VOLUME 11 ENVIRONMENTAL ASSESSMENT

SECTION 3 ENVIRONMENTAL ASSESSMENT TECHNIQUES

PART 1

AIR QUALITY

SUMMARY

This document gives guidance on methods for the assessment of the impact of roads on local and regional air quality. It provides a revised methodology for the estimation of the local and regional air quality impact of roads, necessitated primarily by the publication of revised vehicle emission rates. A number of other changes have also been made to bring it in line with the latest information.

INSTRUCTIONS FOR USE

This revision replaces Section 3, Part 1 of Volume 11 dated May 1999 and its two amendments dated August 1999 and March 2000.

1. Insert replace Part 1 into DMRB Volume 11, Section 3.

2. Remove existing Part 1 dated May 1999, Amendment No. 1 dated August 1999 and Amendment No. 2 dated March 2000 and archive as appropriate.

3. Please archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from The Stationery Office Ltd.

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DESIGN MANUAL FOR ROADS AND BRIDGES

THE HIGHWAYS AGENCY

SCOTTISH EXECUTIVE DEVELOPMENT DEPARTMENT

WELSH ASSEMBLY GOVERNMENT
LLYWODRAETH CYNULLIAD CYMRU

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND

Air Quality

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1. INTRODUCTION

1.1 The compounds released to the air by road vehicles are involved in a variety of environmental effects over different geographical ranges and time periods. Some compounds have an immediate and very local effect. For example, a plume of black smoke is instantly unpleasant to those who see it, while on a longer time scale, repeated exposure to vehicle smoke can cause soiling to buildings and materials in its vicinity.

1.2 The combustion of a hydrocarbon fuel in air produces mainly carbon dioxide (CO_2) and water vapour (H_2O). However, combustion engines are not perfectly efficient, and some of the fuel is not burnt or only partly burnt, which results in the presence in the exhaust of hydrocarbons and other organic compounds (VOC), carbon monoxide (CO) and particles containing carbon and other contaminants. In addition, at the high temperatures and pressures found in the combustion chamber, some of the nitrogen in the air and fuel is oxidised, forming mainly nitric oxide (NO) with a small amount of nitrogen dioxide (NO_2). The total emissions of oxides of nitrogen are conventionally abbreviated NO_X.

1.3 It is these pollutants: VOC, CO, NO_X, particles and prior to 2000, lead, that have normally been regarded as the ones of most concern, and whose rates of emission are legally restricted in many countries. Carbon dioxide, being a main contributor to global warming, is now also considered to be a major atmospheric pollutant.

1.4 Some of the compounds emitted have the potential to damage either health, the environment, or both. Geographically, the main direct effects are in the area near to the road as the rapid dispersion and dilution of the exhaust pollutants quickly reduces their concentrations to levels at which risks are minimal. However, some exhaust components are known or suspected carcinogens, for which no absolutely safe exposure level can be defined. In practice, though, the probability of health damage from them is low at roadside concentrations.

1.5 Many of the pollutants emitted from road vehicles react together and with pollutants from other sources to form secondary pollutants which can also have significant effects. However, because they disperse widely in the atmosphere during the time taken for reaction, the concentrations of secondary pollutants are not always highest near to the source of the emissions. Their impacts may therefore spread over large areas not confined to the locality of the traffic.

1.6 Vehicle emissions also contribute to a general degradation of air quality, restricted only by the time taken for their physical or chemical removal from the air by natural processes. A stable compound such as CO_2 may therefore contribute to environmental problems on a global scale for many years.

1.7 Most of the pollutants emitted by road vehicles are also produced by a wide range of other industrial and domestic processes. But in the UK (1999), as in most developed countries, road transport sources produced most of the emissions of carbon monoxide (CO; 69%) and substantial amounts of hydrocarbons (VOC, excluding methane; 27%), oxides of nitrogen (NO_X; 45%), particulate matter (17% measured as PM_{10}[1], 48% as black smoke) and carbon dioxide (CO_2; 22%) (Goodwin *et al.*, 2001). In heavily trafficked urban areas, these proportions may be much higher or, conversely, where there are significant non-traffic sources such as industry or power generation, transport's contribution can be lower than the national average. Estimates for the whole of the UK, and a number of UK conurbations are shown in Table 1. Variations between the estimates for these conurbations and regions may be related to the dominance of industry, transport or other sources within an area. In the case of Belfast, for example, the emission of particles is heavily influenced by the continued use of coal as a domestic fuel.

[1] PM_{10} is particulate material with an aerodynamic diameter of less than 10 microns.

Table 1 Pollutant emissions from road transport in urban areas in the UK

City/Region	Percentage of total emissions from road transport				
	CO	NMVOC	NO_x	PM_{10}	CO_2
UK[1]	69	27	45	17	22
London[2]	97	53	75	77	29
Greater Manchester[3]	95	20	63	31	21
West Midlands[4]	98	46	85	56	43
Merseyside[5]	91	28	42	8	18
Bristol[5]	97	60	61	36	26
Southampton/Portsmouth[5]	93	46	47	24	24
Swansea/Port Talbot[5]	86	33	30	16	18
City of Glasgow[6]	95	56	76	73	29
Middlesbrough[6]	22	10	17	19	3
Urban West Yorkshire[6]	95	42	73	64	17
Swansea/Port Talbot (revised)[6]	83	38	28	13	17
Greater Belfast[7]	75	66	60	17	19

[1] National Atmospheric Emission Inventory 1999 data
[2] Buckingham *et al.*, 1997a
[3] Buckingham *et al.*, 1997b
[4] Hutchinson and Clewley 1996
[5] Buckingham *et al.*, 1997c
[6] Buckingham *et al.*, 1998
[7] Buckingham *et al.*, 1999
NMVOC = Non-methane volatile organic compounds

Road schemes and air quality

1.8 A new road scheme may change traffic flows in a locality in a number of ways, with corresponding impacts on air quality. Road schemes are often perceived as having only negative effects. In some cases, however, the overall effect will be beneficial. If a scheme relieves congestion it can cause vehicles to operate in ways that produce less emissions, so reducing overall pollution levels. This occurs because vehicles operate most efficiently and produce least pollution when they are driven in freely flowing traffic at moderate speeds. If traffic is re-routed, the locations where pollution levels are highest will change, and may be transferred away from heavily populated areas where effects would be felt by most people. These effects may offset any increase in emissions caused by traffic using a longer new route (for example, a bypass instead of existing roads through a congested town centre), or by increases in traffic flows. The impact of road schemes upon air pollution is assessed in terms of their effects upon local air quality and on total emissions across the region.

