Department
for Environment
Food & Rural Affairs

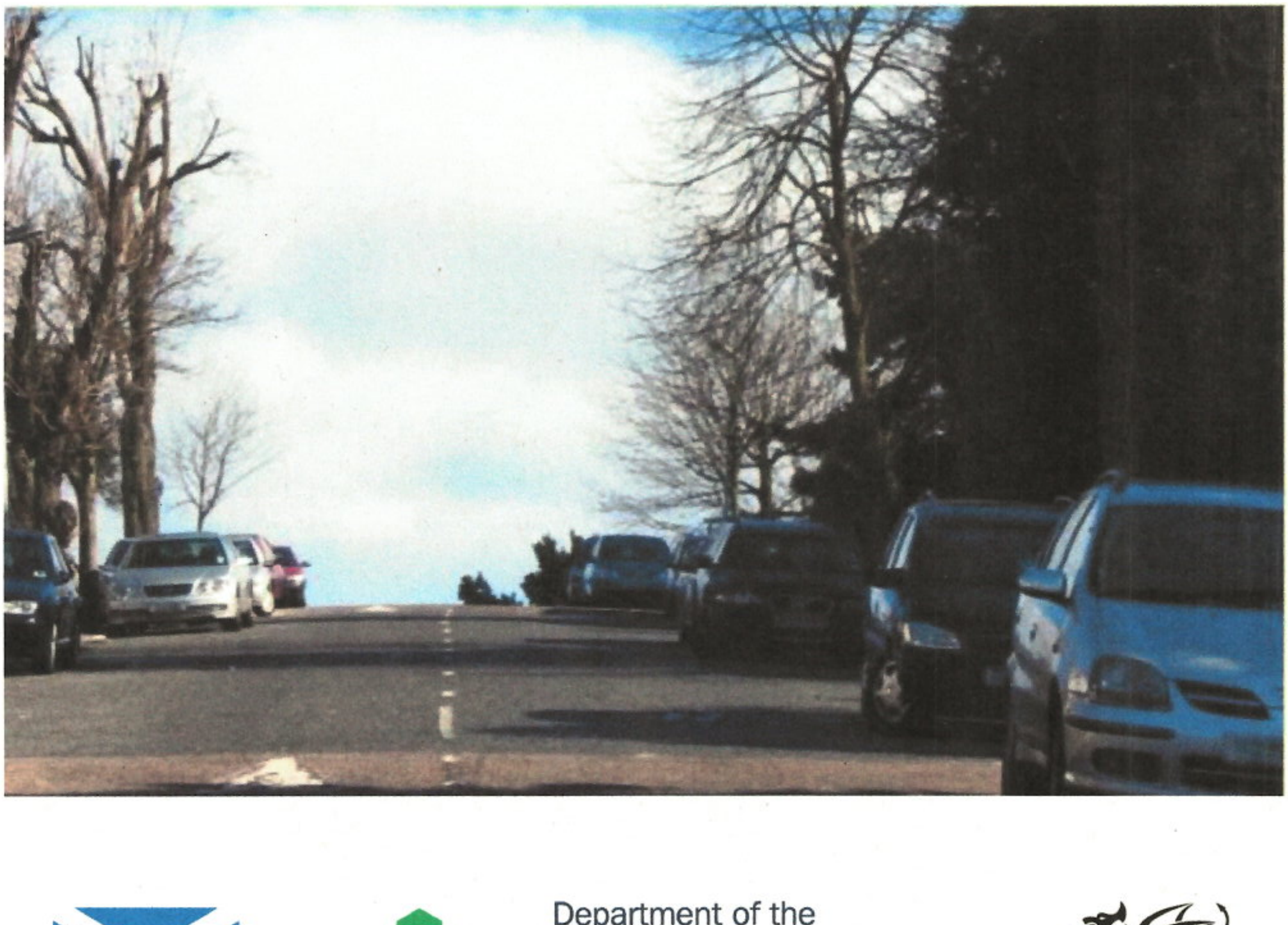
Part IV of the Environment Act 1995

Environment (Northern Ireland) Order 2002 Part III

Local Air Quality Management

Technical Guidance (TG16)

February 2018



The Scottish Government
Riaghaltas na h-Alba

Department of the Environment
www.doeni.gov.uk

Llywodraeth Cymru
Welsh Government

Box 1.1 – Examples of Where the Air Quality Objectives Should Apply

Averaging Period	Objectives should apply at:	Objectives should generally not apply at:
Annual mean	All locations where members of the public might be regularly exposed. Building façades of residential properties, schools, hospitals, care homes etc.	Building façades of offices or other places of work where members of the public do not have regular access. Hotels, unless people live there as their permanent residence. Gardens of residential properties. Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
24-hour mean and 8-hour mean	All locations where the annual mean objective would apply, together with hotels. Gardens of residential properties[10].	Kerbside sites (as opposed to locations at the building façade), or any other location where public exposure is expected to be short term.
1-hour mean	All locations where the annual mean and: 24 and 8-hour mean objectives apply. Kerbside sites (for example, pavements of busy shopping streets). Those parts of car parks, bus stations and railway stations etc. which are not fully enclosed, where members of the public might reasonably be expected to spend one hour or more. Any outdoor locations where members of the public might reasonably expected to spend one hour or longer.	Kerbside sites where the public would not be expected to have regular access.
15-min mean	All locations where members of the public might reasonably be exposed for a period of 15 minutes or longer.	

Further information

1.53 Supplementary or revised technical guidance will be issued periodically to reflect any new information as it arises. Local authorities should register for updates at the LAQM Support Helpdesk operated on behalf of Defra and the Devolved Administrations (see Box 1.2), which will ensure they are automatically notified of new guidance as soon as it is issued.

[10] Such locations should represent parts of the garden where relevant public exposure to pollutants is likely, for example where there is seating or play areas. It is unlikely that relevant public exposure to pollutants would occur at the extremities of the garden boundary, or in front gardens, although local judgement should always be applied

3 – Estimating Emissions

Introduction

7.217 This section provides authorities with guidance on determining emissions associated with those sources that are, based upon the evidence of recent years, most likely to be identified as contributing to poor air quality and thus increase the potential for air quality exceedances.

7.218 In the majority of cases, road transport and stationary large point sources are likely to be the most common problems. However, residential areas burning solid fuel may also be of concern. Estimating emissions from these sources for input into detailed studies is therefore the focus of this section. For advice on compiling emissions estimates for other sources that may warrant detailed consideration, such as large ship ports, railways or airports, the LAQM Support Helpdesk should be contacted.

7.219 Emissions data should be gathered for the specific sector(s) that require detailed consideration following the guidance below. In addition, background emissions and concentrations data can be used to account for sectors not specifically assessed in the detailed studies. These data can be obtained from the National Atmospheric Emissions Inventory (NAEI) website[71] and the UK-Air website[66]. Further detail on these data sources is included in Appendix C.

