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

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## 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 [1] and is suitable for local-scale studies of the impact of road traffic on air. It includes chemistry algorithms for calculating $NO_2$ 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 [2]. CALINE4 is a Gaussian model that can model junctions, parking lots, street canyons, bridges and underpasses. It includes the "Discrete Parcel Model" for $NO_X$ chemistry. DMRB (the Design Manual for Roads and Bridges 1999 [3]) 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:

1. Comparison of ADMS-Roads and CALINE4 using the Caltrans Highway 99 dataset

2. Comparison of ADMS-Roads with data from a continuous monitoring site adjacent to the M4 motorway in South-East England

3. Comparison of ADMS-Roads and DMRB for a typical road

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## 2 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 [4]. The experiment is repeated here using ADMS-Roads and the results compared to the CALINE4 results.

Highway 99 is a dual carriageway, each carriageway is 7.3m 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 $SF_6$ 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.

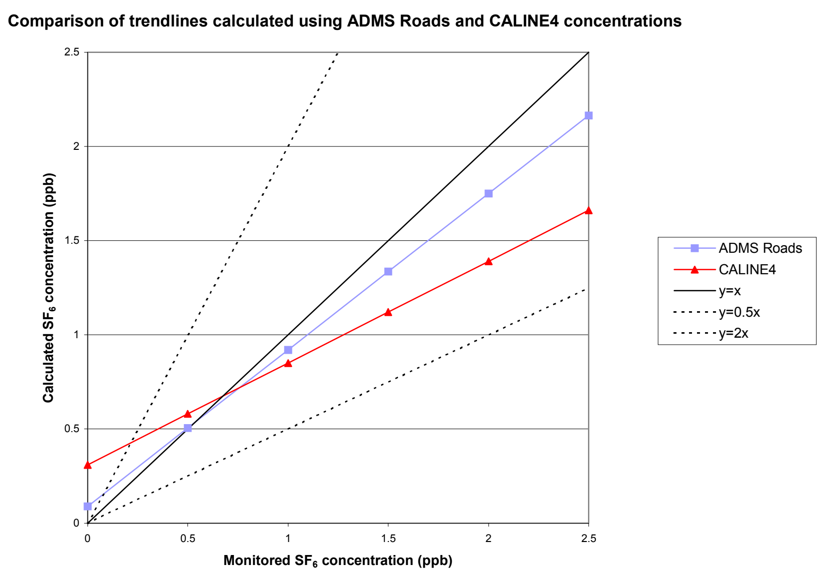


***Figure 1*** *Comparison of trendlines calculated from ADMS-Roads and CALINE4 concentrations*

| 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 |

***Table 1*** *$SF_6$ (ppt) concentration statistics (549 observations)*

The raw data results for the CALINE4 results are unavailable although the correlation is given as 0.51 and the equation of the line of best fit is given. 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.

## 3 Calculating concentrations on the M4 using ADMS-Roads

ADMS-Roads has been used to compare calculated and monitored concentrations of NOx, $NO_2$ and $PM_{10}$ 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 NOx and ozone from Harwell and $PM_{10}$ 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 $PM_{10}$ concentration.

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

| 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 2a*** *M4 NOx (ppb) statistics (3446 observations)*

| Model | $99.8^{th}$ percentile | $99^{th}$ percentile | $98^{th}$ percentile |
|---|---|---|---|
| Observed | 574 | 488 | 424 |
| ADMS-Roads | 847 | 671 | 536 |

***Table 2b*** *M4 NOx (ppb) percentiles (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 3a** M4 $NO_2$ (ppb) statistics (3446 observations)*

| Model | 99.8th percentile | 99th percentile | 98th percentile |
|---|---|---|---|
| Observed | 70 | 58 | 53 |
| ADMS-Roads | 80 | 68 | 62 |

***Table 3b** M4 $NO_2$ (ppb) percentiles (3446 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 4a** M4 $PM_{10}$ ($\mu g/m^3$) statistics (4298 observations)*

| Model | 99.8th percentile | 99th percentile | 98th percentile |
|---|---|---|---|
| Observed | 85 | 70 | 63 |
| ADMS-Roads | 92 | 77 | 69 |

