, NO<sub>2</sub> and PM<sub>10</sub> on the M4 between junctions 11 and 12, during 1997. The monitor is situated under a bridge over the M4. The M4 has been modelled with a width of 28m, an AADT of 102,000 vehicles and 12% heavy vehicles. Meteorological data from Heathrow has been used in the modelling with background concentrations of NO<sub>x</sub> and ozone from Harwell and PM<sub>10</sub> from Rochester. The background concentrations have been multiplied by the ratio of the annual average concentrations at the background monitoring sites to the annual average background concentrations at the roadside monitors. Tables 2 to 4 show the statistics of the calculated concentrations. Figure 2 shows a time series plot of the calculated and monitored PM<sub>10</sub> concentration.

The annual average concentrations show good agreement between modelled and monitored concentrations for all pollutants. The high percentiles show an overestimate in concentration with lower concentrations underestimated. The presence of the bridge is not accounted for in the modelling and will have some affect upon dispersion.

Table 2a M4 NO<sub>x</sub> (ppb) statistics (3446 observations).

Model	Mean	sigma	bias	nmse	cor	fa2	fb	fs
Observed	130.7	109.6	0	0	1	1	0	0
ADMS-Roads	114.4	133.2	16.23	0.84	0.596	0.585	0.132	-0.194

Table 2b M4 NO<sub>x</sub> (ppb) percentiles (3446 observations).

Model	99.8 <sup>th</sup> percentile	99 <sup>th</sup> percentile	98 <sup>th</sup> percentile
Observed	574	488	424
ADMS-Roads	847	671	536

**Table 3a** M4 NO<sub>2</sub> (ppb) statistics (3446 observations).

Model	mean	sigma	bias	nmse	cor	fa2	fb	fs
Observed	24.4	11.78	0	0	1	1	0	0
ADMS-Roads	21.66	15.23	2.74	0.53	0.275	0.615	0.119	-0.256

**Table 3b** M4 NO<sub>2</sub> (ppb) percentiles (3446 observations).

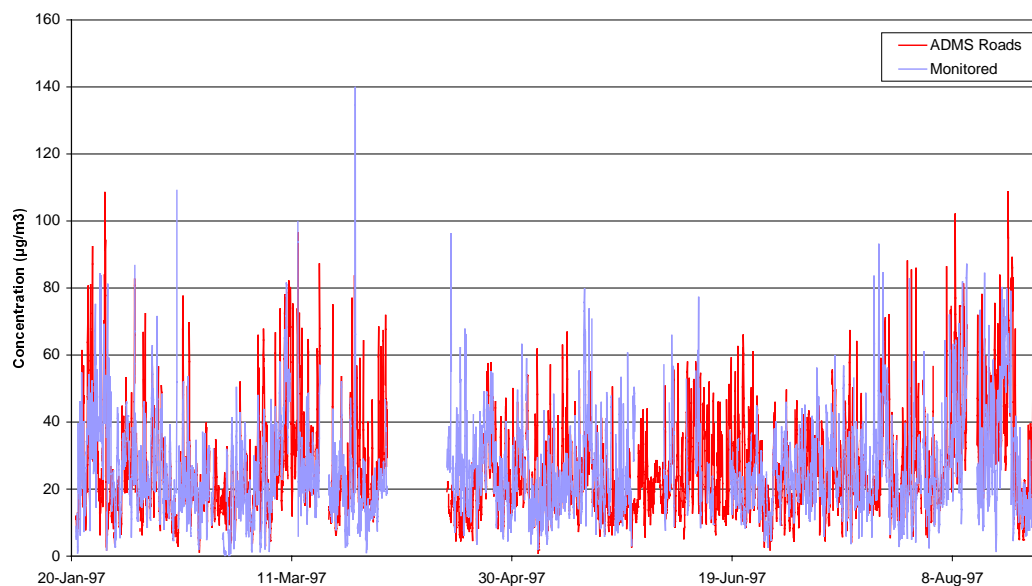
Model	99.8 <sup>th</sup> percentile	99 <sup>th</sup> percentile	98 <sup>th</sup> percentile
Observed	70	58	53
ADMS-Roads	80	68	62