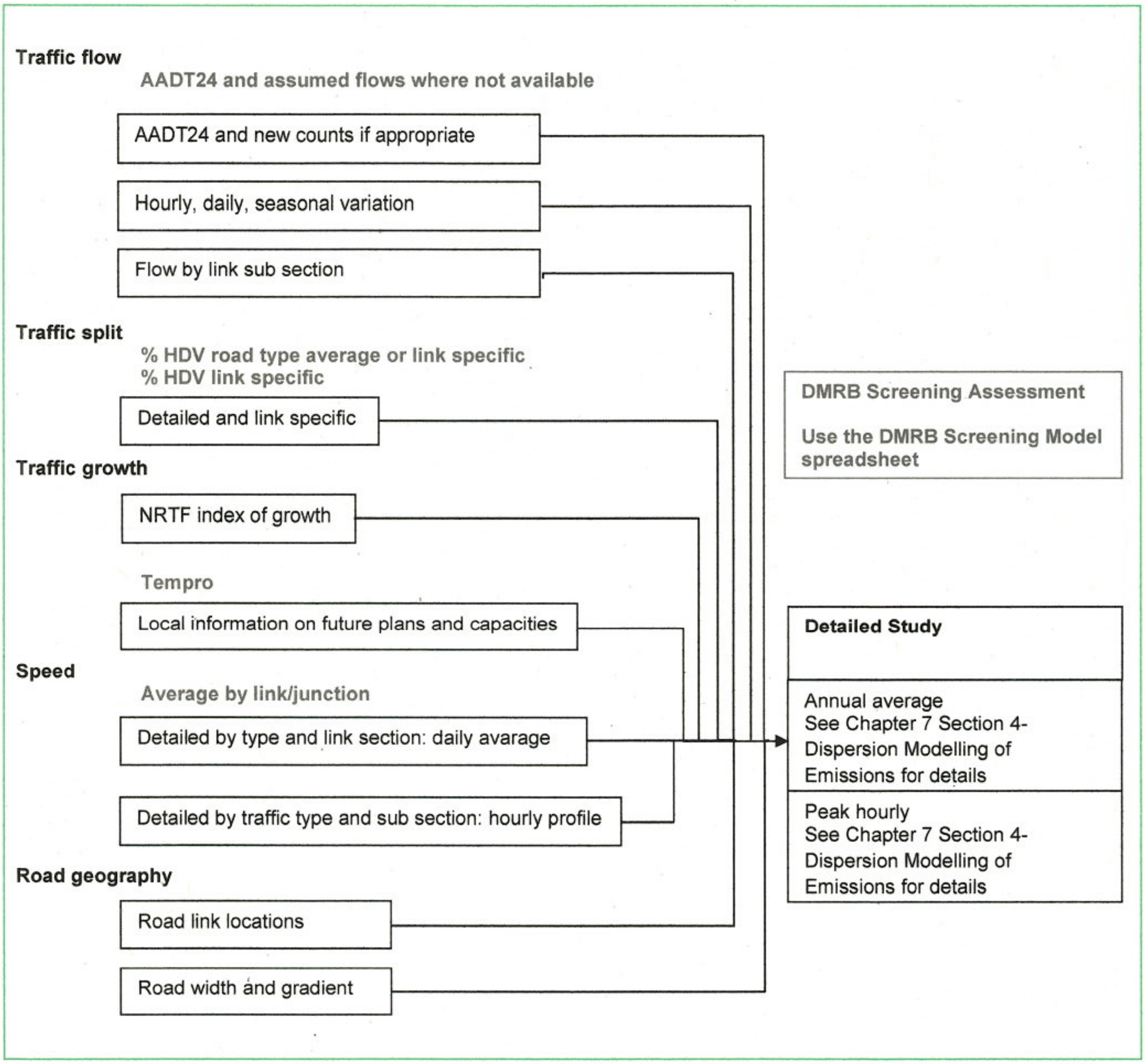
Road Transport

Introduction

7.220 A detailed study of road traffic emissions will involve some form of modelling, requiring high quality emissions estimates and other data as inputs. Figure 7.3 illustrates the data required for both screening assessments and detailed studies of road transport sources.

[71] http://naei.beis.gov.uk/

Figure 7.3 – Collecting Emissions Data: Road Transport Sources



7.221 With such sufficient information, the emissions for each road link can be estimated using the Emissions Factors Toolkit (EFT) – a spreadsheet tool published by Defra, which allows the calculation of road traffic exhaust emissions for different vehicle categories and splits, at various speeds, and on different road types. Emission factors (EFs) for each specific link being assessed will be calculated, which can then be used as input into a dispersion model. The latest version of the EFT and an associated User Guide are available via the LAQM Support website[72]. Alternatively, if not using the EFT then the raw vehicle EF data are available from the NAEI website[71].

[72] https://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html

7.222 As a minimum, the following information will be required for each link in order to estimate the associated pollutant emissions:

- Road type, i.e. whether motorway, urban or rural in nature;
- Traffic flows;
- Fleet composition; and
- Vehicle speeds and congestion.

7.223 Whilst not essential for the calculation of emissions, road geometry information (including OS coordinates of road centrelines and accurate road widths) is required to accompany the emissions data input into a model.

7.224 Further guidance on key elements that require careful consideration when calculating EFs for road transport sources is provided in the sections below.

Traffic Flows

7.225 Traffic flow data in 24-hour Annual Average Daily Traffic (AADT) format) is required.

7.226 There are two main categories of traffic flow information from which AADT flows can be estimated:

- **Traffic counts:** made either by human observation ('manual counts') or machine ('automatic' or 'continuous' counts), which are (usually) 'classified' based upon the main vehicle types over a time period. These should be used in preference to traffic model data; and
- **Traffic/transportation models**: a computerised representation of traffic flows on the road network.

7.227 Data from traffic models is generally considered less robust as this has a greater amount of uncertainty associated with it than measured flows at the individual link level. However, there are several disadvantages of 'Traffic Count' data to be aware of:

- Resource-intensive to collect for other than a small number of links;
- Care needs to be taken in extrapolating what are essentially point-based observations to whole 'roads'; and
- Data do not take account of changes to traffic flow in subsequent years.

7.228 Depending upon the format of the provided data, it may be required to transform the traffic data, e.g. from AM/PM peaks, 12-hour counts or 18-hour AAWT (Annual Average Weekday Traffic) flows (commonly used for noise assessments), to the required 24-hour AADT format. Council transport departments should be able to provide factors to achieve this. Where possible, local conversion factors should be used in preference to national factors where available. Any additional uncertainty introduced by such data transformations should be considered.

7.229 If using short-term counts to factor traffic flows to 24-hour AADT format, careful consideration should be given to whether the measurement period is considered typical or not. For example, Friday and Monday counts are likely to overestimate AADT flows, while weekend counts are likely to underestimate AADT flows.

7.230 Some authorities will also need to consider seasonal patterns, particularly in tourist areas, when estimating AADT flows. This can be achieved by comparing the flows on the day of the manual count with 24-hour flows from Automatic Traffic Count (ATC) or similar data over the same period.

7.231 For instance, if manual count was taken on a Friday local authorities should:

- Obtain ATC data for the same period on a similar road;
- Compare the same Friday with the rest of the week to check if there were significant differences between the average on that day and the 7-day average;
- If the data from the ATC is available over a wider time period, check to see if that week was typical of the wider period or season; and
- Other long-term traffic data can also be used to confirm estimates of traffic flows.

7.232 Local authorities may need to project traffic flows forward to the relevant assessment year. Each transport department within a local authority should have estimates of the expected growth on roads under their jurisdiction. Year-by-year growth factors based on road types should be used, as the growth on motorways for example is likely to be different to the growth on urban roads.

7.233 The Department for Transport (DfT) Road Traffic Forecasts[73] provided for England from the National Traffic Model (NTM) should be used to undertake the necessary projections where local information is not available. For areas outside England, the Scottish Government, the Welsh Government or the Department of Regional Development (Northern Ireland) should be contacted. In addition, the National Modelling Maps[24] can be used to help assess current and future modelled exceedances (including those for $PM_{2.5}$, which will be of particular benefit for Scotland).

7.234 Forecast estimates specific to each local authority district in Great Britain are provided by the Department for Transport Trip End Model Presentation Programme (TEMPro)[74]. TEMPro provides forecast data on trips for transport planning purposes. However, it does not take into account changes to fuel cost and vehicle operating cost over time, so is not suitable for direct use as a growth factor to be applied to traffic flows. It therefore needs to be used with DfT's published forecast from the NTM. Consideration should be given to the appropriateness of NTM derived 'regional' traffic growth forecasts for the roads under study, particularly where (as is the case in many cities) roads are effectively already operating at "maximum capacity".

7.235 Specific future plans (either to reduce traffic congestion or to develop housing or commercial areas) will have an effect on the traffic flows and may even include the construction of new roads. Depending on the maturity of these plans there may already

[73] https://www.gov.uk/government/publications/road-traffic-forecasts-2015

[74] https://www.gov.uk/government/collections/tempro

be flow estimates and even impact assessment data available from the planning department of the local authority or the County Council.

7.236 Traffic flow data may be sourced from a variety of locations, including the local traffic/transport/highways department. Street-level traffic data for every junction-to-junction link on the 'A' road and motorway network in Great Britain is also published on DfT's Traffic Counts website[75].

Fleet Composition

7.237 The proportion of HDV/LDV split is required as a minimum, but further breakdown of vehicle classes is preferable, e.g. percentage of Cars, LGVs, HGVs, Buses and Coaches and Motorcycles.

7.238 Basic vehicle splits (as a minimum including the percentage of HDVs/LDVs) should be provided with the traffic flow information. In circumstances where such local information is not provided, estimates by region and road type can be obtained from the NAEI[76], for both the current and forecasted national traffic split.

Vehicle Speeds

7.239 Speed data may be obtained directly from a traffic model, although users should understand the basis (and any associated limitations) upon which the model speeds are calculated. Speed data may also be obtained from "floating-car" studies or from theoretical extrapolations based on speed limit/flow.

7.240 Consideration of hourly speeds on each link throughout the day may also be necessary. This should be assessed locally if possible.

7.241 For junctions, common sense, driving experience and local knowledge are helpful to estimate speeds. For example, for a section of road leading up to traffic lights, the aim should be to estimate average speeds over a 50m section of road:

- Traffic pulling away from the lights, e.g. 40-50 kph;
- Traffic approaching the lights when green, e.g. 20-50 kph; and
- Traffic on the carriageway approaching the lights when red, e.g. 5-20 kph, depending on the time of day and how congested the junction is.

7.242 It is considered that the combined effect of these three conditions is likely in most instances to be a two-way average speed for all vehicles of 20 to 40 kph. Speeds in similar ranges would also apply at roundabouts, although on sections of large roundabouts, speeds may well average between 40-50 kph. EFs for the determined

[75] https://www.dft.gov.uk/traffic-counts/

[76] http://naei.beis.gov.uk/data/ef-transport

speeds should then be calculated.

Temporal Variations

7.243 It is often important to consider temporal variations with regards to both traffic flows and speed data. This should include details of local diurnal and weekly variation for peak hour exceedance calculations, and for some authorities, consideration to seasonal patterns, particularly in tourist areas, will be required.

7.244 An example of diurnal traffic flow profiles is provided in Figure 7.4, and diurnal speed profiles provided in Figure 7.5.