***Table 4b** M4 PM10 (µg/m3) percentiles (4298 observations)*

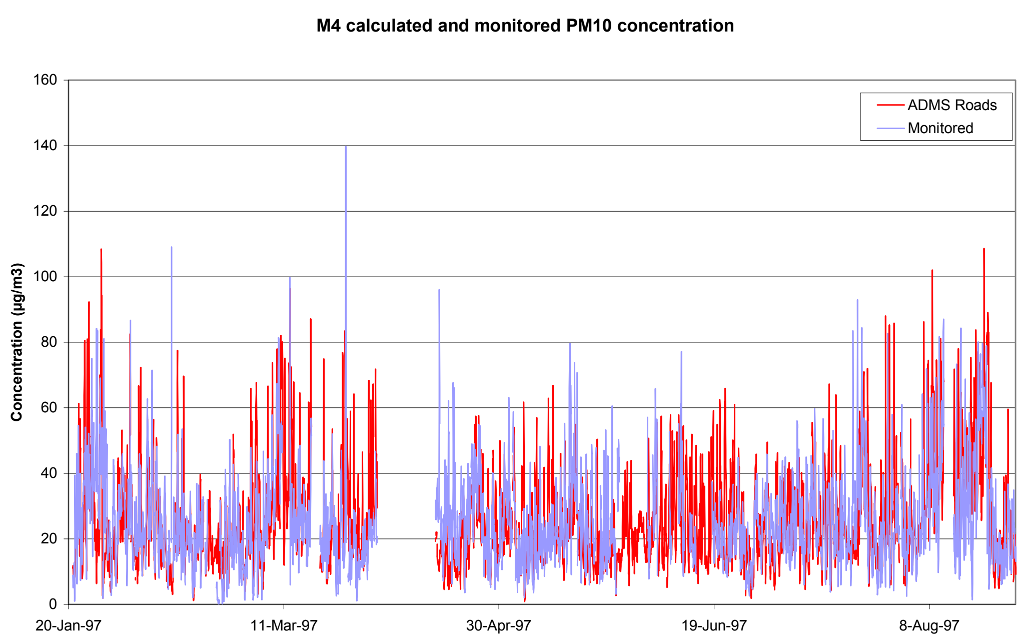


***Figure 2** M4 calculated and monitored concentrations of $PM_{10}$ ($\mu g/m^3$)*

## 4 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.

| | |
|---|---|
| **Year** | 1997 |
| **AADT (vehicles/hour)** | 4250 |
| **% HGV** | 12 |
| **Speed (km/hr)** | 70 |

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

| | |
|---|---|
| **Meteorology** | Heathrow |
| **Surface roughness (m)** | 0.1 |
| **Minimum Monin-Obukov length (m)** | 30 |
| **Road length (m)** | 2000 |
| **Road width (m)** | 40m and 10m |

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

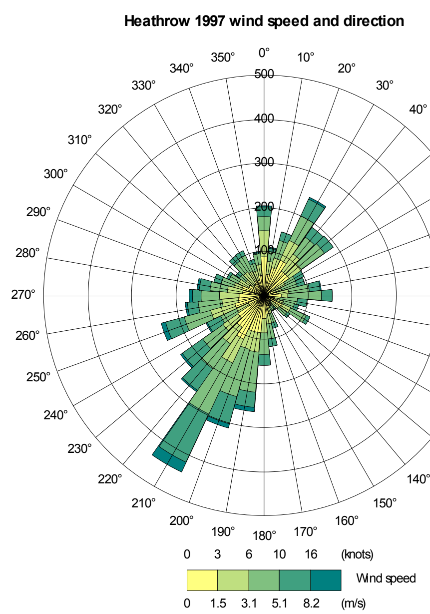


***Figure 3*** *Graphical representation of wind speed and direction in the Heathrow 1997 meteorological dataset*

Using ADMS-Roads one 40m-wide road was modelled in four different orientations (see figure 4). The first road (A) ran East-West with concentrations calculated to the North and South. The road and receptors were then moved through 45° (B). This was repeated a further two times (C and D) giving four lines of calculated concentrations, each line running perpendicular to the modelled road.

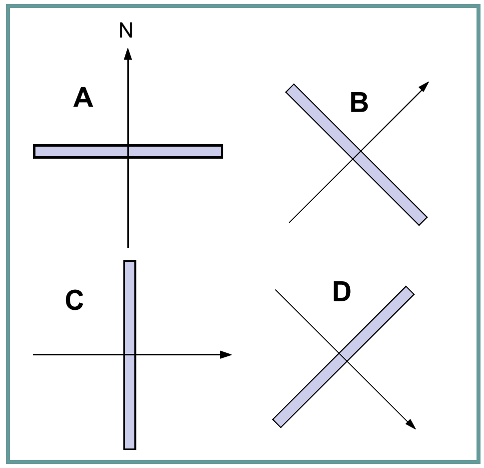


***Figure 4*** *Road orientations A, B, C and D (shaded rectangle represents road)*

Figures 5 and 6 show, on a log scale, the calculated annual average concentration and 99.8th percentile of hourly average concentration against the distance from the centre of the road for each of the four orientations. The direction of the arrows in figure 4 indicates positive distance in figures 5 and 6. Results from DMRB for the same 40m-wide road are also plotted. For comparison, ADMS results for a 10m-wide road in D orientation are shown (ADMS D - Narrow).

