A585 Windy Harbour to Skippool Improvement Scheme

TR010035

6.6.1 ES Appendix 6.1: Air Quality Model Verification

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Infrastructure Planning

Planning Act 2008

The Infrastructure Planning
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ES APPENDIX 6.1: AIR QUALITY MODEL VERIFICATION

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1 MODEL VERIFICATION

1.1 Background

1.1.1 The comparison of modelled concentrations with local monitored concentrations is a process termed ‘verification’. Model verification identifies any discrepancies between modelled and measured concentrations, which can arise for a range of reasons. The following are examples of potential causes of such discrepancies:

- Estimates of background pollutant concentrations
- Meteorological data uncertainties
- Traffic data uncertainties
- Emission factor uncertainties
- Model input parameters, such as ‘roughness length’
- Overall limitations of the ability of the dispersion model to model dispersion in a complex urban environment

1.1.2 The verification process involves a review of the modelled pollutant concentrations against corresponding monitoring data to determine how well the air quality model has performed. Depending on the outcome it may be considered that the model has performed adequately and that there is no need to adjust any of the modelled results.

1.1.3 Alternatively, the model may perform poorly against the monitoring data, as a result there is a need to check all the input data to ensure that it is reasonable and accurately represented in the air quality modelling process. Where all input data, such as traffic data, emissions rates and background concentrations have been checked and considered reasonable, then the modelled results may require adjustment to best align them with the monitoring data. This may be either be a single verification adjustment factor to be applied to the modelled concentrations across the study area or a range of different adjustment factors to account for different situations within the study area.

1.2 Residual Uncertainty

1.2.1 Residual uncertainty may remain after systematic error or ‘overall model accuracy’ has been accounted for in the final predictions. Residual uncertainty may be considered synonymous with the ‘residual inaccuracies’ of the model predictions, i.e. how wide the scatter or residual variability of the predicted values compare with the monitored ‘true value’, once systematic error has been allowed for. The quantification of final model accuracy provides an estimate of how the final predictions may deviate from the ‘true’ (monitored) values at the same location over the same period. It must though be recognised that some of the residual uncertainty will be down to uncertainties in the monitored values. This uncertainty is greater for monitoring using diffusion tubes than for automatic monitors.

1.2.2 Suitable local monitoring data for the purpose of verification is available for concentrations of NO_2 as detailed in Appendix 6.3 (document reference TR010035/APP/6.6.3). This monitoring data has been used to validate the dispersion model prediction and obtain adjustment factors which can be applied to predictions of pollutant concentrations in the base and future years.

1.3 Model Performance

1.3.1 An evaluation of model performance has been undertaken to establish confidence in model results. LAQM.TG(16) identifies a number of statistical procedures that are appropriate to evaluate model performance and assess the uncertainty. The statistical parameters used in this assessment are:

- Root mean square error (RMSE)
- Fractional bias (FB)
- Correlation coefficient (CC)

1.3.2 A brief for explanation of each statistic is provided in Table 1 and further details can be found in LAQM.TG(16) Box A3.7.

Table 1: Statistical Parameters used to Estimate Model Performance

Statistical Parameter	Comments	Ideal Value
RMSE	RMSE is used to define the average error or uncertainty of the model. The units of RMSE are the same as the quantities compared. If the RMSE values are higher than 25% of the objective being assessed, it is recommended that the model inputs and verification should be revisited in order to make improvements. For example, if the model predictions are for the annual mean NO_2 objective of 40µg/m^3, if an RMSE of 10µg/m^3 or above is determined for a model it is advised to revisit the model parameters and model verification. Ideally an RMSE within 10% of the air quality objective would be derived, which equates to ±4µg/m^3 for the annual mean NO_2 objective.	0.01
FB	It is used to identify if the model shows a systematic tendency to over or under predict. FB values vary between +2 and -2 and have an ideal value of zero. Negative values suggest a model over-prediction and positive values suggest a model under-prediction.	0.00
CC	It is used to measure the linear relationship between predicted and observed data. A value of zero means no relationship and a value of 1 means absolute relationship. This statistic can be particularly useful when comparing a large number of model and observed data points.	1.00

1.3.3 These parameters estimate how the model results agree or diverge from the observations. These calculations have been carried out prior to, and after, adjustment and provide information on the improvement of the model predictions as a result of the application of the verification adjustment factors.