**Table 4a** M4 PM<sub>10</sub> (µg/m<sup>3</sup>) statistics (4298 observations).

Model	mean	sigma	bias	nmse	cor	fa2	fb	fs
Observed	25.01	14.14	0	0	1	1	0	0
ADMS-Roads	26.12	15.15	-1.11	0.34	0.493	0.802	-0.043	-0.069

**Table 4b** M4 PM<sub>10</sub> (µg/m<sup>3</sup>) percentiles (4298 observations).

Model	99.8 <sup>th</sup> percentile	99 <sup>th</sup> percentile	98 <sup>th</sup> percentile
Observed	85	70	63
ADMS-Roads	92	77	69

**M4 calculated and monitored PM10 concentration****Figure 2**

### Comparing calculated concentrations using ADMS Roads and DMRB

A simplified road has been modelled using DMRB (version 1) and ADMS Roads. The results using ADMS Roads show how pollution can vary across roads. The road has been modelled with the parameters given in Tables 5 and 6.

**Table 5** Modelling data used by both models.

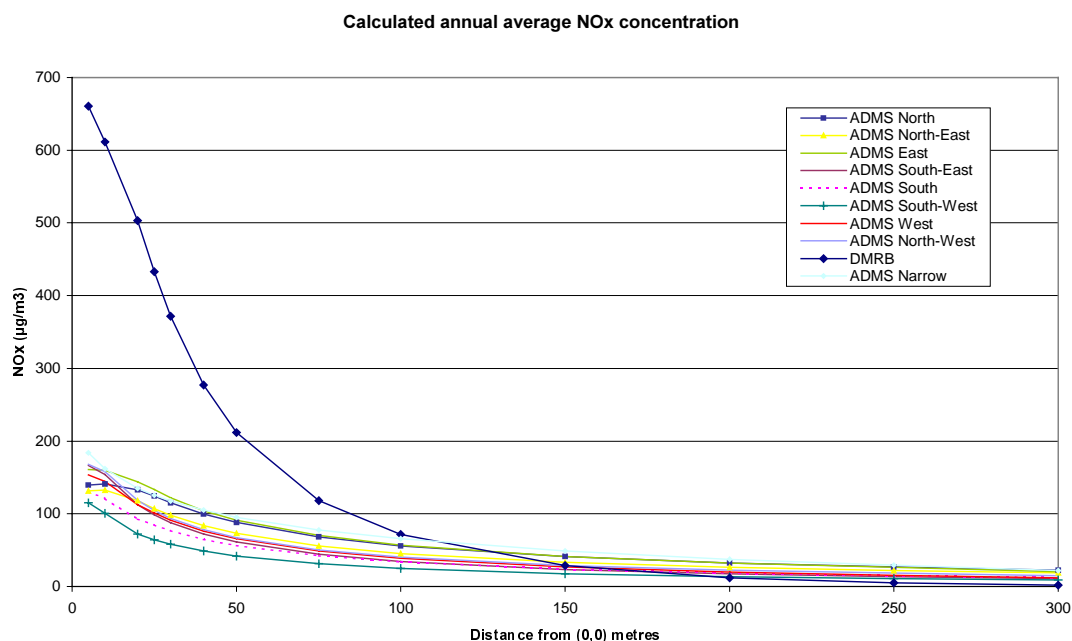
<b>Year</b>	1997
<b>AADT (vehicles/hour)</b>	4250
<b>% HGV</b>	12
<b>Speed (km/hr)</b>	70