Vehicle emission standards

1.9 In recognition of the contribution of vehicle emissions to air pollution, measures have been taken to reduce the quantities emitted. Since the early 1970s, limits have been applied to permissible levels of carbon monoxide, hydrocarbons and oxides of nitrogen in petrol vehicle exhaust. The limits have been reduced many times since they were introduced, and changes have been made to the test method to make it more realistic and effective.

1.10 All light-duty vehicle models and heavy-duty engine models sold in the UK must be approved with respect to exhaust emissions in accordance with European Union Directives. Since their first introduction, changes have been made to the standards to include more pollutants among those controlled, to reduce emission limits, and to improve test procedures. The changes in emission standards for cars, referred to as ‘Euro’ standards from 1990 onwards, are illustrated in Figure 1. It should be noted that the graphs give only an approximation of the regulations, which sometimes have different limit values depending on vehicle weight, engine size or technology, and are sometimes introduced in different years for different vehicle types, and so on. More detailed information is given in Annex 1, which also includes tables describing the emission legislation that applies to light-duty commercial vehicles, heavy-duty diesel engines, and motorcycles.

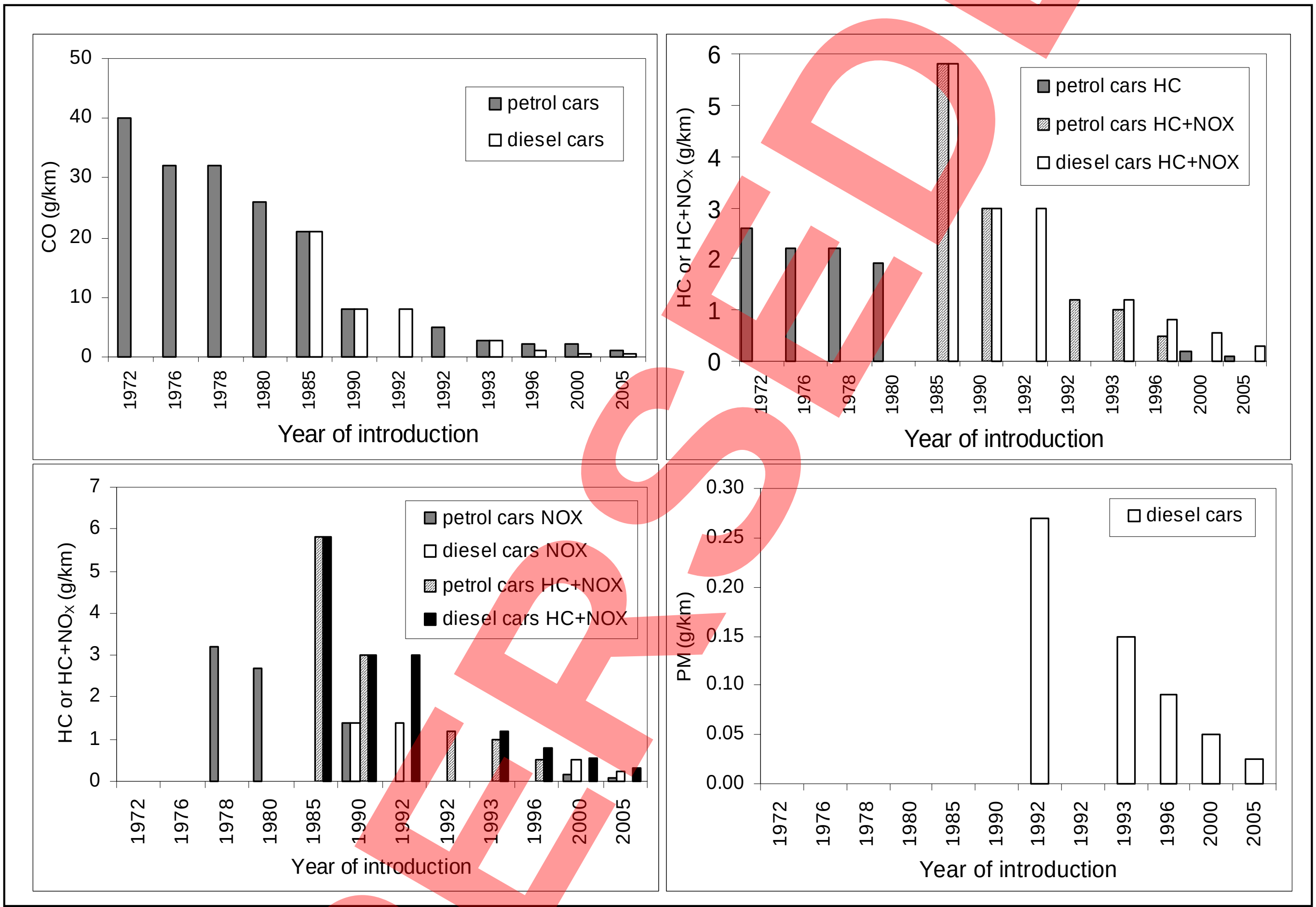

Figure 1 Changes in the emission standards for cars in the EU

1.11 In recent years one of the most significant improvements to vehicle emissions was associated with the introduction of the three-way catalyst to the light duty fleet for petrol vehicles entering service after 1992. The most recent light duty standards (Euro III), applicable to new models from January 2000 and for new registrations from January 2001, show a reduction of about 80%[2] compared with the values in the early 1970s. Further changes have already been accepted for introduction in 2005. Diesel engined vehicles are also subject to emission limits and these too will be made progressively more severe in the coming years.

1.12 Before a new model may enter the UK market, an example must be tested and certified to achieve compliance with the appropriate emission limits. All

[2] The exact reduction varies for different pollutants and vehicle types.