Figure 7.4 – Example of Diurnal Traffic Flow Profiles

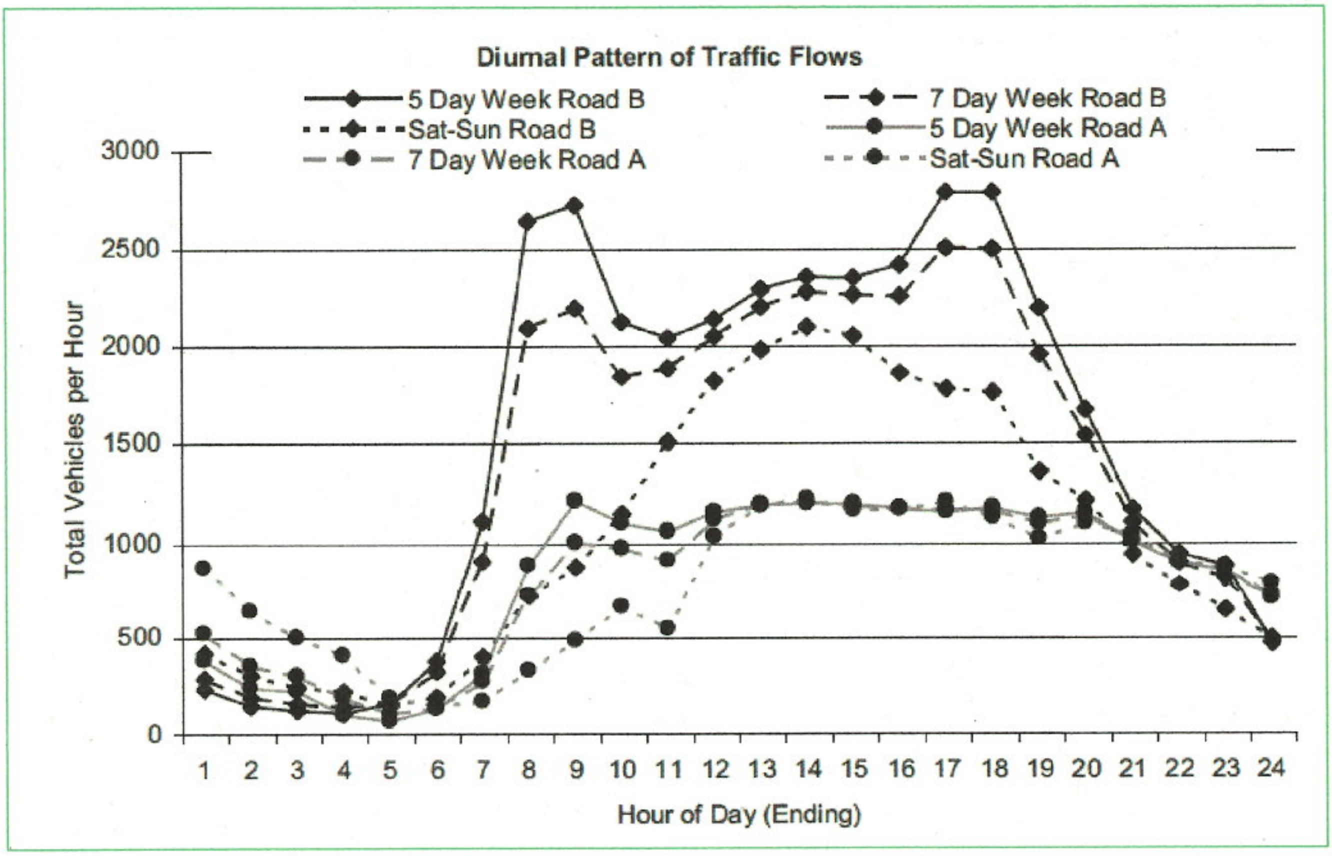
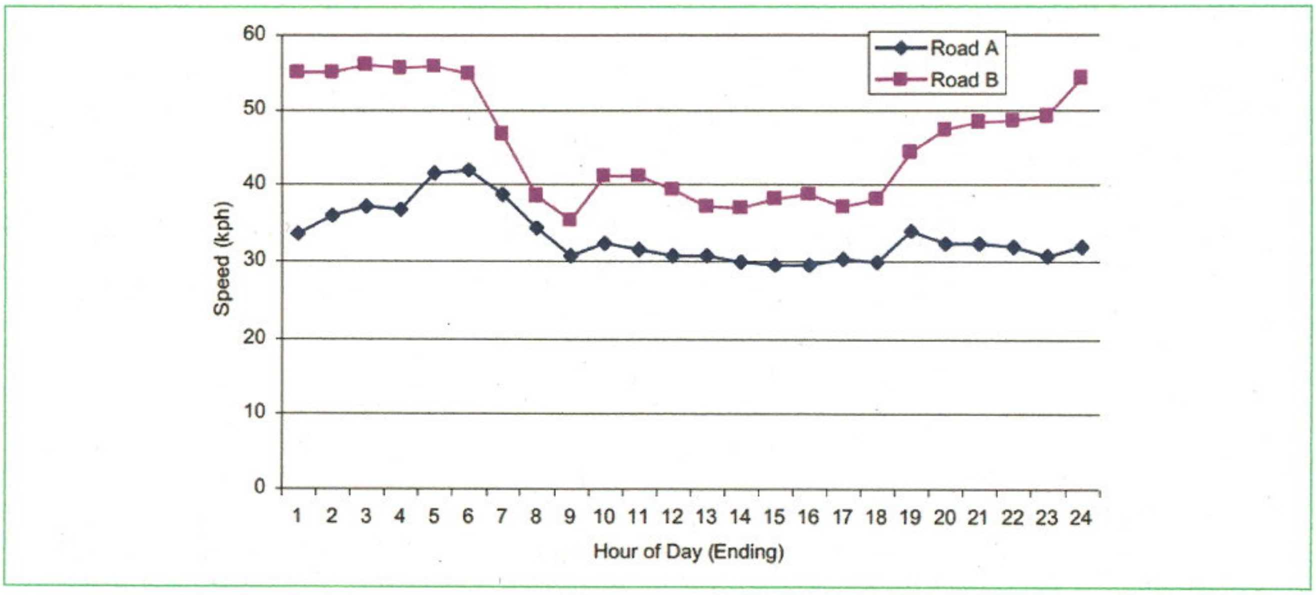


Figure 7.5 – Example of Diurnal Speed Profiles



7.245 Where such variations are considered to be of relevance to the detailed consideration of road traffic emissions, suitable data that allows comparable profiles for traffic flows and speeds to be calculated should be obtained. Many dispersion models allow diurnal and other time varying factors to be included as a model input.

Congestion

7.246 Average vehicle speeds during traffic congestion will fall, and there is no simple factor that can be applied to the average speed to calculate a speed applicable to congested periods. The preferred approach it to calculate the emission rate for the affected sections of each road for each hour of the day or week on the basis of the road speeds and traffic flows for each hour. The calculated emissions profile could then be used in the dispersion model.

7.247 In some circumstances it may be necessary to calculate a weighted average EF due to particular model constraints. The LAQM Support Helpdesk can provide further support if such circumstances arise.

7.248 Where local information with regards to congestion and associated speeds is not available, assumptions can be made as follows:

- For a busy junction, assume that traffic approaching the junction slows to an average of 20kph. These should allow for a junction, which suffers from a lot of congestion and stopping traffic. In general, these speeds are relevant for approach distances of approximately 25m;
- For other junctions (non-motorway) and roundabouts where some slowing of traffic occurs, you should assume that the speed is 10kph slower than the average free flowing speed; and

- For motorway or trunk slip roads you should assume average speeds of 40–45kph close to the junction.

Idling Vehicles

7.249 It may be necessary to calculate the exhaust emissions from stationary traffic, for instance at bus stops or taxi ranks. In such circumstances, the EF may be assumed to be equal to that corresponding to the vehicle travelling at 5kph (the lowest possible speed in the EFT).

Gradients

7.250 Road gradient can have a significant effect on vehicle emissions. Even hills with slight gradients can increase the power demanded from the vehicle engine, particularly for HDVs. As the power-demand increases, emissions increase. For vehicles going down the hill, the opposite occurs, and emissions decrease. Therefore, calculated vehicle emissions may need to be adjusted as per the methodology described below.

7.251 This methodology is based on an analysis of the EF published for use within the COPERT 4 model. Older vehicles are based on the EF published in August 2007, and newer vehicles are based on the September 2014 update.

7.252 For passenger cars and LDVs, the normal speed-related EFs should be used, taking into account that the average speed on the hill section may differ from that on the flatter sections either side of the hill.