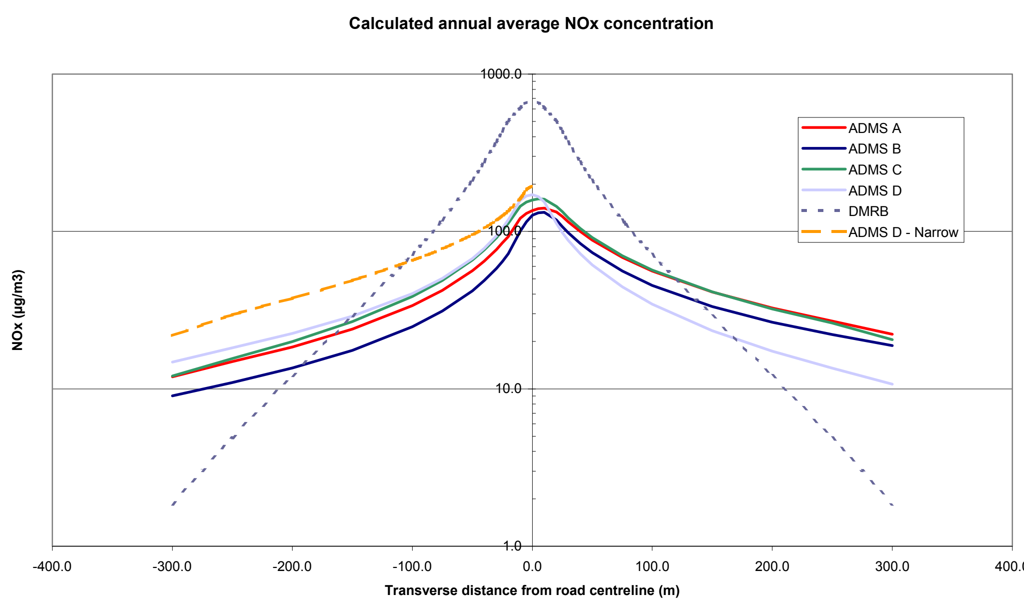


***Figure 5*** *Calculated annual average $NO_x$ concentration (µg/m$^3$)*

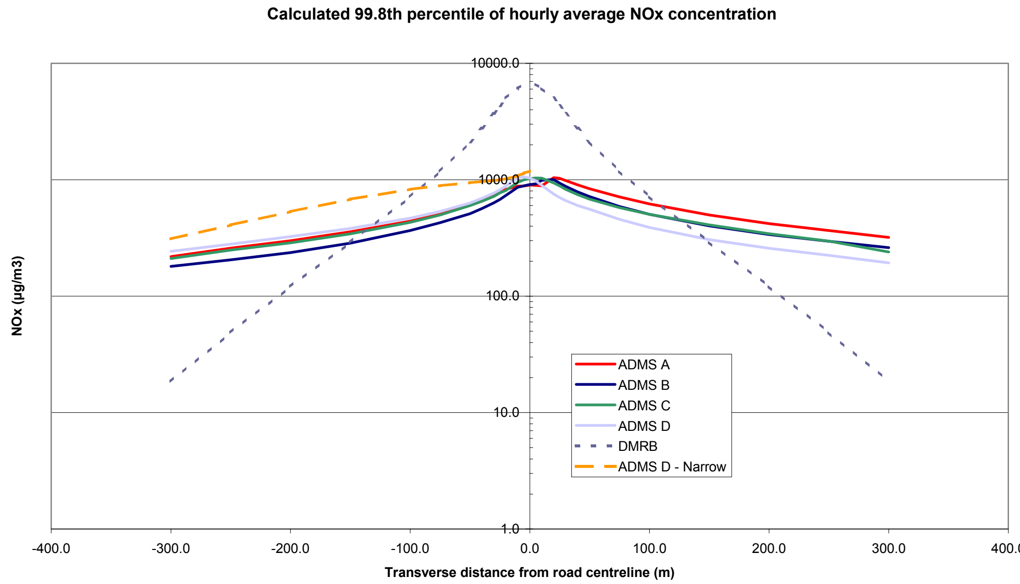


***Figure 6*** *Calculated 99.8th percentile of hourly average* $NO_x$ *concentration (µg/m$^3$)*

The concentrations calculated using ADMS-Roads demonstrate that road orientation and width affect concentrations away from the road. The orientation 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 independent of road orientation, since DMRB takes no account of meteorological conditions, and are also independent of road width. DMRB concentrations are much higher close to the road centre than those calculated using ADMS-Roads, and drop off quickly within 150m of the road. The results using ADMS-Roads to model a 10m-wide road demonstrate that if road width is decreased less air will be mixed with the emissions along the road resulting in higher concentrations away from the road.

## 5 References

[1] 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.*

[2] 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).*

[3] 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*

[4] The Highway 99 Tracer experiment is described in the CALINE4 (CAlifornia LINE Source Dispersion Model) manual, section 8 *Model Verification*, the raw data are given in *Appendix C* of the manual. The manual is available from Californian government web site, http://www.dot.ca.gov/hq/env/air/index.htm.

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