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production vehicles must then comply with conformity of production standards, which are in some cases slightly less stringent than the type approval limits. There is evidence, though, that emissions from vehicles in use do not remain at the design levels, especially if a vehicle is poorly maintained. To give better control of emissions from vehicles in service, an emission check was included in the annual roadworthiness 'MOT' test for light duty petrol vehicles from November 1991. A smoke check has since been introduced for light duty diesels, and the annual smoke check for heavy duty diesel vehicles has been improved. A sliding scale of emission limits is applicable in-service, with the newest vehicles required to maintain the most stringent limits.

1.13 As a result of these and other measures to control vehicle emissions, the amount of pollution from each vehicle has reduced. This will continue as new vehicles built to more exacting standards replace older, more polluting types.

1.14 These changes in vehicle technology are of great importance in the appraisal of future air quality impacts. The number of 'low-emission' vehicles in the fleet and the number of vehicles on the roads are likely to be much more significant in determining emission and pollution levels than any factor in the control of the design and network management organisation. But other factors are nevertheless important. The way in which a vehicle is operated affects emissions, and the precise location of a road will determine the severity of local impacts. These clearly are factors that the design and network management organisation can influence.

Fuel standards

1.15 Another means of controlling emissions is through the specification of the fuels that vehicles use. A significant fuel change was the limiting of lead in leaded petrol and the introduction of unleaded petrol. In 1972, the average lead content of UK petrol was 0.55 g/l. Following a series of reductions in the maximum amount permitted, the average content fell to 0.14 g/l in 1986. All petrol engined vehicles first used after April 1991 were required to be capable of using unleaded petrol, with the lead content restricted to a maximum of 0.013 g/l. On 1 January 2000 the general sale of lead additives was banned (with some limited exceptions) in petrol used in the EU. The removal of leaded fuels from the EU market was balanced by the introduction of lead replacement fuel. This lead replacement fuel (containing alternative additives) allows the continued use of those vehicles remaining in the fleet which are not easily adjusted to operate on unleaded fuels. The maximum lead content of unleaded petrol was further reduced at the start of 2000, to 0.005 g/l. As a result, lead concentrations near roads are not expected to be raised above background levels.

1.16 Other fuel properties that have an effect on emissions are also regulated, and are subject to review. Prior to the introduction of the 98/70 Directive the maximum sulphur content of both leaded petrol and diesel was set at a maximum of 2000 mg/kg, with that for unleaded fuels at 500 mg/kg. The introduction of future advanced catalyst technology requires fuels with a far lower sulphur content, and this was partly responsible for the compositional changes that came into force at the start of 2000. Relevant parts of the recent specifications from the European Directive are given in Table 2. Implementation of these fuel quality standards in the UK was encouraged through a reduced rate of duty. Compliance with the 2005 sulphur standard has subsequently been achieved approximately 3 years ahead of the required implementation date.

Table 2 Standard road fuel specifications, EU Directive 98/70/EC

Fuel parameter (maximum)	**Implementation year**	
	2000	**2005**
Petrol		
Sulphur (mg/kg)	150	50
Aromatics (%)	42	35
Benzene (%)	1	1
Lead (g/l)	0.005	0.005
Diesel		
Sulphur (mg/kg)	350	50
PAH (%)	11	11

Vehicle emission factors

1.17 The exhaust emission characteristics of the UK light-duty vehicle fleet have been assessed through a series of large scale surveys, the first of which was conducted in 1968. Follow-up surveys have taken place periodically to provide continuing information on emissions from the evolving vehicle fleet. Information from these surveys has been supplemented by many other studies in the UK and elsewhere in Europe, often examining a particular aspect of vehicles' emissions performance. Items such as the effects of maintenance, of driving patterns and cold starting have all been the subject of special investigations. Although they have been less extensively studied, there is also a growing body of information on the exhaust emissions from other types of vehicle: from lorries, buses, light vans and motorcycles. The latest revision to the UK emission factor database was issued by DfT in 2001 (Barlow *et al.*, 2001).

1.18 Measurements have shown that the highest rates of emission (in g/km) occur in congested, slow moving traffic, and that there is also a tendency for emission rates to increase at high speeds, especially those of oxides of nitrogen. Graphs illustrating typical variations in emission rates as a function of average speed are given in Figure 2, for catalyst-equipped petrol engined cars. Other types of engine and vehicle respond differently to changes in average speed. However, emissions from a particular vehicle operated under specific circumstances may deviate considerably from the average pattern.