7.253 However, road gradients can lead to larger and significant changes in emissions generated by HDVs.

7.254 The general equation for the amended speed-related EF for vehicles going up a hill is[77]:

$$EF_2 = EF_1 (1 + G \times [C_1 \times V + C_2])$$

where:

EF_1 = emission factor for vehicles travelling at the speed V on a level road (grams per vehicle km);

EF_2 = revised (greater) emission factor for vehicles travelling uphill at the same speed V (grams per vehicle km);

V = vehicle speed (km per hour);

G = the gradient of the hill, expressed as a decimal fraction (for example, a 6% gradient should be expressed as 0.06); and

C_1 and C_2 = gradient coefficients, which differ according to the HDV type, the emission standard and the pollutant of concern. These coefficients are given

[77] These relationships were developed from fitting speed related emission factors in the EMEP CORINAIR Emissions guidebook for =2%, +4% and +6% gradients.

in Table 7.9 below for specific vehicle weight categories, along with a worked example assuming vehicles travelling at 24 and 40 kph (15 and 25 mph) for a 6% gradient.

7.255 For vehicles going down a hill the amended (reduced) EF is:

$$EF_2 = EF_1\ (1 - G \times [C_1 \times V + C_2])\ \text{for gradients} \leq 2.5\%;\ \text{and}$$

$$EF_2 = EF_1\ (1 - 0.025 \times [C_1 \times V + C_2])\ \text{for gradients} > 2.5\%$$

7.256 The overall effect of these two equations is that for roads with gradients up to 2.5% and with approximately equal numbers of vehicles ascending and descending the hill, there are no net changes in emissions, i.e. the effect of gradients on all vehicles can be justifiably neglected.

7.257 The NO_x and PM EF for Euro I to Euro VI HDVs on level roads (at 50% loading for HGVs) was compared for the different vehicle weight categories.

7.258 For NO_x, HDVs meeting Euro III to Euro V standards have been treated as one vehicle age group (vehicles registered before 1st January 2014). For HDVs meeting the Euro VI standard (vehicles registered after 1st January 2014), emissions are typically around 8% of those from a Euro III vehicle, and these have been treated as a separate vehicle age group.

7.259 The gradient dependence of vehicles fitted with SCR (Selective Catalytic Reduction) emission abatement, i.e. the 2014 and later HDVs, does not follow a simple relationship. This is likely to be because the amount of NO_x reduction reagent added is actively controlled, depending on engine speed and load. This complex behaviour and the overall low EF for these vehicles means that no gradient compensation is required (setting C1 and C2 to zero leads to a scaling factor of 1 for these vehicles).

7.260 For PM, emissions from Euro III and pre-Euro III can be grouped (vehicles registered before October 2006), and those from Euro IV and later grouped in a separate category (vehicles registered from October 2006 onwards). EFs for the newer vehicles are around 80% lower than those for the older vehicles.

7.261 The gradient dependence of vehicles fitted with Diesel Particulate Filters (DPF) (i.e. the October 2006 and later HDVs) does follow a simple relationship, like the older models, as the DPF efficiency is constant at different engine speeds and loads. This leads to the simpler, linear behaviour seen for older vehicles, with increasing gradients leading to marked increases in PM emissions. This is modelled using the C1 and C2 gradient coefficients.

7.262 The relationship was developed for speeds between 10kph and 48kph (6 – 30 mph), becoming less accurate outside this range, but typically still useable up to 64kph (40 mph). Evaluation of the expression at speeds of 24 and 40 kph (15 and 25 mph) for a 6% gradient are evaluated and given as examples. This shows that the PM emissions multiplier increases with vehicle weight and increasing speed.

Table 7.9 – Road Gradient Emission Coefficients

NO_x by Vehicle Category	Gradient Coefficients				Uphill Example (EF_2)[a]			
	Old Vehicles (pre 2014)		New Vehicles (from 2014)		Old Vehicles (pre 2014)		New Vehicles (from 2014)	
Vehicle weight category	C_1	C_2	C_1	C_2	24 kph	40 kph	24 kph	40 kph
Small rigid HGV[b]	0.29	10.74	0	0	2.06	2.34	1	1
Medium rigid HGV[c]	0.48	10.81	0	0	2.34	2.8	1	1
Articulated trucks	0.62	12.44	0	0	2.64	3.23	1	1
Urban buses and coaches	0.48	7.41	0	0	2.14	2.60	1	1
PM by Vehicle Category	Old Vehicles (pre Oct 2006)		New Vehicles (from Oct 2006)		Old Vehicles (pre Oct 2006)		New Vehicles (from Oct 2006)	
Vehicle weight category	C_1	C_2	C_1	C_2	24 kph	40 kph	24 kph	40 kph
Small rigid HGV	0.12	-2.29	0.14	4.57	1.04	1.15	1.48	1.61
Medium rigid HGV	0.36	-2.27	0.38	5.40	1.38	1.73	1.87	2.24
Articulated trucks	0.46	-0.80	0.43	7.30	1.61	2.06	2.06	2.47
Urban buses and coaches	0.17	5.01	0.15	4.78	1.55	1.71	1.50	1.65

[a] Assuming $EF_1 = 1$, and $G = 0.06$ (i.e. 6%).
[b] Small rigid HGV is defined as up to 14 tonnes.
[c] Medium rigid HGV is defined as 14 tonnes and over.

Cold Starts

7.263 It may be necessary to consider cold start emissions. Emission factors for cold starts are provided in the Data section of the NAEI website[76]. For example, in the case of cold start emissions from large car parks, the number of trip ends (i.e. half the number of overall vehicle movements to/from the car park) can be used in combination with the NAEI EFs to obtain an estimate of the associated cold start emissions from the car park.

Hot Soaks

7.264 'Hot soaks' represent the evaporation of petrol fuel vapour from the fuel delivery system when a hot engine is turned off and the vehicle is stationary, which can lead to significant increases in benzene emissions. It arises from the transfer of heat from the engine and hot exhaust to the fuel system where fuel is no longer flowing. Emissions from hot soaks can be estimated in a similar manner to those from cold starts, i.e. on the basis of the number of trip ends and the EFs for hot soaks obtained from the Data section of the NAEI website[71].

Particulate Matter Resuspension

7.265 Emissions of particulate matter from brake and tyre wear and road abrasion are now included in the EFT emissions calculations. However, it may be necessary in certain circumstances to calculate the additional emissions associated with resuspended material from the road surface, e.g. in proximity to construction sites where roads are experiencing track-out.

7.266 There are no direct measurements available that quantify resuspension emissions in terms of grams per kilometre. The significance of resuspension is governed by many factors (for example, vehicle type, road surface condition and meteorological conditions), resuspended material is highly variable in terms of its source emission rate. In the event that such emissions are required to be considered in detail, please contact the LAQM Support Helpdesk for further advice.

Minor Roads

7.267 Roads not being assessed in detail will include minor roads and rural or more distant major roads. These may still collectively contribute to exceedances of the Air Quality Objectives.

7.268 Although local data describing traffic flows on minor roads is often sparse, in the absence of such data, emissions can be accounted for using the estimates provided by the NAEI[71]. These datasets distribute the UK total minor road emissions, based on average flow by road type and OS minor road density maps.

Point Sources

Introduction

7.269 A detailed study of point source emissions will involve some form of screening or modelling, requiring high quality emissions estimates and other data as inputs. An industrial source could still meet the requirement for assessment under the LAQM regime even if it is in compliance with its emissions permit as in some cases permits were developed before the national air quality objectives were adopted and are not reflected in the emission conditions.

7.270 Figure 7.6 illustrates the data required for screening assessment and detailed studies for point sources.

4 – Dispersion Modelling of Emissions

Introduction

7.372 This section provides advice to local authorities on the use of air quality dispersion models for the purposes of Review and Assessment. Dispersion models are a valuable tool for a variety of reasons:

- To quantify the contribution of pollutant emissions arising from different sources types on overall concentrations;
- Concentrations can be predicted across a wider geographical area than is possible through monitoring alone;
- Geographic boundaries of any exceedances of the air quality objectives can be determined;
- Concentrations can be predicted for future years, taking into account changes in emissions sources and emissions data; and
- Scenario testing can be undertaken in order to determine the source contributions and effects of AQAP measures on predicted concentrations.

7.373 The purpose of this section of the Technical Guidance is to:

- Promote best practice and the efficient use of resources for dispersion modelling;
- Provide local authorities with useful information and methods to consider when undertaking detailed dispersion modelling;
- Help obtain as reasonable results as practicably possible from dispersion models and increase the confidence in model predictions; and
- Assist in the sensible interpretation of results.

7.374 This section consider the following topics, which should cover the main issues faced by local authorities when carrying out dispersion modelling:

- How to model road-traffic sources;
- How to model point sources (i.e. stacks from industrial facilities or commercial and domestic sources such as biomass combustion sources);
- How to model fugitive sources; and
- How to verify modelled results using monitoring data.

7.375 The main sources requiring detailed dispersion modelling of emissions should be identified through the screening assessments carried out by local authorities. Based on the findings of the previous rounds of Review and Assessments, these sources are expected to include mainly road transport and some industrial processes. Therefore, this section mainly focuses on these sources. However, a number of other transport sources (aircraft, railways and shipping) or fugitive sources such as quarries, waste transfer sites and major construction sites, may require modelling in certain circumstances. In this case, the local authority may want to contact the LAQM Support Helpdesk to obtain further information.

Modelling Road Traffic Sources

7.376 The main roads of concern requiring detailed dispersion modelling should have been identified through a screening assessment using the DMRB air quality screening tool (see para 7.80), the National Modelling Maps[24], and/or air quality monitoring reported in the local authority's LAQM reports.