1.4 Monitoring Data used for Verification

1.4.1 The air quality monitoring data collected as part of this assessment and detailed in Appendix 6.3 (document reference TR010035/APP/6.6.3) was reviewed to determine the suitability of each of the monitoring locations for inclusion into the model verification process. The criteria used to determine the suitability of the monitoring for inclusion into the verification exercise is outlined below:

- Within 200m of the modelled road network
- Greater than 75% data capture
- Sites classified as roadside
- Location confirmed to a satisfactory standard

1.4.2 Following the removal of the monitoring locations which did not adhere to the aforementioned criteria, a total of ten diffusion tube monitoring sites were used in the verification. Suitable local monitoring data for the purpose of verification is available for concentrations of NO_2 at the locations shown in Table 2. This monitoring data has been used to validate the ADMS model prediction and obtain adjustment factors which can be applied to predictions of pollutant concentrations in the base and future years.

Table 2: Monitoring Data used for Model Verification

Site ID	X	Y	Diffusion Tube Height (m)	2015 NO_2 Concentration (µg/m^3)
Site L	333722	442189	1.94	20.11
Site R.1-3	334898	439425	2.22	31.10
Site R.4-6	334888	439451	2.50	32.86
Site S	334721	439550	2.26	17.80
Site T	335252	440087	2.15	26.67
Site 3	346137	441167	1.97	28.30
Site 8	334797	438992	2.01	16.21
Site 9	334831	439320	2.10	20.12
Site 11	333965	441346	2.04	17.61
Site 14	334876	439525	2.19	30.28

1.5 Verification Methodology

1.5.1 The verification method used for this assessment follows the process detailed in LAQM.TG(16). The initial verification was undertaken by comparing the modelled versus monitored Road NO_x. Road NO_x measured at the diffusion tubes were calculated using the latest Defra NO_x to NO_2 calculator (v5.1), as diffusion tubes only measure NO_2 and do not directly measure NO_x.

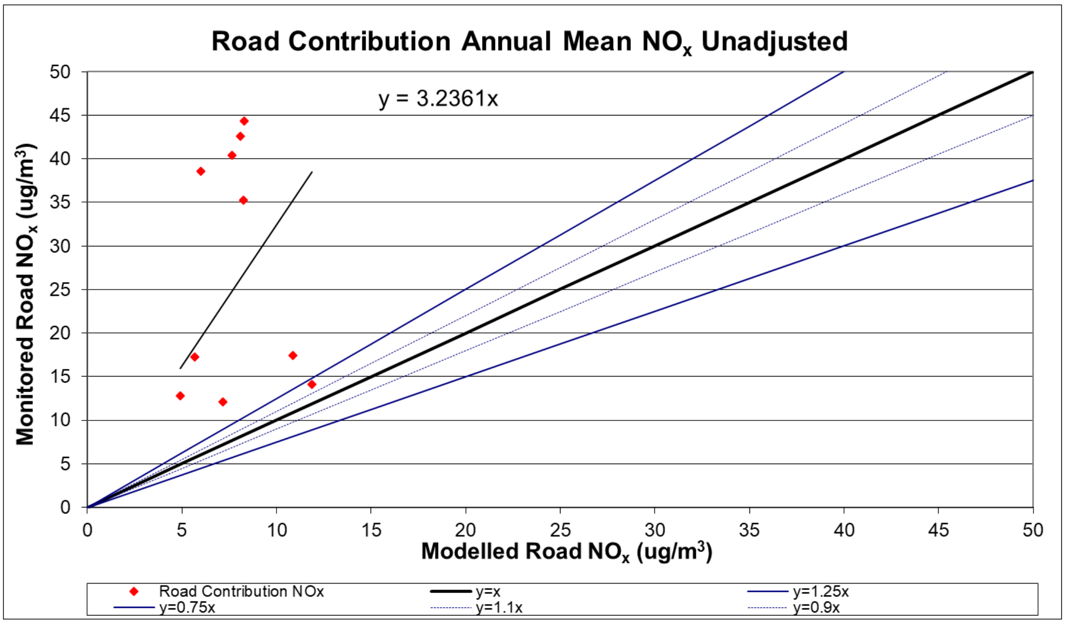
1.5.2 For each monitoring site, the relevant 1x1km 2015 background concentrations for NO_x and NO_2 were acquired. The NO_2 to NO_x tool was used to calculate the total road NO_x at each monitoring site. Table 3 summarises the background NO_x/NO_2 concentrations, raw (i.e. no adjustment) modelled and monitored road NO_x concentrations and raw modelled and monitored total NO_2 concentrations.