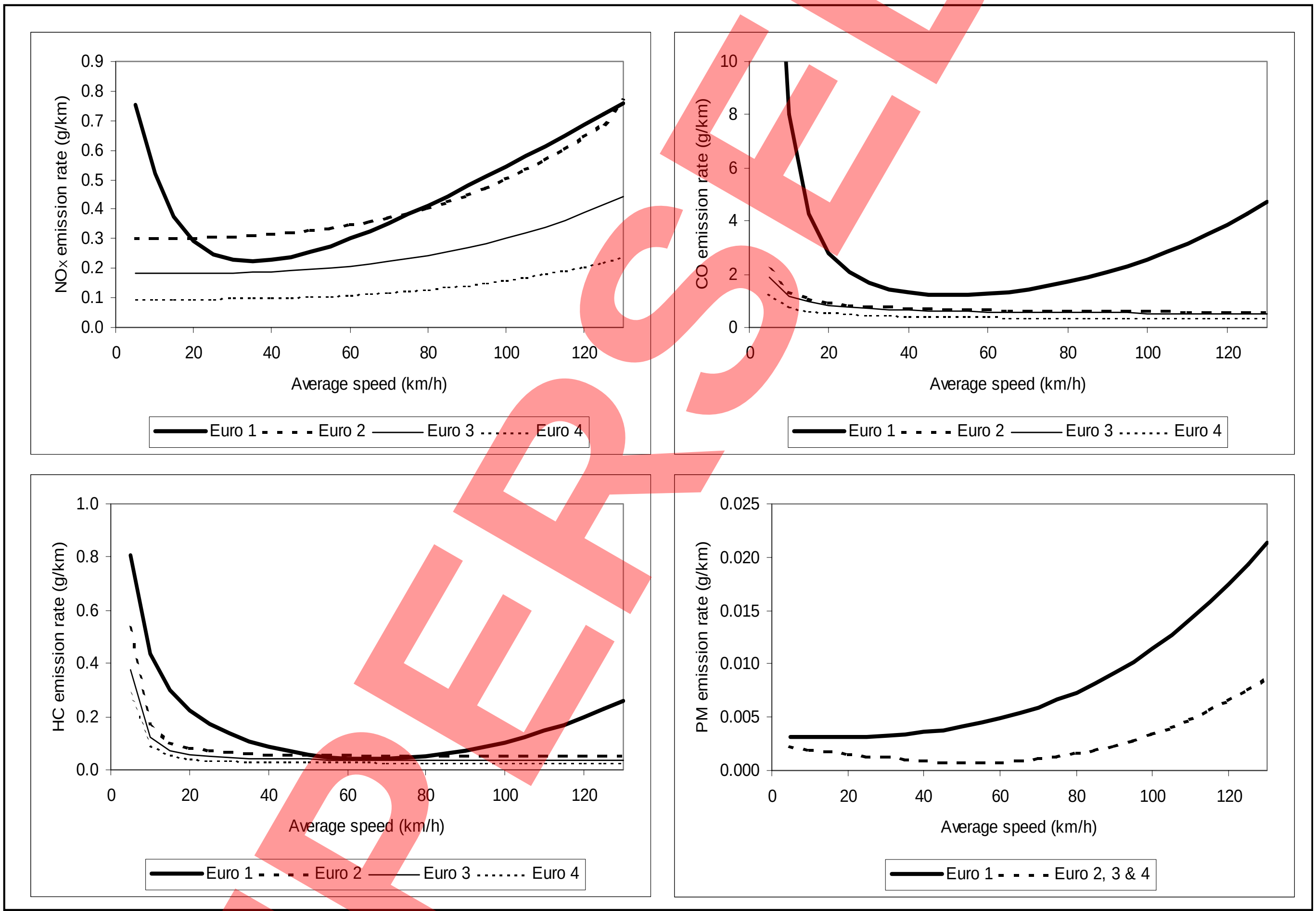

Figure 2 Typical speed related emission factors for petrol engined cars, with an engine size between 1.4 and 2 litres

1.19 Emission rates under stop-start driving conditions (often associated with congested traffic conditions) are much higher than those when vehicles are driven more smoothly. For example, studies have shown HC emissions from a car travelling at a steady speed to be only half of those measured at the same average speed, but with the car driven in a more typical way, over driving cycles containing accelerations, decelerations and periods of idling.

1.20 An engine that is cold is inefficient, and extra fuel has to be supplied for satisfactory operation. This significantly increases the rates of emission of CO and HC, and the fuel consumption. The effect is greatly compounded in the case of vehicles with catalytic emission control systems. Catalysts do not begin to work until their temperature reaches a 'light-off' value of around 300 ^{o}C, and also require an accurately controlled exhaust composition for full effectiveness. So, not only does a cold engine produce more emissions, but they are not treated by the catalyst system. Typical results for non-catalyst petrol cars show emission increases of 40 - 50% for CO and HC, and 10% for CO_2 from tests in which the engines were started cold, at an ambient temperature of 20 - 25^{o}C. Similar tests on catalyst equipped cars show emission increases of an order of magnitude (though their absolute rates of emission when cold are no higher than for non-catalyst cars). These, and many other factors will influence the emissions from traffic in specific locations.

Air quality criteria

1.21 Assessments of the significance of a particular level of pollution are often made with reference to air quality standards. These are usually based on the effects of pollutants on human health, though other factors, such as effects on vegetation, are sometimes taken into account. The air quality standards operable in the UK are those specified in European Union Directives and those specified in the UK Air Quality Strategy (AQS). Other nations and international organisations also mandate or recommend air quality standards. A notable example is the World Health Organisation, who has issued recommended standards for a wide range of compounds.

1.22 Air quality standards in the EU were first established in the 1980s, and Directives were issued to control smoke and sulphur dioxide (80/779/EEC), lead (82/884/EEC), nitrogen dioxide (85/203/EEC) and ozone (92/72/EEC). Subsequently, Directive 96/62/EC introduced a framework for ambient air quality management in the EU. This Directive does not itself contain any specific air quality standards, but establishes the air pollution management and monitoring framework within which standards will apply: the standards themselves are published in a series of pollutant-specific 'Daughter Directives'. The framework directive was transposed in England by the Air Quality Limit Values Regulations 2001 of 19 July, and equivalent regulations in the devolved administrations. The pollutants to be considered for the implementation of the Daughter Directives are indicated in Table 3. These Daughter Directives will gradually supersede those earlier standards, discussed previously.

Table 3 Air quality standards for the EU

Directive	Pollutant and limit values	Comment
1st Daughter Directive (1999/30/EC)	SO_2:1-hour limit value 350 µg/m^3, not to be exceeded more than 24 times. 24-hour limit of 125 µg/m^3, not to be exceeded more than 3 times. Compliance 01/01/05. NO_2: 1-hour limit value 200 µg/m^3, not to be exceeded more than 18 times. Annual limit of 40 µg/m^3. Compliance 01/01/10. PM_{10}: (stage 1) 24-hour limit value 50 µg/m^3, not to be exceeded more than 35 times. Annual limit of 40 µg/m^3. Compliance 01/01/05. PM_{10}: (Stage 2) 24-hour limit value 50 µg/m^3, not to be exceeded more than 7 times. Annual limit of 20 µg/m^3. Compliance 01/01/10. Pb: Annual limit of 0.5 µg/m^3. Compliance 01/01/05 or 2010 in the immediate vicinity of specific industrial locations.	Transposed in England by the Air Quality Limit Values Regulations 2001 of 19 July, and equivalent regulations in the devolved administrations. To be reviewed in 2003.
2nd Daughter Directive (2000/69/EC)	Benzene: Annual limit of 5 µg/m^3. Compliance 01/01/10. CO: Maximum daily running 8-hour mean of 10 mg/m^3. Compliance date 01/01/05.	Requirement to transpose into UK regulations by the end of 2002.
3rd Daughter Directive (2002/3/EC)	Ozone	Sets health and ecosystem target value for O_3 (2010), and long term objectives. Target linked with the emissions ceilings directive (2001/81/EC) through interaction as precursors. Requirement to transpose into UK regulations by the end of 2003.
4th Daughter Directive	Arsenic, cadmium, nickel, PAH	Will set health based limit values, and long term objectives for PAH and arsenic. Draft Commission proposal withdrawn, with a new proposal expected late 2002.