7.377 The information in the sections below provides further information on methods to assess road traffic sources in more detail based on more complex dispersion models.

7.378 Local authorities are reminded that any detailed dispersion modelling, should be compared against local monitoring data in order to provide confidence in the results and any decisions made based on the outcome of the modelling. However, this should be only possible if the measurements are of good quality, have been measured over a reasonable time period, and are representative of the receptor location assessed. Although the DMRB air quality model is not considered below (as not a detailed dispersion model), DMRB results should also be compared with local monitoring data wherever possible.

7.379 Monitoring data should also be considered as part of any detailed dispersion modelling work, as they can provide further information on pollution levels in complex areas, such as large and/or congested junctions, street canyons or other situations that may not be assessed well by dispersion models.

7.380 Most local authorities proceeding to detailed modelling of road traffic sources will be mainly concerned with potential exceedances of the annual mean (for NO_2 and/or PM_{10}) and the 24-hour mean PM_{10} objectives. However, the potential for exceedances of the 1-hour mean NO_2 objective should also be considered at relevant receptor locations. Predictions of these short-term concentrations will inevitably be less accurate than predictions of the annual mean. Short-term predictions can be carried out directly by dispersion models, and although they often perform poorly in linking short-term concentrations with specific meteorological conditions, the actual concentrations predicted can be reasonable if the model is validated correctly. Alternatively, the empirical relationships discussed in paras 7.90-7.93 can be used to estimate short-term concentrations from the annual mean.

7.381 In some instances, authorities may also consider annual mean $PM_{2.5}$ concentrations, with reference to the potential to increase $PM_{2.5}$ emissions (England and Wales) or the objective limit value (Scotland).

Traffic Input Data for Dispersion Modelling

7.382 The level of detail of traffic input data will vary depending on how much information is available, but in general, should include the following as a minimum, for all identified roads:

- Traffic flows as Annual Average Daily Traffic (AADT);
- Average vehicle speed; and
- Fleet composition including at least the split between LDVs and HDVs (generally

provided as %HDVs within the total traffic flows).

7.383 When carrying out detailed dispersion modelling, local authorities may consider focusing on small specific areas and sensitive receptors to scales of 10's of metres, as opposed to wider scale modelling that may miss out the details at roadside locations where exceedances are more likely and so miss pollution hotspots. However, it is recognised that some authorities have already set up models covering wider urban areas, or city / town centres as a whole, which may include many different types of sources. It may however be useful for some sources to be refined in more detail where there are specific local concerns or where local knowledge indicates that an area requires greater attention.

7.384 In general, the use of complex dispersion models will require geographical information such as:

- A numerical model of the road layout to be included in the dispersion model, using a Geographical Information System (GIS) to extract OS coordinates of all roads, including all vertices representing the path of the road;
- The width and elevation of each road sections;
- The grid reference of all specific receptors at which pollution levels need to be assessed; and
- A grid of receptors so that pollutant concentration contour maps showing the potential exceedance of the relevant air quality objectives can be produced, based on the dispersion modelling results

7.385 It is important that to model the source-to-receptor distance as accurately as possible. A visual check (through model interface or GIS) should be carried out to ensure that the modelled roads follow the actual alignment appropriately, and that the start/end nodes and vertices of links are in the correct place.

7.386 The use of GIS can be a quick and easy way to map the correct coordinates for sources and export them directly into dispersion models. In addition, web-based aerial mapping sites can be extremely useful when building dispersion models, as they can provide information on layout and alignment of roads.

Traffic Patterns

7.387 Most dispersion models can take into account complex traffic patterns such as:

- Variations of AADT flows during a week, month or season; and
- Hourly variations of traffic flows along the day (including change of patterns during weekends).

7.388 A diurnal pattern of average hourly speeds may also be available to use in modelling predictions. Local authorities may consider further splitting a road link, for example at the approach of a junction, in order to model the reduction in average speed in these locations.

7.389 Local authorities may consider different vehicle speeds over different time periods in order to account for congestion during peak hours and more free flowing traffic at night. Example time periods could be as follows:

- Morning Peak (7am – 10am)
- Inter-peak (10am – 4pm)
- Evening Peak (4pm – 7pm)
- Night-time (7pm – 7am).

7.390 It should be noted that diurnal patterns (both in terms of traffic flow and speed) may be related to two-way flows, and therefore the road links within a model should reflect this. Where a road, for example a motorway or A-road, has been modelled as separate sources depending on direction of flow, then the diurnal patterns for each of these sources should also reflect the direction of flow. This may be important for example where a road experiences a larger volume of traffic in one direction in the morning, whilst the flow on the other direction has a different pattern, with large flows in the afternoon.

<u>Modelling Variable Speeds</u>

7.391 Average vehicle speed can vary significantly throughout the day, with much lower speeds observed during AM and PM peak hours. Where significant variations in hourly speeds are known to occur, it may be useful to account for speed variations. Some models may allow detailed variations to be input relatively easily. Other models may require the user to split or duplicate links a number of times in order to emulate variable inputs. A few options are discussed below.

7.392 The simplest way to consider variable speeds is to split road links into three sections – one at each end of the link representing the sections of the road approaching a junction (considering a lower speed over these sections), whilst the middle section represents the average free flowing speed. This is not strictly a variable pattern as the same speed for each hour is still considered, but provides an easy method to account for lower average speeds, for example where queuing is known to occur.

7.393 Where a model does not allow the user to input hourly speed information, a more complex method may still be used, which involves overlapping links a number of times and using hourly emissions profiles to apply different emissions at the appropriate hours in the day. This is illustrated with the example below:

- Enter the same link a number of times within the model and provide emissions for the relevant speed as representative of the hour required for each copied link.
- Use variable emissions profile to effectively "turn-on" or "turn-off" the relevant link in the dispersion at the appropriate time. For example, a link may be copied four times thus:
    - Link1_AM: AM peak speed (hours beginning 7am - 10am);
    - Link1_PM: PM peak hour speed (hour beginning 4pm - 7pm);
    - Link1_Eve: Night-time speed (for hours between 7pm - 7am); and

- Link1_Inter: Inter-peak speed (for hours between 10am - 4pm).

- When setting up the road links, the speed for the relevant hour may be:
  - Link1_AM: 10 mph
  - Link1_PM: 15 mph
  - Link1_Eve: 40 mph
  - Link1_Inter: 30 mph

7.394 The emission profile for Link1_AM will then be provided so that only the hours 7am-10am have emissions accounted for. This can be done by providing a factor of one for these two hours, whilst all other hours are set to 0 (zero emission).

7.395 The use of this overlapping system allows greater variability of inputs, and may also be used to vary other data such as proportions and speeds of HDVs. In this way, detailed traffic flows and speeds can be considered within dispersion models. An example of when this type of detailed approach may be useful is when assessing the impact of traffic management measures expected to reduce queue lengths of traffic, improve speeds on roads, or vary the diurnal pattern or speed of traffic flows on specific roads.

Varying Speeds and Traffic Flows for Different Hours

7.396 In many models, the user can vary the number of vehicles per hour per link assuming a particular speed. For example, the vehicles per hour entered for Link1_AM is 1200 vehicles per hour at 10mph, which represents the 7am traffic flow and speed. The emissions profile for that link can also be used to alter the traffic flow for the hour 8am but keeping the same speed. For example, the traffic flow at 8am is twice that of the 7am flow (with an average speed of 10mph). Using the emissions profile, the factor for the hour 7am remains at one, but for 8am is factored up by two (thus doubling the hourly traffic flow whilst maintaining the same speed).

7.397 Note, it may be more difficult to use the emissions profiles in the same way to vary the proportion of HDV and speed at the same time as the factors are more difficult to determine (unless emissions tools and inventories are used to perform the calculations). If this is required, and a model does not allow hourly input to this level, a duplicate set of links may be entered, one for example for LDVs only, and one set for HDVs only. Each can then be varied for speed and/or flow throughout the day using link copies.

Modelling Congestion

7.398 In many cases, the area requiring detailed dispersion modelling is likely to include busy junctions where traffic congestion is a main concern. Modelling congestion can be carried out in a number of ways depending on the constraints of the model, in particular the number of links that can be entered.

7.399 A simple way to model congestion is to split the road link into three sections, similar to that representing a junction or crossing, and reduce the speeds in those sections where queuing traffic is known to occur. Additional complex methods may also involve accounting for the variable speeds during different hours as described above.

7.400 However, other model setups may be considered, such as varying certain links representing queues. For that purpose, estimates of the following would be required:

- Queue length;
- Traffic speed; and
- Variability of congestion throughout the day.

7.401 To represent the variability of congestion during the day, the method described above for overlapping links can also be used. Local authorities should be careful not to double count emissions of traffic when modelling queues and diurnal patterns. Both variable speeds and idling emissions could be used in some specific locations, for example for complex junctions.

Modelling Accurate Vehicle Fleet Composition

7.402 Whilst some models may only allow LDV and HDV flows as input data, most models should allow entering user-defined pollutant emissions rates, allowing a better representation of the actual vehicle fleet composition.