Table 3: Unadjusted Modelled versus Monitored NO_2 and Road NO_x

Site ID	BG NO_x (µg/m³)	BG NO_2 (µg/m³)	Monitored NO_2 (µg/m³)	Modelled Total NO_2 (µg/m³)	Monitored v Modelled Total NO_2 % Difference	Monitored Road NO_x (µg/m³)	Modelled Road NO_x (µg/m³)	Monitored v Modelled Road NOx % Difference
Site L	14.77	11.06	20.11	14.1	-29.8%	17.3	5.7	3.04
Site R.1-3	14.7	10.99	31.1	15.1	-51.5%	40.4	7.6	5.30
Site R.4-6	14.7	10.99	32.86	15.4	-53.0%	44.4	8.3	5.34
Site S	14.7	10.99	17.8	13.7	-23.3%	12.9	4.9	2.61
Site T	11.49	8.74	26.67	13.2	-50.5%	35.3	8.3	4.26
Site 3	8.87	6.84	28.3	11.3	-60.2%	42.6	8.1	5.26
Site 8	12.92	9.75	16.21	13.6	-15.9%	12.1	7.2	1.69
Site 9	14.7	10.99	20.12	16.8	-16.7%	17.4	10.8	1.60
Site 11	13.44	10.12	17.61	16.5	-6.5%	14.1	11.9	1.19
Site 14	14.7	10.99	30.28	14.2	-53.0%	38.6	6.0	6.42

1.5.3 The modelled versus monitored road NOx component concentrations for the diffusion tubes were plotted on a scatter graph as presented in Insert 1.

Insert 1: Unadjusted Modelled vs Monitored Road NOx



1.5.4 The graph in Insert 1 illustrates that the modelled concentrations underpredict the road component of NO_x in relation to the monitored concentrations. These sites were looked at in further detail and a justification was found to treat two groups of sites separately. One group for those sites located in narrow streets with a potential street canyon effect, and the others that are located in more open streets in another group. The verification process was continued for the two groups separately. The sites included in the 'Narrow Streets' group are as follows:

- Site R 1-3
- Site R 4-6
- Site 9
- Site 3
- Site 14

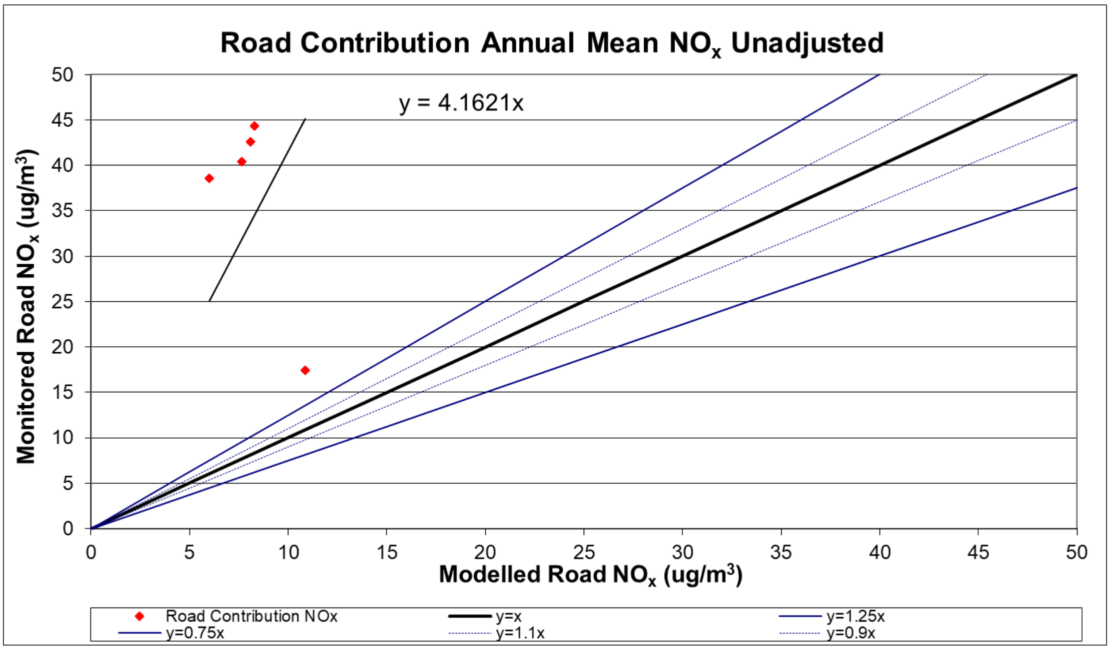
1.5.5 The sites included in the 'Open Streets' group are as follows:

- Site L
- Site S
- Site T
- Site 8
- Site 11

Narrow Streets

1.5.6 The graph in Insert 2 illustrates that the modelled concentrations under predict the road component of NO_x in relation to the monitored concentrations for the sites located in narrow streets.

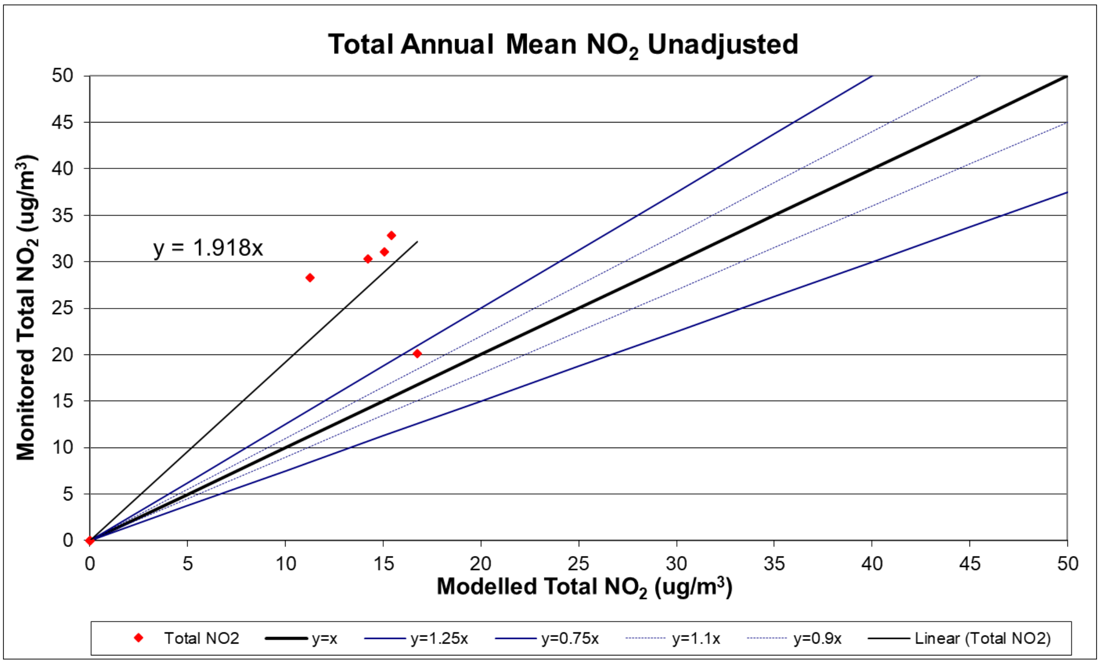
Insert 2: Unadjusted Modelled vs Monitored Road NO_x for Sites Located in Narrow Streets