1.23 In the UK, Part IV of the Environment Act 1995 sets out a system for local air quality management in which local authorities are required to undertake periodic reviews to assess present and future air quality against objectives set by regulation. The Air Quality Strategy details the standards and objectives, which are based mainly on the recommendations of the Expert Panel on Air Quality Standards (EPAQS) and, where applicable, in compliance with the EU air quality Daughter Directives. The Air Quality Strategy, originally published in March 1997, has been subject to a series of consultations and revisions, with the latest version published in January 2000. Reviews to this Strategy are on a pollutant-by-pollutant basis, driven by policy and scientific developments. A consultation document published in September 2001, has recently resulted in the introduction of an objective for polycyclic aromatic hydrocarbons, changes to that for carbon monoxide and additional objectives for particles and benzene. The 2010 objectives for particles will not be incorporated into Regulations until the EU has reviewed its Stage 2 limit values. The revised objectives of the AQS are listed in Table 4. However, all of the objectives contained within the AQS are either equivalent or more stringent than those currently described under EU Directives. The most significant difference between the Air Quality Strategy objectives and the EU Directives is for nitrogen dioxide which has a target date of 2005 for the Strategy objectives and 2010 for the EU limit values.

1.24 In addition to the air quality objectives for the purposes of local air quality management, supplementary national objectives have been proposed designed for the protection of health, vegetation and ecosystems, and these are listed in Table 5.

Table 4 Objectives of the UK Air Quality Strategy, for the purposes of local air quality management

Pollutant	Objective	Compliance date
Nitrogen dioxide	Hourly average concentration should not exceed 200 µg/m³ (105 ppb) more than 18 times a year. Annual mean concentration should not exceed 40 µg/m³ (21 ppb).	31 December 2005
Particulate matter, expressed as PM_{10}	24-hour mean concentration should not exceed 50 µg/m³ more than 35 times a year. Annual mean concentration should not exceed 40 µg/m³.	31 December 2004
	Scotland: 24-hour mean concentration should not exceed 50 µg/m³ more than 7 times a year. Annual mean concentration should not exceed 18 µg/m³.	31 December 2010
	Northern Ireland, Wales and England (apart from London): 24-hour mean concentration should not exceed 50 µg/m³ more than 7 times a year. Annual mean concentration should not exceed 20 µg/m³.	31 December 2010
	London: 24-hour mean concentration should not exceed 50 µg/m³ more than 10 times a year. Annual mean concentration should not exceed 23 µg/m³.	31 December 2010
Benzene	Running annual mean concentration should not exceed 16.25 µg/m³ (5 ppb)	31 December 2003
	Scotland, Northern Ireland and Wales: Annual mean concentration should not exceed 3.25 µg/m³ (1.00 ppb)	31 December 2010
	England: Annual mean concentration should not exceed 5 µg/m³ (1.54 ppb)	31 December 2010
1,3-butadiene	Running annual mean concentration should not exceed 2.25 µg/m³ (1 ppb)	31 December 2003
Carbon monoxide	Running 8-hour mean concentration should not exceed 10 mg/m³ (8.6 ppm)	31 December 2003
Lead	Annual average concentration should not exceed 0.5 µg/m³. Annual average concentration should not exceed 0.25 µg/m³.	31 December 2004 31 December 2008
Sulphur dioxide	Hourly average concentration of 132 ppb (350 µg/m³) not to be exceeded more than 24 times a year. 24-hour average of 47 ppb (125 µg/m³) not to be exceeded more than 3 times a year.	31 December 2004
	15-minute mean of 100 ppb (266 µg/m³) not to be exceeded more than 35 times a year.	31 December 2005
Note that some of these objectives are provisional and/or not yet adopted into regulations. Their status is likely to change during the currency of this document, and should be checked before any assessment is carried out.		

Table 5 Objectives of the Air Quality Strategy, not included in local air quality management

Pollutant	Objective	Compliance date
Ozone[1]	Running 8-hour concentration of 100 µg/m³ (50 ppb) not to be exceeded more than 10 times a year	31 December 2005
Polycyclic aromatic hydrocarbons (PAHs)[1]	Annual mean concentration should not exceed 0.25 ng/m³	31 December 2010
Nitrogen oxides[2]	Annual average concentration of 30 µg/m³ (16 ppb)	31 December 2000
Sulphur dioxide	Annual average concentration of 20 µg/m³ (8 ppb). Winter average concentration (1 October to 31 March) of 20 µg/m³ (8 ppb)	31 December 2000

[1] objective for O_3 is provisional
[2] assumes NO_X is taken as NO_2

Environmental effects

1.25 The environmental effects to which vehicle emissions contribute are many and various. The most significant of these effects are listed in the following paragraphs. However, these are included for guidance and are not intended as an exhaustive or comprehensive list. There are many hundreds of compounds present in vehicle exhaust, of which only a small fraction have received detailed attention. More complete information on air pollutants and their effects may be found in many of the publications listed in the bibliography (Chapter 4).

1.26 **Carbon monoxide (CO).** Road transport is responsible for a significant proportion of total emissions of carbon monoxide. It is rapidly absorbed by the blood, reducing its oxygen carrying capacity. Because of its effects on human health, it is included in the EU Daughter Directive and Air Quality Strategy. It is a relatively stable compound that takes part only slowly in atmospheric chemical reactions. It contributes indirectly to the greenhouse effect by depleting atmospheric levels of hydroxyl radicals and thus slowing the destruction of methane, which is a powerful greenhouse gas.

1.27 **Oxides of nitrogen (NO_x).** Road transport is responsible for about half of the NO_x produced in the UK. Most is emitted as NO. In the air it is oxidised to NO_2, which is more toxic, affecting the respiratory system and hence is included in the EU Daughter Directive and Air Quality Strategy. Oxides of nitrogen are important in atmospheric chemistry, contributing to photochemical smog formation and acid deposition. Some of the products of reactions involving NO_x are powerful greenhouse gases.

