A7.2 Air Quality Monitoring, Verification and Adjustment

1 Introduction

1.1 The comparison of modelled concentrations with local monitored concentrations is a process termed 'verification'. Model verification investigates the discrepancies between modelled and measured concentrations, which can arise due to the presence of inaccuracies and/or uncertainties in model input data, modelling and monitoring data assumptions. The following are examples of potential causes of such discrepancy:

- estimates of background pollutant concentrations;
- meteorological data uncertainties;
- traffic data uncertainties;
- model input parameters, such as 'roughness length'; and
- overall limitations of the dispersion model.

2 Model Precision

2.1 Residual uncertainty may remain after systematic error or 'model accuracy' has been accounted for in the final predictions. Residual uncertainty may be considered synonymous with the 'precision' 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 model precision provides an estimate of how the final predictions may deviate from true (monitored) values at the same location over the same period.

3 Model Performance

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 uncertainty. The statistical parameters used in this assessment are:

- root mean square error (RMSE);
- fractional bias (FB); and
- correlation coefficient (CC).

3.2 A brief explanation of each statistic is provided in Table 1, and further details can be found in LAQM.TG(16) Box 7.17.

Table 1: Model Performance Statistics

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 40 µg/m^3, if an RMSE of 10 µg/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 4 µg/m^3 for the annual mean NO_2 objective.	0.01
FB	FB is used to identify if the model shows a systematic tendency to over or under predict. FB values vary between +2 and -2 and has an ideal value of zero. Negative values suggest a model over-prediction and positive values suggest a model under-prediction.	0.00

Statistical Parameter	Comments	Ideal value
CC	CC 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

3.3 These parameters estimate how the model results agree or diverge from the observations.

3.4 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.

3.5 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.

3.6 Alternatively the model may perform poorly[1] against the monitoring data, in which case there is a need to check all the input data to ensure that it is reasonable and accurately represented by 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 improve alignment with the monitoring data. This adjustment may be either using by 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 in the study area.

4 Air Quality Monitoring Survey Data

4.1 A nitrogen dioxide diffusion tube survey was undertaken at 27 locations across the anticipated study area. The survey ran for six months from July 2015 to January 2016. The monthly monitoring data is provided in Table 2.

Table 2: Monthly Air Quality Monitoring Survey Data – NO_2 Diffusion Tubes

Monitoring Location	Location		Survey Month Data NO_2 Concentration (µg/m³)						Raw survey period mean	Adjusted 2014 annual mean	Data Capture%
	X	Y	1	2	3	4	5	6			
01_LP Barn Church Roundabout	270261	846335	29.2	33.9	39.4	37.5	45.7	32.4	36.4	36.2	100%
02_LP Barn Church Road	270612	846040	10.5	14.0	14.0	13.3	-	14.2	13.2	13.2	83%
03_RS A96	271528	847478	17.3	20.4	23.9	18.6	21.6	15.2	19.5	19.4	100%
04_LP Wellside Road	273028	847396	5.5	8.4	10.6	13.0	13.1	9.4	10.0	10.0	100%
05_TP A96 Next to Bungalow	275118	849202	15.5	21.4	29.6	28.7	32.1	27.7	25.8	25.7	100%
06_TP Kerrowaid	276164	849703	11.2	15.5	16.7	-	-	13.6	14.2	14.2	67%
07_TP Airport Roundabout	277351	850860	12.5	15.2	16.2	14.7	15.7	11.1	14.2	14.2	100%
08_TP Military Rd Balsparoon	279937	852717	3.5	6.0	5.8	10.9	8.9	6.7	7.0	7.0	100%

[1] The acceptable limits of model verification performance are set out in Defra's Local Air Quality Management Technical Guidance (LAQM.TG(16))