7.403 These may include (but are not limited to) the following vehicle type classifications:

- Cars (petrol and diesel);
- LGVs (petrol and diesel);
- HGVs (rigid and articulated);
- Buses and coaches; and
- Taxis (sometimes defined as a separate category when derived from traffic models).

7.404 A combined emission rate can be entered for a road link based on the relevant proportions of each type of vehicle. If this is the case, the speed for all vehicles will be assumed to be the same. In some cases the speed may be different (for example, HDVs on motorways), or a local authority may be interested in calculating the contribution a certain type of vehicle makes to the total pollutant concentrations at a nearby sensitive receptor. This may be done using the "layering" system described above, by setting up several emission sources on top of each other for each vehicle type, and entering in emissions for that type only. For example, a road source termed "Road1" which incorporates all vehicle types could be modelled as "Road1_Cars", "Road1_LGVs", "Road1_HGVs" and "Road1_Buses" as separate sources.

7.405 This type of setup can be useful as the contribution of each road link to concentrations predicted at a receptor can easily be determined, and the model input can also easily be changed. For example, this can be used to determine what happens if the vehicle speed or number of vehicles changes for a specific vehicle category.

7.406 Local authorities may have more detailed estimates of vehicle classifications such as proportions of diesel and petrol cars and LGVs, rigid and articulated HGVs, along with separate estimates of buses and coaches. Local estimates should be included in dispersion modelling where available. However, in the absence of local estimates, default splits of petrol/diesel and EURO emission categories are built into the EFs within the NAEI and the EFT.

Source Apportionment for Different Vehicle Types

7.407 Source apportionment studies should be carried out as part of LAQM assessments in order to determine the relative contribution of vehicle types at specific worst-case receptor locations. These source apportionment studies can also be useful when considering the impacts of different traffic management options, for example as part of scenario testing within action plans. The methodology is described in para 7.94 and a worked example provided in Box 7.5.

Modelling Street Canyons

7.408 Accurate dispersion modelling in urban areas can be difficult due to the presence of obstacles (buildings, trees, walls, etc) that modify the wind flow locally and alter dispersion. This is especially the case in so called "street canyons", where buildings on both sides of the road can lead to the formation of vortices and recirculation of air flow that can trap pollutants and restrict dispersion (often termed as the "canyon effect"). Although street canyons can generally be defined as narrow streets where the height of buildings on both sides of the road is greater than the road width, there are numerous example whereby broader streets may also be considered as street canyons where buildings result in reduced dispersion and elevated concentrations (which may be demonstrated by monitoring data). Therefore, canyon effects can occur both in small towns or large cities.

7.409 Studies involving monitoring campaigns on both sides of street canyons have shown that background concentrations influence pollutant levels within street canyons, as the air mass at rooftop level moves into the canyon, leading to increased ventilation and "flushing out" of polluted air. Similarly, gaps between buildings may allow increased wind flows to enter the canyon thus re-circulating pollutants away from the junctions, but causing increased concentrations further away. The opposite effect however may occur if the gap is at junction, where road traffic emissions are carried into the canyon, resulting in higher concentrations.

7.410 Even when using complex three dimensional models (Computational Fluid Dynamics – CFD models), it is unlikely that such degrees of complexity are adequately accounted for, and the uncertainties of modelled results can be difficult to quantify.

Street Canyon Models

7.411 Models designed for the prediction of air pollution concentrations within street canyons aim to calculate the zone of recirculation of wind flow in order determine the resulting concentrations within these locations. Wind direction and velocity is used to determine where (for example on which side), and how large the recirculation zone may be. The size of the recirculation zone varies and may occupy the whole width of the street, or the leeward side only (the upwind side). Concentrations within the recirculation zone are considered to be uniform (or homogenous) by many dispersion models.

Main Parameters to Consider when Modelling Street Canyons

7.412 Weather conditions such as wind speed, direction and temperature will affect the dispersion of pollutants within street canyons. These parameters are usually included in a meteorological file (generally hourly sequential data for a whole year) as model input data. Other parameters that need to be considered (for each modelled road link assumed to be a street canyon) are:

- the street canyon width, which is not the road width, but the distance measured as façade to façade of buildings on either side of the street; and
- the average height of buildings on both sides of the road (some models may allow specifying different heights for each side).

7.413 Where a street can be partially classified as a street canyon, for example where there are gaps in between blocks of buildings, monitoring in such locations may indicate elevated concentrations. It is therefore recommended that local authorities consider these links as street canyons; otherwise predicted concentrations are likely to be underestimated.

Potential Issues Associated with Street Canyon Modelling

7.414 The limitations associated to street canyon modelling should be understood by consulting model suppliers and user guides. A common mistake is to model specific receptors outside of a street canyon. Models accounting for street canyons generally split the modelled area in two parts: the actual street canyon (delimited by the canyon width) and areas outside the canyon on both sides of the road. While predicted concentrations within the canyon are higher, modelled concentrations outside the canyon may decrease rapidly. Therefore, it is recommended to check the distance of receptors to the centre of the road and compare to the canyon width, to ensure they are correctly located within the street canyon.

Installing Monitoring Sites in a Street Canyon

7.415 Local authorities are advised in most circumstances to monitor concentrations at the roadside and building façade at a number of locations within a street canyon. In the absence of widespread monitoring in a number of street canyons, the results from a single detailed study could be used to help assess similar areas on the bases of comparisons of traffic flows and to compare against the predictions from models.

Modelling Junctions

7.416 Junctions are relatively easy to set up in a dispersion model. The model set up should consider changes in speeds, road widths, queue lengths and congestion as described in the sections above. In many cases a simple approach may be sufficient to model a junction, by accounting for reduced speeds on road links within 25m to 50 m of the junction, and including diurnal patterns of traffic flows. More detailed modelling may be required, such as considering street canyons (see para 7.408), splitting the main roads into multiple lanes to account for separate traffic movements on the various arms of the junction (see para 7.433), including bus lanes. The requirement to increase the level of detail at a junction will depend on the level of relevant exposure at the location and the risk of exceeding the objectives. Local knowledge and data gathered through local monitoring studies will assist in this regard.

Modelling Car Parks

7.417 Car parks are unlikely to require detailed modelling for Review and Assessment. However, local authorities should still consider the local access roads, which are of more concern locally, particularly where queuing or congestion is created on these roads (typically during peak hours). In some cases, local authorities may wish to consider the impact of a proposed new car park on local air quality, if there are receptors close by. Information on the potential ways to model car parks is provided below.

7.418 There are a number of different types of car parks including surface, multi-storey, underground and mezzanine. Car park emissions may be fugitive, through open-to-air façades, or controlled via mechanical or passive ventilation systems. Emissions from surface and multi-storey car parks may be typically modelled as area or volume sources, whilst emissions from underground car parks fitted with a mechanical ventilation system may be modelled as point sources. Model developers and user guides should be referred to for the specific requirements associated to these sources.

7.419 It is recommended that for multi-storey car parks, a series of area sources be used as opposed to one single volume source, to better represent the spatial distribution of emissions in relation to nearby receptors.

7.420 Where detailed modelling of car parks is deemed necessary the following information is likely to be required:

- The hourly profile of number of vehicles entering and leaving the car park;
- Assumptions related to idling time for vehicles. This may vary for short-term and long-term car parks, but emissions should be calculated (in the absence of idling emission factors) assuming a speed of 5kph;
- Assumption of the proportion of vehicles assumed to enter and/or leave the car park under cold start conditions;
- Assumption of the proportion of vehicles assumed to experience 'hot soaks' (only of relevance for benzene);
- An estimated average distance travelled by each car within the car park and the average speed (often a speed limit of 5 to 10 mph is in place). Where this is not

known, it may be assumed, for example, that each vehicle travels a distance equivalent to the perimeter of the car park; and

- Diurnal profile of traffic flows on the car park access roads.

Modelling Bus Stations and Bus Stops

7.421 It is sometimes necessary to include the contribution of emissions from a bus station or bus stops when carrying out detailed modelling, as these are often responsible for hot spots of pollution concentrations in urban areas. In particular, emissions from bus stations and bus stops may lead to exceedances of the 1-hour mean objective for NO_2. As modelling exceedances of this objective is difficult, local authorities should focus on identifying modelled NO_2 annual mean > 60µg/m^3 (see further information in para 7.91).

7.422 The main difficulty in bus station/stop modelling is the uncertainty associate to bus EFs, especially from idling engines.

7.423 Note that if a bus station or bus stop is modelled as part of a wider area (part of a town or city centre), a separate model verification may be necessary for the bus station area alone (based on monitoring data from sites located near the station), while the rest of the model is verified with results from typical roadside monitoring sites.

Bus Stations

7.424 Modelling a bus station should not be undertaken without robust monitoring data to verify modelled results, as these are likely to be subject to significant uncertainties. Given these uncertainties, local authorities may even choose to rely on monitoring alone to determine whether there is a risk of exceedance of the air quality objectives.

7.425 The most common way of modelling a bus station is to include an area or volume source in the model set up with a specific EF, as well as modelling emissions from the access roads. EFs should be combined with local parameters such as:

- The number of buses per hour stopping at the station, and
- The average time of idling.