1.28 **Hydrocarbons (HC).** Road transport emissions account for about a third of the HC produced in the UK. The term is used generally to include all organic compounds emitted (both in the exhaust and by evaporation from the fuel system) and embraces many hundreds of different species. Some hydrocarbon compounds, such as benzene and 1,3-butadiene, are toxic or carcinogenic. Benzene is included in the second EU air quality Daughter Directive and the Air Quality Strategy whereas 1,3-butadiene is included in the Air Quality Strategy only. Inventories show that road transport is a significant source of benzene and 1,3-butadiene, representing approximately 70% and 85% of UK emissions in 1999. The reactivity of hydrocarbon species varies widely but they are important precursors of photochemical smog, acidic and oxidising compounds. They contribute directly and indirectly to the greenhouse effect. The composition of HC emissions is strongly influenced by the composition of the fuel, so changes in fuel specifications can modify their impacts.

1.29 **Particulate Matter (PM).** Road vehicles emit about a quarter of the primary particle air pollution in the UK. Particles may be emitted from the exhaust, through the resuspension of road surface dust, and are generated as abrasion products from tyre, brake and road surface wear. Diesel exhaust contains much higher particle concentrations (in terms of mass) than petrol exhaust. These emissions comprise carbonaceous material onto which a wide range of organic and inorganic compounds may be adsorbed. Exhaust particle emissions are generally fine, with an aerodynamic diameter of less than 1.0 micron. Particles are also formed through a range of atmospheric chemical processes which result in the formation of secondary particles such as, nitrates and sulphates, which are associated with the acidification of water courses. Studies of the health effects of particulate matter have historically concentrated on the chemical composition, but the emphasis of the research has now moved towards the identification of effects associated with the physical particle size and relative surface area. Studies from the United States and elsewhere have shown a correlation between the concentrations of fine particles and mortality and morbidity that seems to be independent of the particulate composition. PM_{10} is included in the EU Daughter Directive and Air Quality Strategy.

1.30 **Sulphur dioxide (SO_2).** Road transport represents only a very minor source (1% in 1999) of UK sulphur emissions. Concentrations may have been slightly elevated at heavily trafficked roadside locations in the past but because the maximum permitted sulphur content of road fuels has been reduced (Table 2), the contribution is now much lower. Road transport is not a significant source of sulphur dioxide.

1.31 **Lead (Pb).** Lead is a recognised neurotoxin and as such is included in both EU and UK legislation. Formerly, lead compounds, mainly in the form of fine particles, were widely emitted by petrol vehicles using leaded petrol, but the phasing out of leaded petrol has reduced concentrations to levels well below those considered harmful except in a very few locations where there remain industrial or other non-traffic sources of lead pollution. Since 1985, concentrations of lead in the air near to busy roads have fallen considerably. For example, monitoring near the Cromwell Road in London showed an annual mean concentration of 1.5 $\mu g/m^3$ in 1985 and 0.2 $\mu g/m^3$ in

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1995, monitoring in Cardiff showed a fall from 1.3 to 0.2 $\mu g/m^3$ and in Manchester from 2.0 $\mu g/m^3$ to 0.1 $\mu g/m^3$. Given observations such as these and the phase out of leaded petrol in 2000, road transport is no longer considered a significant source of airborne lead pollution.

1.32 **Carbon dioxide (CO_2).** About 20% of the CO_2 produced in the UK is from road transport. It is a major product of the combustion of all carbon containing materials. It is the most abundant man-made greenhouse gas in the atmosphere. Carbon dioxide is not considered in local air quality assessment since it is not toxic and causes no adverse environmental effects on a local scale but is included in the regional assessments as it is a greenhouse gas.

1.33 **Ozone.** Ozone differs from the other pollutants in that it is not produced directly from emission sources, but is created by photochemical reactions in the atmosphere involving oxides of nitrogen, hydrocarbons and other compounds. Because road transport is a major source of the compounds involved in the reactions, it is an important contributor to ground level O_3 concentrations. However, for several reasons, it is not included in the initial assessment. Near to roads, the amount of O_3 in the air is governed mainly by the reaction between NO and O_3, to produce NO_2. Because roads provide an excess of NO from the traffic emissions, the reaction proceeds until most of the O_3 is depleted, and consequently, O_3 levels near to roads tend to be low. Thus a local, roadside assessment would probably show that the limitation of traffic emissions would produce higher O_3 concentrations while, when viewed on a larger scale, the opposite is likely[3]. Because the control of O_3 depends ultimately on the control of emissions of NO_X and HC on a large scale, broad inferences of the effects of a road network or specific scheme may be based on the regional impact assessment.

1.34 **Polycyclic aromatic hydrocarbons.** A standard for polycyclic aromatic hydrocarbons (PAH) is scheduled to be introduced in the fourth EU air quality Daughter Directive. In advance of this development, these compounds have recently been included in the Air Quality Strategy. They are produced by all types of combustion, with road transport estimated to contribute 7% of UK emissions. By far the most significant sources are specific industrial processes such as aluminium production, coke ovens and anode baking. These industrial sources were estimated in 1996 to contribute approximately 45% of the total UK PAH emissions. The Air Quality Strategy has recently adopted a PAH standard expressed in terms of an individual marker compound, benzo(a)pyrene (B(a)P), not to exceed 0.25 ng/m^3 as an annual average. Given the relatively low contribution to total PAH from road transport, and the absence of appropriate transport emission data, it is not considered in road assessments. However, it is estimated that the road transport contribution to B(a)P emissions is somewhat higher than to total PAH (24% of 1999 UK emissions).

1.35 **Trace metals.** Standards for cadmium, arsenic, nickel and mercury have not yet been proposed. They will be limited under the Framework Directive, but are not currently covered by the Air Quality Strategy. Little is known about road traffic emissions, but they are likely to be less important than those from industrial processes. Road traffic is likely to be a relatively minor source so they are not considered in road assessments.

Protocols and targets for emission reductions

1.36 There are a number of international protocols under which many countries, including the UK, have agreed on targets for reductions in emissions. The achievement of the targets will be through a combination of controls on many emission sources, including road transport.