Monitoring Location	Location		Survey Month Data NO_2 Concentration (µg/m³)						Raw survey period mean	Adjusted 2014 annual mean	Data Capture%
	X	Y	1	2	3	4	5	6			
09_TP Caravan Park	284942	854582	2.8	3.8	5.5	-	2.8	-	3.7	3.7	67%
10_TP	285636	855708	20.0	20.4	4.7	23.6	27.2	17.4	18.9	18.8	100%
11_RS B9091	286409	854055	2.2	3.3	6.2	5.0	4.7	4.6	4.3	4.3	100%
12_LP Tradespark Road	286856	855946	12.1	12.9	24.7	18.0	18.2	17.9	17.3	17.2	100%
13_LP	287749	856216	17.1	16.4	17.0	29.8	29.1	28.6	23.0	22.9	100%
14_LP	288415	856711	18.9	20.4	45.2	25.8	23.2	21.8	25.9	25.8	100%
15_LP Near Garage	288900	856447	20.6	24.5	-	27.7	-	-	24.3	24.2	50%
16_LP Sainsbury's	289535	856223	11.1	15.7	33.2	-	-	11.7	17.9	17.9	67%
17_TP Garden Center	287903	854930	0.5	3.9	4.7	-	5.4	5.2	3.9	3.9	83%
18_LP_B Househill Meadows	288746	855358	2.1	3.5	4.6	5.0	4.6	5.4	4.2	4.2	100%
19_TP B-Road @ Cottage	290616	854527	2.0	3.4	7.6	3.4	3.7	-	4.0	4.0	83%
20_LP Covanters Inn	291707	855451	3.9	6.7	10.2	8.1	6.1	7.1	7.0	7.0	100%
21_TP	292180	856037	2.4	3.7	17.8		6.0	5.6	7.1	7.0	83%
22_TP Unnamed Rd, North of Auldearn	294219	855912	5.2	5.7	2.3	10.0	10.5	9.7	7.2	7.2	100%
23_LP_B Meadow Road	273822	846892	2.0	3.5	0.2	4.9	5.0	3.7	3.2	3.2	100%
24_LP	288365	856667	30.2	34.6	27.9	41.7	44.1	32.9	35.2	35.1	100%
25_LP	288459	856694	39.3	42.7	24.8	53.5	53.8	44.3	43.1	42.9	100%
26_TP East Lodge Cottage	291253	856358	2.6	4.1	6.1	4.8	5.9	-	4.7	4.7	83%
Property 322	270261	846335	Not applicable				3.9	4.1	4.0	4.0	100%
Telford Street Continuous Analyser – Co-location	265708	845671	18.7	20.4	28.6	28.8	32.2	28.1	26.1	26.0	100%

4.2 An additional diffusion tube site was located at a residential property towards the end of the survey period, and data was collected for two months. The data capture for this location (Property_322) is reported in the table as 100%, as both months of data were collected. However, a two month period of data capture is not sufficient for its inclusion within the verification process.

4.3 Each monitoring site was reviewed to determine the suitability of the locations for inclusion in the model verification process. The criteria used to determine the suitability of the monitoring data for inclusion into the verification process are outlined below:

- Monitoring location within the defined air quality study area;
- Monitoring data capture greater than 90% complete; and

- Adjacent road link traffic data was available for inclusion in dispersion model.

5 Bias Adjustment & Annualisation

5.1 To account for potential systematic bias in the diffusion tube equipment, diffusion tubes are co-located with chemiluminescent analysers during the survey period. The bias factor is the calculated ratio of the continuous analyser result against the diffusion tube monitoring survey. The Inverness continuous analyser results for 2014 are fully ratified. The results of the co-location study are presented in Table 3.

Table 3: Bias Adjustment Factor

Monitor	NO_2 Concentration (µg/m³)	Data Capture (%)
Diffusion tube	26.1	100%
Continuous analyser	29.4	97%
Bias factor	**1.13**	

5.2 The bias factor of 1.13 was applied to the raw diffusion tube monitoring survey results.

5.3 Concentrations of NO_2 vary over the course of a year with concentrations being typically greater in the winter than the summer, due to the photochemical relationship between NO_2 and ozone, and other meteorological factors. To enable comparison of the 6 month survey with the annual mean AQO and the traffic base year, the survey results must be annualised, by comparing measured trends at background monitoring sites over the same period as the survey. The data to be used to develop the annualisation factor is set out in Table 4.

Table 4: Annualisation Factor

Monitor	Annual Mean 2014 (A_m)	Period Mean (P_m)	Ratio (A_m/P_m)
Fort William	11.0	13.56	0.81
Aberdeen (Erol Place)	21.7	22.6	0.96
Annualisation factor			0.89

5.4 The annualisation factor of 0.89 has been applied to the raw diffusion tube monitoring survey results.

6 Verification Methodology – NOx / NO_2

6.1 The verification method followed the process detailed in LAQM TG(16). The first stage of verification was undertaken by comparing the modelled versus monitored Road NOx. Road NOx measured at the diffusion tubes were calculated using the latest Defra NOx to NO_2 calculator, because diffusion tubes only measure NO_2 and do not directly measure NOx.

6.2 Once the modelled Road NOx component had been adjusted, this value was used in the Defra NOx to NO_2 calculator, and the calculated Road NO_2 component was adjusted following comparison with the monitored Road NO_2.

7 Verification Summary: NOx / NO2

7.1 A review was undertaken of the modelled versus monitoring performance across the whole study area. The summary results and model performance statistics defined in LAQM.TG(16) are provided in Table 5.