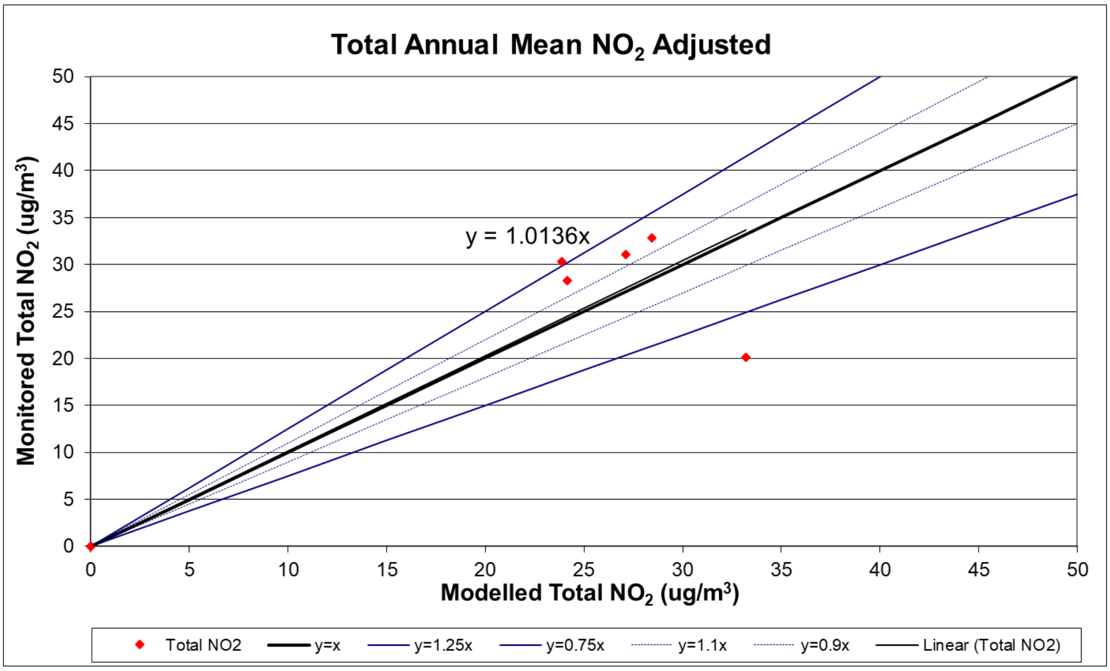
1.5.7 The verification factor derived from the model verification as shown in the graph above was 4.2, showing that the model underestimated pollutant concentrations.

1.5.8 Insert 4 presents the verified modelled versus monitored total NO_2 concentrations using the verification factor of 4.2. Insert 4 demonstrates that once adjusted for road NO_x, total modelled NO_2 concentrations are closer to monitored total NO_2 concentrations than the unadjusted total modelled NO_2 in Insert 3.

Insert 3: Unadjusted Modelled vs Monitored Total NO_2 for Sites Located in Narrow Streets



Insert 4: Adjusted Modelled vs Monitored Total NO_2 for Sites Located in Narrow Streets



1.5.9 Table 4 summarises the model performance statistics for before and after adjustment.

Table 4: Model Performance Statistics - Narrow Streets

Parameter	Results Without Adjustment	Results With Adjustment
Correlation Coefficient	-0.3	-0.7
RMSE µg/m^3	13.7	7.3
Fractional Bias	0.6	0.0

1.5.10 The model performance statistics show that the model had a tendency to under predict actual concentrations because the fractional bias was greater than zero. When road NO_x is adjusted by applying the verification factor of 4.2, the RMSE is reduced from 13.7µg/m^3 to 7.3µg/m^3. The model does not systematically under or over predict actual concentrations once adjusted because the fractional bias is zero. The adjusted model thus provides a much improved model performance.