1.37 The United Nations Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Air Pollution entered into force in 1983, and lays down general principles for international co-operation on the abatement of air pollution. It has been followed by a series of protocols giving more specific commitments. The Helsinki Protocol (1985) called for a reduction of SO_2 emissions by 30%, based on 1980 levels, to be achieved by 1993, and the Sofia Protocol (1988) required that NO_X emissions should return to 1987 levels by 1994. The UK met both of those targets, although it was not formally a party to the Helsinki Protocol.

[3] This discussion is a very simplified account of the rather complex reaction mechanisms. In some areas, depending on the climate and other local environmental conditions, reduced primary emissions of NO_x could lead to an increase or decrease in regional ozone formation, while reduced HC emissions should always reduce ozone formation.

1.38 Two further current protocols under this Convention have also been ratified by the UK. The Protocol Concerning Emissions of VOCs or their Transboundary Fluxes (1991) commits parties to a reduction in emissions of 30%, based on 1988 levels, by 1999. The Second Protocol on the Further Reduction of Sulphur Emissions (1994) requires the UK to reduce emissions by 80%, based on 1980 levels, by 2010.

1.39 In 1997, the Kyoto Protocol was adopted by parties to the United Nations Framework Convention on Climate Change. Under this agreement, the EU has a legally binding target to reduce emissions of greenhouse gases by 8% below 1990 levels over the 'commitment period' of 2008 to 2012. The target will be shared between Member States, and the UK's contribution will be a reduction of 12.5%. This legally binding commitment is further strengthened by a domestic goal of reducing CO_2 emissions by 20% by 2010, although subsequently the Royal Commission on Environmental Pollution has proposed a 60% reduction in emissions of greenhouse gases by 2050. Given that road transport contributes approximately 25% of the total European CO_2 emissions, the motor industry has entered into a voluntary agreement involving European, Japanese and Korean car manufactures. This agreement, reached in 1998, commits the manufacturers to reduce average emissions from new cars to 140 g/km by 2008, and represents an improvement of more than 25%. Further information on many of these protocols may be found at the website of the University of East Anglia: http://www.uea.ac.uk.

1.40 In 1999 the Directive on the limitation of emissions of VOCs due to the use of organic solvents, came into force. This Directive, 1999/13/EC was aimed at tighter controls and limits in certain industrial sectors, with the intention of reducing emissions of these important O_3 precursors.

1.41 More recently the National Emissions Ceilings Directive (2001/81/EC) has been implemented which sets ceilings for the emissions from industrial plants for SO_2, NO_X, VOC and ammonia, with the aim of reducing acidification, eutrophication and ground level O_3.

1.42 Table 6 shows the total UK road transport emissions as estimated in the NAEI for 1999. This may be a useful guide when assessing the significance of a change in emissions due to a road scheme.

Table 6 Emissions from UK road transport sources, 1999

Pollutant	UK road transport emissions (KT)
Carbon monoxide	3293
Total oxides of nitrogen[1]	714
Volatile organic compounds[2]	473
Particulate matter	32
Carbon dioxide	114561

[1] NO_2 equivalents
[2] Excludes methane and therefore equivalent to 'non-methane hydrocarbons'

2. BACKGROUND TO THE ASSESSMENT METHOD

2.1 The air quality assessment for a road scheme has two main elements. The first of these is the estimation of roadside air pollution concentrations, referred to as local impacts, associated with new or modified road schemes. The second is an estimation of total annual emissions arising from a road scheme, referred to as regional impacts. A Screening Method was developed to assist with the assessments associated with these two elements.

2.2 The local impacts Screening Method has become a cornerstone of the local authority review and assessment process for air quality, which is a requirement under Part IV of the Environment Act 1995. The DMRB Screening Method was included in DEFRA's Pollutant Specific Guidance as a recommended means of undertaking road traffic assessments at the second stage review and assessment level. However, as the model was designed to be a conservative screening application, primarily for the assessment of major new road schemes in relatively rural areas, it purposefully overestimated concentrations.

2.3 This latest revision to the DMRB Screening Method was necessary in order to include the new vehicle emission rate data (Barlow *et al.*, 2001). In addition, the opportunity was taken to re-evaluate a range of additional parameters, including:

- a revised vehicle fleet composition model available from the latest version of the National Atmospheric Emission Inventory (NAEI),
- an examination of the applicability of the existing roadside dispersion curves,
- revised empirical relationships to estimate NO_2 from NO_X concentrations,
- the relationships between annual mean concentrations and others relevant to the air quality criteria,
- the level of overestimation of concentrations inherent in the method.

2.4 The work of updating the Screening Method has been undertaken on behalf of the Highways Agency by TRL. To assist with this process, the HA formed an advisory group that included representatives from DEFRA and a number of their consultants, including NETCEN, Air Quality Consultants and Casella Stanger. One of the main aims of this collaboration has been to ensure consistency and compatibility with related applications. Thus, for example, the vehicle emission factors and fleet data are the same as those used in compiling the NAEI, and the relationship between NO_X and NO_2 is the same as in DEFRA's Technical Guidance (2002).

The local air quality impacts of road schemes

2.5 Following a road scheme there may be localised changes in air pollution, either increases or reductions, in the immediate vicinity of all or part of the scheme, and changes may also occur in the air quality near to the existing road network. The DMRB Screening Method provides an initial test that is designed to establish whether a road scheme ought to be subjected to a more detailed air quality assessment.

2.6 In order to forecast the magnitude of possible impacts, it is necessary to compare current pollution levels with those anticipated in the future if the scheme is not built, and those anticipated if the scheme is built. As it is only possible to measure the first of these situations, it is necessary to compare modelled levels for all three cases to ensure that comparison is made on a consistent basis. Traffic flows modelled under high growth assumptions should be used. Changes in pollution levels will result from a number of factors: changes in the road network and traffic, general growth of traffic flows, and changes in vehicle emissions resulting from better emission control technologies and fuel specifications. Because of the conflict between some of these influences (vehicles are likely to become cleaner as time progresses but traffic flows are likely to increase) and the tightening air quality criteria, the assessment of the future options should be carried out for a number of years. All assessments should address the base year and opening year of the scheme with and without the proposals. In addition, the years 2005 and 2010 should be evaluated both with and without the proposals if the proposals would be operational at these times. The air quality criteria are set with a number of target dates for compliance, and are likely to change over time. Results for the different assessment years should be evaluated against the relevant air quality criteria in that year.