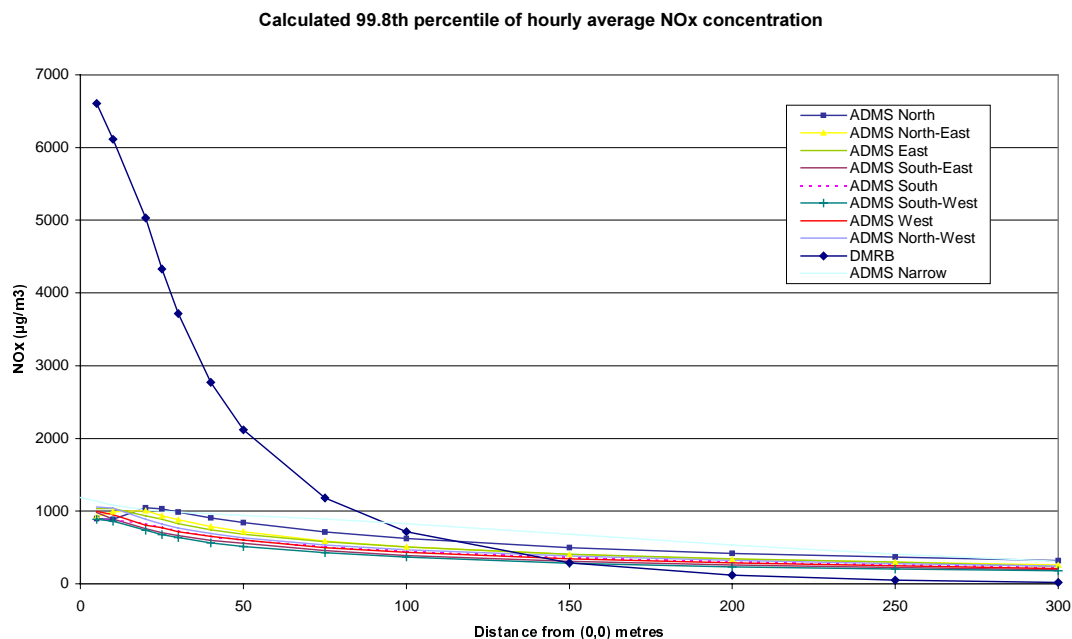
**Table 6** Extra modelling data used by ADMS Roads.

<b>Meteorology</b>	Heathrow
<b>Surface roughness (m)</b>	0.1
<b>Minimum Monin-Obukov length (m)</b>	30
<b>Road length (m)</b>	2000
<b>Road width (m)</b>	40m and 10m

Using ADMS Roads and hourly sequential meteorological data for Heathrow Airport four similar roads were modelled, which differed only in their orientation and hence direction relative to the prevailing wind. The first road ran East-West with concentrations calculated to the North and South. The road and receptors were then moved through 45<sup>o</sup>, this was repeated a further two times giving eight lines of calculated concentrations, each line running perpendicular to the modelled road.

Figures 3 and 4 show the calculated annual average concentration and 99.8<sup>th</sup> percentile of hourly average concentration. There are eight lines of concentration using ADMS Roads with a 40m wide road, showing how concentration can vary with road position. Another curve demonstrates how concentration varies with road width, modelling a 10m wide road.

**Figure 3**



**Figure 4**

The concentrations calculated using ADMS Roads show how road position and width affect concentrations away from the road. The position of the road is important, as this will define how the prevailing wind direction will affect the dispersion of pollution away from the road. Concentrations calculated using DMRB are much higher close to the road centre than those calculated using ADMS Roads, and drop off quickly within 150 m of the road. Calculated concentrations using ADMS Roads show how if road width is decreased less air will be mixed with the pollution along the road resulting in higher concentrations away from the road. This effect cannot be modelled within DMRB.

## References

- McHugh C.A., Carruthers D.J. and Edmunds H.A. (1997) ADMS-Urban: an Air Quality Management System for Traffic, Domestic and Industrial Pollution *Int. J. Environment and Pollution Vol. 8, nos. 306, pp 437-440.*
- Benson, Paul E., (1979) CALINE3 – A Versatile Dispersion Model for Predicting Air Pollutant Levels Near Highways and Arterial Streets. *Interim Report, Report Number FHWA/CA/TL-79/23. Federal Highway Administration, Washington, D.C. (NTIS No. PB 80-220841).*
- Department of the Environment, Transport and the Regions (1999) Design Manual for Roads and Bridges (DMRB), Volume 11, Section 3, Part 1 ‘Air Quality’, *The Stationery Office.*