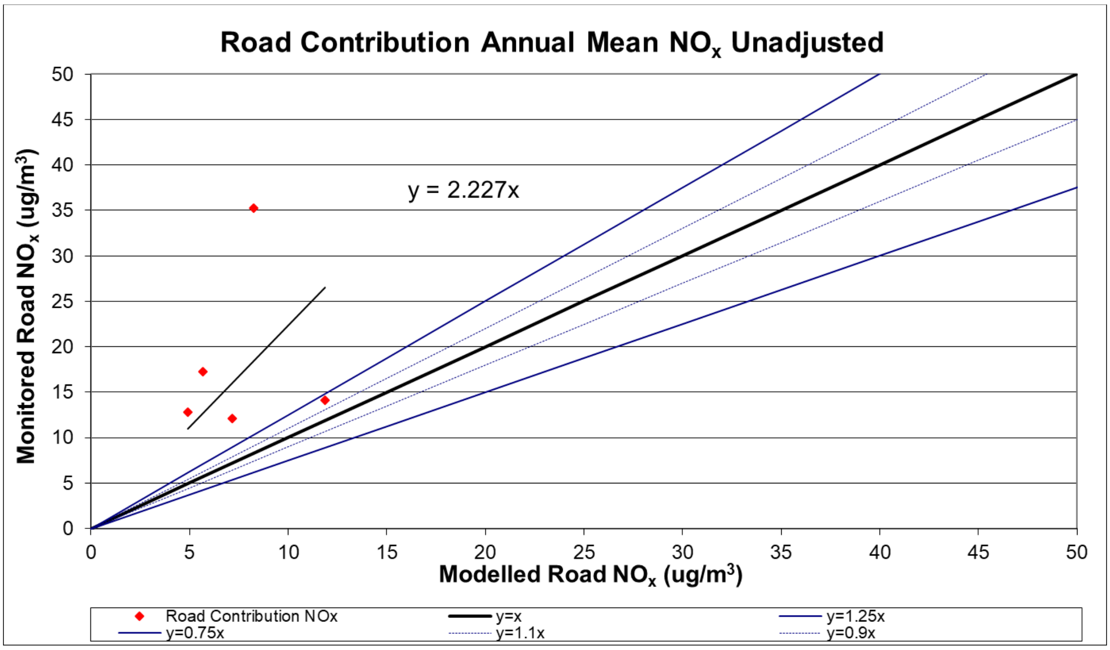
1.5.11 To provide a robust assessment, the verification factor of 4.2 for 'Narrow Street' sites was applied to the modelling results for the following receptors:

- R17
- R21

Open Streets

1.5.12 The graph in Insert 5 illustrates that the modelled concentrations under predict the road component of NO_x in relation to the monitored concentrations for the sites located in open streets.

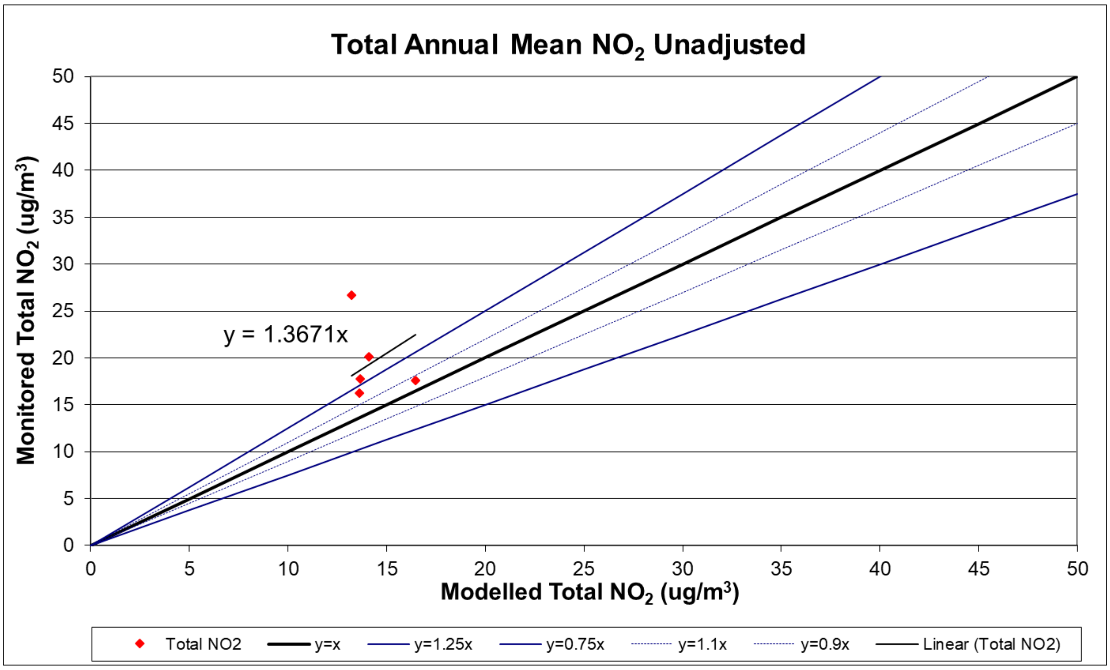
Insert 5: Unadjusted Modelled vs Monitored Road NO_x for Sites Located in Open Streets