7.426 This should allow the calculation of an overall emission rate that reflects the local conditions.

7.427 The diurnal pattern should also be included to reflect the variations of bus flows throughout the day. This could involve undertaking detailed traffic counts on relevant roads close to bus stations in order to determine patterns appropriately, or bus station timetables could be used to determine the frequency of buses throughout the day.

7.428 In the absence of idling emissions factors for buses, it is possible to estimate emissions assuming buses travelling at a low speed (the lowest speed allowed by the EFT should be used, typically 5kph). If using speed related EFs for idling buses, the method described above (for car parks) should be used, with the relevant EFs for buses, and the estimated idling time for each bus to determine the emission rate. It is recommended that idling times are based on the observed operation of buses as these may vary.

Bus Stops

7.429 In practice, it can be difficult to model all bus stops within a large area. Therefore, the decision to include bus stops in the model set-up should, wherever possible, be based on evidence from monitoring data that the air quality objectives are at risk of being exceeded at sensitive receptors nearby.

7.430 Local authorities should take care when selecting suitable monitoring locations near bus stops, as these sites are only likely to be representative in terms of exposure to the 1-hour mean objective for NO_2 (if there are no residential properties or other sensitive receptors relevant for the annual mean objectives nearby).

7.431 As for bus stations, bus stops may be modelled as area or volume sources. The overall emission rate should ideally be based on:

- An idling EF;
- The number of buses per hour (or per day); and
- A diurnal pattern to take into account variability in bus traffic throughout the day.

7.432 If a bus stop affects the speed of traffic locally, it may be useful to split road links close to the bus stop to assign appropriate lower speed to vehicles.

Modelling Multiple Lanes of Traffic

7.433 In certain circumstances, it can be useful to model separate traffic lanes (for different directions) instead of modelling one road. This is likely to improve the accuracy of predicted results along the road of concern. Locations where separate lanes may be useful to consider include:

- Wide roads, like dual carriageway, A-Roads or motorways; and
- Queuing on one side of the road near a junction while the other side is free-flowing.

7.434 Care should be taken with regard to how the model deals with road widths, particularly in areas that are being modelled as street canyons.

7.435 If traffic data are available, detailed dispersion modelling of wide roads may include separate road sources for each direction. This may be beneficial as it should allow a better representation of different speeds for traffic travelling in different directions (for example approaching or leaving a major junction), and different proportions of vehicles and diurnal traffic patterns may be incorporated.

7.436 Splitting wide roads into separate directional links within the dispersion model may lead to vehicle-induced turbulence effects being incorrectly represented within the dispersion model. However, in many cases, having a more accurate representation of traffic flows in the model is likely to be more preferable than the uncertainty introduced by this potential issue.

Modelling Road Gradients

7.437 As discussed in section 3 of this chapter dealing with emission estimates (para 7.250), road-traffic emissions on roads with significant gradient (>2.5%) can increase significantly (especially exhaust emissions from HDVs), as the engine power demand for vehicles going can increase significantly.

7.438 Adjusted HDV emissions factors for roads with significant gradient have been described in this Chapter (section 3 para 7.250).

7.439 Local authorities may want to model the effect of road gradient on overall road traffic emissions using this methodology. This should require identification of all roads with a gradient >2.5%. This information should be available from the Council's transport department.

Taking Terrain into Account

7.440 Most of the dispersion models have been developed to predict pollutant concentrations on flat terrain, i.e. without taking topography into account. However, in reality complex terrain such as hills or valleys may have a significant effect on the dispersion of pollutants, especially for large scale modelling (over 1km). A number of dispersion models may include an option to model the effect of terrain on pollutant dispersion, based on a Digital Terrain Model (DTM), which can be entered in the model set-up.

7.441 However, the effect of terrain is mostly considered in the case of point source modelling, where emissions from stacks can have an impact far from the source. This case is discussed in further detail in para 7.462.

7.442 Model providers should be contacted for advice on including terrain when modelling sources such as roads. The standard criterion in considering terrain is a 10% gradient in slopes. Under this value, it is generally unnecessary to include terrain in the model set-up. However, in practice, it is likely that the effect of buildings in urban areas, and in particular the street canyon effect, will be a more important parameter affecting the dispersion of pollutants.

Modelling Road Layouts which Vary with Height

7.443 A typical approach to modelling a road network is to consider the road elevation and the modelled receptor heights to be input into the model, for example, a road elevation at 0m (or at grade) and ground level receptors at 1.5m (or at a particular building storey height). Some, but not all, dispersion models allow the type of road to be defined including bridges, depressions and cuttings, embankments, elevated roundabouts and slip roads.

7.444 Setting up the model to account for varying road source heights, especially where there are sensitive receptors, is an important point to consider. Although a key consideration should be to assign road and receptor heights ensuring that the relative difference in height between source and receptor is correct, the absolute height of each above the ground is equally important as the model considers the release height of the source and the vertical profile of the wind field as part of the dispersion calculations.

7.445 Where a model does not incorporate different road types such as bridges and/or cuttings, or easily account for height differences between sources, and only the relative height of source and receptor above ground can be considered, users should be aware that setting the whole road network at an elevated base level may result in the model under predicting, whilst not accounting for elevated road sections appropriately may result in the model over predicting. Such effects are particularly important to consider where these locations are being used for the purposes of model verification (and possibly adjustment).

7.446 Model suppliers should be contacted for further advice on representing variably source heights within models, particularly where heights greater than 10m are thought to be required as vertical wind profiles determined within models may affect modelled concentrations. As for many detailed dispersion modelling options, some testing of the sensitivity of results to these options is recommended, particularly where model verification is being performed.

Spatial Resolution of Modelled Receptors

7.447 The aim of detailed dispersion modelling is to focus on specific hot spots such as single roads or junctions where potential exceedances of the air quality objectives have been identified through previous screening assessments.

7.448 Typically, dispersion models should be set up so that concentrations can be predicted at:

- Specific receptor locations representative of exposure; and
- On a grid of receptors with a 5m resolution or less near to the roadside to determine the extent of areas where exceedances are more likely to occur, which can then be used to declare AQMAs.

7.449 Where models generate receptor locations automatically (for example based on a function determined by road width) local authorities should check that receptor locations are representative of relevant exposure and do not miss out the areas closest to the road source (worst-case locations).

7.450 Concentration contours are generally drawn for the areas where exceedances have been identified based on verified dispersion modelling of road traffic sources. This does not mean that whole urban areas need to be contoured, particularly background locations in smaller towns where pollutant concentrations are unlikely to approach the objectives. Specific receptors should first be used for any detailed modelling at the roadside and then contours produced for the relevant areas with, or close to exceedances. This approach can save considerable time and resources.

7.451 Where contour maps for a whole urban area are required, these should include greater detail within 30m to 50m of roads (sometimes further for dual carriageways or motorway sites, where the drop-off distance for concentrations to reach background levels is greater), and generally be based on a grid spacing of 5m to 10m. General background concentrations for most urban areas are well known and do not require detailed contouring. However, verified modelled background concentrations based on local emission inventories may be useful for wider decision making purposes.

7.452 The risk of modelling pollutant concentrations in large regions with a low spatial resolution is that the model is likely to miss hot spots of air pollution where exceedances are likely. It is particularly important for dispersion modelling of road traffic emissions, as concentrations tend to reduce quickly as the distance from the road increases. Therefore, the spatial resolution of a modelled grid of receptors is a key parameter of model setup.

Background Concentrations for Road Traffic Modelling

7.453 Although dispersion models may allow users to provide hourly background concentrations, in most cases, annual mean background concentrations should be sufficient for road traffic assessments.

7.454 The way to project annual mean background concentrations to future years is set out in para 7.70. Local authorities will also need to project hourly background data for future years where these values are used in an assessment. In the absence of more detailed projection factors, the hourly background concentrations may be adjusted using the projection factors derived from the annual mean data.

Modelling Point Sources

7.455 When predicting the impacts of stack emissions for Review and Assessment purposes, the use of Emission Limit Values (ELVs) for authorised processes is often pessimistic and many plants operate well below these. The modelling assumptions should be realistic but conservative. The onus has to be on information from the operators. Useful data may also be obtained from the annual returns from process operators to the regulatory agencies (see para 7.274).

7.456 It is important to identify the emissions profiles for point sources as these have an impact on the contributions to short-term concentrations. It is also advisable for local authorities to contact the regulatory agencies for information on any previous modelling assessments they may have carried out, in order to avoid duplication of effort and ensure consistency.

Modelling Variable Emissions from Stacks

7.457 In the first instance, modelling stack emissions assuming a constant annual emission rate should be carried out. Modelling variable emissions should only be carried out if this simpler approach has indicated potential exceedances of the relevant air quality objective (considering both stack and background contributions to overall concentrations). For large industrial facilities, it is likely that continuous emission rates, on an hourly basis, will these are treated as area or volume sources, where emission rates can be estimated. Operators may be able to assist in the estimation of emissions due to fugitive losses from a site or process through mass balance calculations. In the case of storage tanks emissions, material balance calculations may be more appropriate.