Table 5: Verification Zone Model Performance – NO_2

Statistical Parameter	No Adjustment	With Adjustment
No. of monitoring sites	**15**	**15**

Statistical Parameter	No Adjustment	With Adjustment
NO_x road adjustment factor	NA	2.331
NO_2 road adjustment factor	NA	0.998
RMSE	**11.5**	**5.6**
FB	0.5	0.01
CC	0.86	0.88
No with +-25% 1-stage	6	12

7.2 The statistics support the methodology adopted. The statistics show that the RMSE and FB are improved when an adjustment is applied, when compared to the RMSE and FB for unadjusted results across the whole study area.

8 Verification Methodology – PM_{10}

8.1 There were no PM_{10} analysers within the study area. Therefore, the NOx Road adjustment factor has been applied to the modelled PM_{10} road contributions, following guidance in LAQM.TG(16).

9 Prediction of Environmental Concentrations including Adjustment for Long-term Trends in NOx and NO_2

9.1 The model is used to predict the road traffic contributions to NOx and PM_{10} concentrations in future years. A further adjustment step is undertaken to account for the observed trends in ambient roadside NOx and NO_2.

9.2 In July 2011 Defra published a report (Defra 2011) examining the long-term air quality trends in NOx and NO_2 concentrations. This identified that there has been a clear decrease in NO_2 concentrations between 1996 and 2002. Thereafter NO_2 concentrations have stabilised with little to no reduction between 2004 and 2012. The consequence of the conclusions of Defra's advice on long-term trends is that there is now a gap between current projected vehicle emission reductions and projections on the annual rate of improvements in ambient air quality, which are built into the vehicle emission factors, the projected background maps and the NOx to NO_2 calculator.

9.3 Highways England has developed the Gap Analysis methodology to adjust model predictions based on the method and tools associated with LAQM.TG(16) to account for the long-term NOx and NO_2 profiles. This uses the relationship between the Base year vehicle emission rates and the Opening year vehicle emission rates, and the measured trends in roadside air quality concentrations to uplift Opening year predicted concentrations to align them better with the long-term trends of NOx and NO_2.

9.4 The current trends in air quality are based on measurements of emissions from the existing vehicle fleet. New vehicles will need to comply with the more stringent Euro 6/VI emissions standards from September 2014 onwards. Vehicles complying with the Euro 6/VI emissions standard are not yet on the road network in sufficient numbers, and therefore their performance is not present in the long-term air quality monitoring trends. If the Euro 6/VI fleet emissions perform as predicted, then this should lead to substantial reductions in predicted future roadside air quality concentrations.

9.5 However, because the likely effects of Euro 6/VI vehicles on air quality are yet to be fully understood, Highways England's advice is that a long-term trend based on the existing fleet is assumed to be linear and continue at this projected rate of decrease into the future. The Euro 6/VI penetration of diesel cars in the Scottish fleet mix is approximately 66% in the Opening year based on the EFT, leading to a reduction into road traffic emissions.

9.6 The Gap Analysis methodology (IAN 170/12v3)[2] incorporates the Euro 6/VI improvements. These

[2] Highways England (2013) INTERIM ADVICE NOTE 170/12 v3 Updated air quality advice on the assessment of future NOx and NO_2 projections for users of DMRB Volume 11, Section 3, Part 1 'Air Quality' (Highways Agency, Scottish Government, Welsh Assembly Government and The Department for Regional Development Northern Ireland 2007).

projection factors are referred to as 'LTT_{E6}'. The LTT_{E6} factors assume that the measured trends from 2004 to 2012 continue to occur for all pre-Euro 6/VI fleet. They also take a precautionary approach to account for uncertainty associated with Euro 6/VI performance and fleet mix in the future, rather than assuming full reductions in emissions occur as predicted by Euro 6/VI, which has not been observed by air quality monitoring trends associated with recent Euro standards. This is implemented into LTT_{E6} by taking the mid-point between the measured trend predictions (which assume no improvement in emissions associated with Euro 6/VI) and predicted Euro 6/VI uptake and emission improvements.

9.7 On this basis, the LTT_{E6} projections are considered by the air quality specialist to be the most reasonable prediction of likely actual future NOx and NO_2 concentrations, and have been used in the calculations for this updated local air quality assessment.

9.8 When forming a judgement on the significance of the effects, both the LAQM.TG(16) results and the results adjusted using the Gap Analysis method (to reflect Long-term Trends (LTT_{E6})) should be provided. Predictions for NO_2 using the LAQM.TG(16) method, which are lower, are also used in the final assessment to provide context for the uncertainty in model predictions.

9.9 The Gap Analysis method is not applied to PM_{10} predictions, and the results based on the LAQM.TG(16) method are the final predicted concentrations throughout the assessment.