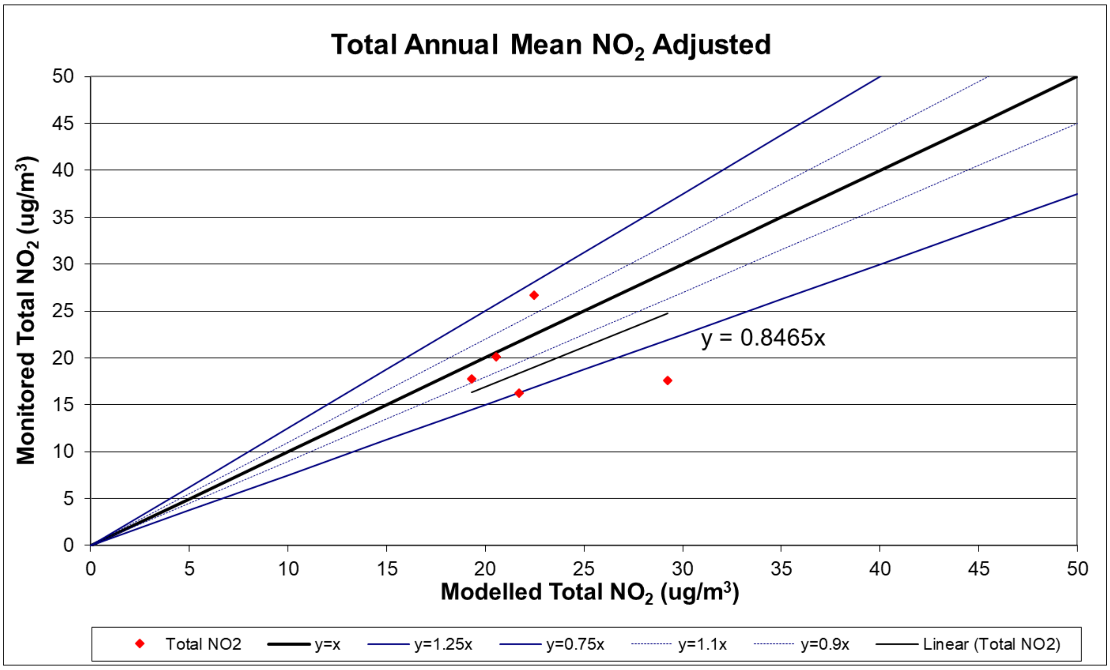
1.5.13 The verification factor derived from the model verification as shown in the graph above was 2.2 showing that the model underestimated pollutant concentrations.

1.5.14 Insert 6 presents the verified modelled versus monitored total NO_2 concentrations using the verification factor of 2.2. Insert 7 demonstrates that once adjusted for road NO_x, total modelled NO_2 concentrations are closer to monitored total NO_2 concentrations than the unadjusted total modelled NO_2 in Insert 6.

Insert 6: Unadjusted Modelled vs Monitored Total NO_2 for Sites Located in Open Streets



Insert 7: Adjusted Modelled vs Monitored Total NO_2 for Sites Located in Open Streets



1.5.15 Table 5 summarises the model performance statistics for before and after adjustment.

Table 5: Model Performance Statistics - Narrow Streets

Parameter	Results Without Adjustment	Results With Adjustment
Correlation Coefficient	-0.4	-0.1
Root Mean Square Error (RMSE) $\mu g/m^3$	7.0	6.1
Fractional Bias	0.3	-0.1

1.5.16 The model performance statistics show that the model had a tendency to under predict actual concentrations because the fractional bias was greater than zero. When road NO_x is adjusted by applying the verification factor of 2.2, the RMSE is reduced from $7.0 \mu g/m^3$ to $6.1 \mu g/m^3$. The model slightly over predicts actual concentrations once adjusted as the fractional bias is -0.1. The adjusted model thus provides a much-improved model performance with a slight negative fractional bias providing 'worst-case' results.

1.5.17 To provide a robust assessment, the verification factor of 2.2 for 'Open Street' sites was applied to the modelling results for all of the 41 receptors other than R17 and R21.

1.5.18 The same verification factors were applied for both NO_x and PM_{10} modelled results at each receptor as no PM_{10} monitoring data was available for verification purposes.