7.507 The LAQM Support Helpdesk can be contacted for further advice regarding modelling and estimation of these types of sources. However, due to the complex nature of many of these sources, including variability of activity and uncertainty of emissions estimates, monitoring will be play an important role in the assessment of the air quality concentrations in their vicinity.

7.508 It is recommended that monitoring is undertaken in order to determine the requirement for more detailed studies, and this monitoring can assist in the verification of any modelling undertaken. Monitoring will also assist authorities in determining the extent of any exceedances of air quality objectives, and in the confirming the need to declare any AQMAs. However, modelling alone of these sources may be insufficient as the uncertainties around the emissions estimates and source parameters are not well defined.

Model Validation, Verification, Adjustment and Uncertainty

7.509 Model validation refers to the general comparison of modelled results against monitoring data carried out by model developers. The model used should have some form of published validation assessment available and/or should be recognised as being fit for purpose by the regulatory authorities.

7.510 However, in most cases, the validation studies performed by model developers are unlikely to have been undertaken in the area being considered. Therefore, it is necessary to perform a comparison of the modelled results versus monitoring results at relevant locations. The results of this comparison should be included in Review and Assessment reports, and is referred to here are model verification.

7.511 The predicted results from a dispersion model may differ from measured concentrations for a large number of reasons:

- Estimates of background concentrations;
- Meteorological data uncertainties;
- Uncertainties in source activity data such as traffic flows, stack emissions and emissions factors;
- Model input parameters such as roughness length, minimum Monin-Obukhov; and overall model limitations; and
- Uncertainties associated with monitoring data, including locations.

7.512 Model verification is the process by which these and other uncertainties are investigated and where possible minimised. In reality, the differences between modelled and monitored results are likely to be a combination of all of these aspects.

7.513 Throughout the Review and Assessment process it has been recognised that in many cases an adjustment of modelled results is required in order ensure that the final concentrations presented are representative of monitoring information from an area.

7.514 It is important that local authorities review the results of their modelling carefully and bear in mind that model adjustment is not the first step in improving the performance of a dispersion model. Before adjustment of a model is applied, local authorities should check their model setup parameters and input data in order reduce the uncertainties. Common improvements that can be made to a "base" model include:

- Checks on traffic data;
- Checks on road widths;
- Checks on distance between sources and monitoring as represented in the model;
- Consideration of speed estimates on roads in particular at junctions where speed limits are unlikely to be appropriate;
- Consideration of source type, such as roads and street canyons;
- Checks on estimates of background concentrations; and
- Checks on the monitoring data.

7.515 Once reasonable efforts have been made to reduce the uncertainties of input data for a model, further comparison of modelled and monitored results can be undertaken. Where discrepancies still remain, local authorities may need to consider adjusting the model.

7.516 The modelled results from industrial sources alone are not expected to be adjusted. It is recognised that appropriate monitoring around stacks may not be available to allow verification of the modelled results. Furthermore, the comparison of a stack model at one monitoring location does not necessarily provide a good indication of the model performance, particularly as the location at which peak concentrations are predicted, will vary from year to year, due to changes in meteorological conditions, and may not be represented by the monitoring data. Where long-term monitoring is available it should be compared against the modelled results and commented upon.

7.517 The results of dispersion modelling of point sources may not agree with the results of monitoring for a number of reasons including:

- Uncertainties in emissions estimates;
- Difficulties in determining emissions profiles;
- Model parameters related to complex effects such as buildings and terrain; and
- Meteorological data.

7.518 Local authorities comparing modelled and monitored results for a stack can contact the LAQM Support Helpdesk for further advice and assistance.

7.519 For the purposes of Review and Assessment, model adjustment is generally only required for road traffic modelling, not for stack or other sources modelling.

What Type of Sites Should be used for Verification?

7.520 Kerbside sites are generally not recommended for the adjustment of road traffic modelling results as the inclusion of these sites may lead to an over-adjustment of modelling at roadside sites. The exception is where kerbside sites are relevant for exposure, for example properties fronting directly onto the road. In that case, kerbside sites may be used in the model verification process.

7.521 Dispersion models may perform differently at kerbside, roadside and background sites. For example, models may predict reasonable concentrations towards background sites, but under-predict at locations closer to the roadside. In most cases, local authorities are concerned with the predictions closer to roadside sites as these are at more risk of exceeding the air quality objectives and model verification is generally based on these locations.

7.522 Where a model has been used to predict background concentrations (for example based on an emissions inventory), the modelled background concentrations should also be verified and where necessary adjusted.

7.523 If national background maps are used, these should first be compared against any local monitoring to check they are representative of the area. In most cases there is good agreement with local monitoring, but some locations may not agree. Local authorities are not expected to verify and adjust the national background maps. Where these estimates do not agree with local monitoring, either local monitoring may be used, or local authorities may consider adjusting the background maps. The LAQM Support Helpdesk should be contacted for advice on adjusting national maps.

7.524 In addition to the consideration of roadside and background sites during model verification, local authorities should also consider separating different types of locations when comparing modelling and monitoring. For example, modelling undertaken for roadside sites in urban areas may require a different adjustment to modelling undertaken for roadside sites near motorways or trunk roads in open settings. In some cases, local authorities may also identify some urban sites such as street canyons, which perform differently to more typical urban locations. Where large differences in an adjustment factor are determined for different types of location, local authorities should consider undertaking separate adjustments within a model area in order to avoid over or under-predicting at the different types of location. For example, adjusting modelling results close to a motorway based on verification and adjustment at street canyon sites could lead to a large over-prediction of results.

What Type of Monitoring Data Should be used for Verification and Adjustment?

7.525 All monitoring used for verification and/or adjustment of modelling results should be undertaken to the standards described in section 2 of this chapter.

7.526 For the verification and adjustment of NO_x/NO_2, a combination of continuous monitoring and diffusion tubes is recommended. As described above, some types of sites can perform differently, and it is considered better to have multiple sites at which to verify results rather than just one continuous monitor. The use of one continuous monitor alone to derive the adjustment factor for a model is not recommended as the monitoring site may not be representative of other locations modelled, and the adjustment factor derived will be heavily dependent on the source to receptor relationship as represented by the meteorological data file used in the dispersion model.

7.527 Where only diffusion tubes are available for model verification, annualisation of any short-term datasets should be undertaken as described in section 2 of this chapter (see worked example in Box 7.10). Longer-term diffusion tube monitoring is preferred to short-term studies and it is recommended that local authorities implement more diffusion tube monitoring in locations identified as requiring detailed dispersion modelling. For example, if a single junction is identified from a screening assessment or the results of a single diffusion tube, then more diffusion tubes should be placed at relevant locations around the junction as soon as possible. This will provide the local authority with more information on the spatial variation of concentrations, and will assist when model verification is undertaken.

How do I Verify and Adjust my Modelling?

7.528 The process of verifying and possible adjusting models can be a difficult process. Box 7.14 and Box 7.15 set out some of the common steps to be taken in order to assist local authorities in understanding if their modelling is appropriate, and to help identify when adjustment of models may be required. This information is provided for NO_x/NO_2 of road traffic sources, but the same methods can be applied to PM modelling. However, local authorities generally have much more limited PM_{10} (and even less $PM_{2.5}$) monitoring sites, and may only have one site. Therefore, care needs to be taken when applying model adjustment based on one monitoring site only as the adjustment may not be representative of other locations.

7.529 In the absence of any PM_{10} data for verification, it may be appropriate to apply the road-NO_x adjustment to the modelled road-PM_{10}. If this identifies exceedances of the objective, then it would be appropriate to monitor PM_{10} to confirm the findings.

7.530 When only road traffic sources have been modelled, the predicted concentration from the model, without any background, should be referred to as the "road source contribution". The contribution can be estimated for both monitored and modelled data by subtracting the background concentration from the total concentration. This may be for NO_x, NO_2 and PM.

7.531 As described above, there are a number of reasons why modelling and monitoring results differ. When modelling road traffic sources, errors are likely to apply to both the road source contribution and background contributions, however, it is common to apply the adjustment to the road source contribution.

7.532 When model adjustment is undertaken this should be based on NO_x and not NO_2, as explained in Box 7.16. Where diffusion tubes are used in the calculation of the model adjustment, NO_x will need to be derived from NO_2 using the NO_x to NO_2 Calculator published on the LAQM Support website[54].

7.533 Local authorities are reminded that adjustment of modelling should not be based on the total NO_x (or NO_2) concentrations unless the adjustment is very small (for example within 5%). This is because any adjustment of the total concentration would also be applied to the background contribution. In many cases background is based on national maps or local monitoring, adjustment of this component could results in unrepresentative estimates of the background concentrations across the area. Such adjustment could result in unrealistic estimates of different source contributions and may affect the outcome of source apportionment studies undertaken as part of further assessments and action plans.

7.534 It is important to remember that a number of assumptions are made when undertaking model adjustment and it should be recognised that any adjustment carried out is a reflection of the specific scenario modelling and the availability and quality of input data and monitoring data.

7.535 Local authorities are encouraged to contact the LAQM Support Helpdesk for advice and assistance during the verification process.