2.7 Ambient monitoring need not be routinely incorporated in the air quality assessment of a road scheme, as the DMRB screening method has been calibrated in a variety of situations. However, monitoring of existing air quality may be useful in certain circumstances for the pollutant of concern. Monitoring should be considered where the proposals are likely to have a significant effect on concentrations, where the initial air quality assessment indicates that a detailed air quality study is needed or if there are unusual features to the scheme. In addition, ambient monitoring may provide additional information on local background pollutant concentrations. It is recommended that any monitoring should, in the first instance, be limited to simple and relatively low-cost methods such as passive or active diffusion tubes and filter sampling. Additional advice on appropriate monitoring techniques is available from a number of sources and is issued as a DEFRA guidance note supporting the AQS review and assessment procedure (DEFRA, 2002).

The regional impact of road schemes

2.8 As well as changes in local air quality following a road scheme, there may be changes in the overall quantity of emissions from the traffic on the road network. To calculate a scheme's net contribution to overall air pollution, it is necessary to calculate total forecast emissions after the proposed scheme has been built and deduct the estimated emissions from the existing road network where traffic patterns are affected by the scheme. The assessment should be conducted for the base year, the opening year and the design year of the scheme. The assessment method requires traffic flow, composition and speed data for different road segments to be amalgamated with speed related emission data to determine the total emissions of selected pollutants.

The format of the assessment method

2.9 The DMRB screening method has previously taken the form of a series of paper-based tables and graphs, to be used in a step-by-step procedure for calculating the contribution of road traffic to both concentrations of air pollutants at a particular location and area-wide emissions. However, given the almost universal availability of personal computers and skills in their use, it was inevitable that the paper-based method would eventually be superseded by a computer-based method. Therefore, as well as the revision of the calculation methodology, this update of the DMRB involved the conversion of the method to a spreadsheet program.

2.10 The DMRB Screening Method spreadsheet was developed in Microsoft Excel 97 and contains several macros written in Visual Basic for Applications (VBA). The spreadsheet can be downloaded from the Highways Agency website (http://www.highways.gov.uk/business/238.aspx in the DMRB section). The instructions for using the spreadsheet are provided in Chapter 3.

Development of the DMRB Screening Method

Pollutants addressed

2.11 The pollutants considered in the local assessment are nitrogen dioxide, particles, carbon monoxide, benzene, and 1,3-butadiene. The rationale supporting the selection of these pollutants was based primarily on the air quality criteria reviewed in the context of road transport emissions and their contribution to air pollution levels. The pollutants considered in the regional assessment are nitrogen oxides, particles, carbon monoxide, carbon dioxide and hydrocarbons (expressed as equivalent to the empirical formula $CH_{1.85}$). Further information about these pollutants is given in Chapter 1.

Present and future vehicle emission functions

2.12 In order to estimate the exhaust emissions from a stream of traffic, it is necessary to know the traffic composition (because different vehicle types emit very different levels of pollution), the volume of traffic, and how the vehicles are being operated. Although a large number of operational factors will influence the emissions from traffic in specific locations (see Chapter 1), they cannot all be taken into account in the simplified, general-purpose procedure used in the DMRB. They should be considered, however, in situations where a detailed air quality impact assessment is necessary. For the DMRB screening assessment, only the effects of average vehicle speed are included as an indication of the vehicles' operating conditions.

2.13 The vehicle classification system used in the National Atmospheric Emission Inventory (NAEI) is shown in Table 7. An emission function was assigned to each of these classes of vehicle. The difficulty in assigning emission functions to these vehicle classes is that for many of the classes the emissions are unknown in practice. There is an extensive database on emissions from cars of most types currently in use, but there is obviously no information on the in-use emissions performance of the future vehicle types (with the exception of limited data for manufacturers' prototypes), and very little for cars built to the most recent standards. Because such information is not readily available, the assumption has been made that changes in emission standards will generally produce corresponding changes in rates of emission.

Table 7 The vehicle classification used in the NAEI

Vehicle category	Regulation	Vehicle category	Regulation
Petrol cars	ECE 15.01	Rigid HGVs	Pre-1988
	ECE 15.02		Pre-Euro I (88/77EEC)
by engine size:	ECE 15.03		Euro I (91/542/EEC)
<1.4 litres	ECE 15.04 + Failed catalysts		Euro II
1.4-2.0 litres	Euro I		Euro III
>2.0 litres	Euro II		Euro IV
	Euro III		Euro IV+
	Euro IV	Articulated HGVs	Pre-1988
Diesel cars	Pre-Euro I		Pre-Euro I (88/77EEC)
	Euro I		Euro I (91/542/EEC)
by engine size:	Euro II		Euro II
<2.0 litres	Euro III		Euro III
>2.0 litres	Euro III + particulate trap		Euro IV
	Euro IV		Euro IV+
	Euro IV + particulate trap	Bus	Pre-1988
Petrol LGV	Pre-Euro I		Pre-Euro I (88/77EEC)
	Euro I (93/59/EEC)		Euro I (91/542/EEC)
	Euro II		Euro II
	Euro III		Euro III
	Euro IV		Euro IV
Diesel LGV	Pre-Euro I		Euro IV+
	Euro I (93/59/EEC)		
	Euro II		
	Euro III		
	Euro IV		

2.14 In September 2001, Barlow *et al.* (2001) produced a new database of emission functions for the DTLR. These algorithms expressed rates of emission (in g/km) as a function of average vehicle speed (5 to 130 km/h for light-duty vehicles, and 5 to 100 km/h for heavy duty vehicles). The functions were based on TRL's compilation of existing measurements and, more importantly, a series of emission measurement programmes conducted on behalf of the DTLR between 1997 and 2000. The inclusion of these more recent data made it possible to base the functions for Euro II and Euro III vehicles on measured results, whereas previously they were derived from Euro I (or earlier) data and assumptions about the way the more stringent standards would take effect. After a period of public consultation on the new emission data and functions, discussions were held between TRL and NETCEN during which a more complete set of functions were agreed (*i.e.* including existing functions for pre-Euro I vehicles and revised assumptions on the effects of future standards for post-Euro II vehicles).

2.15 These agreed functions are now used in the compilation of the UK NAEI, and the opportunity has been taken to incorporate them into the DMRB procedure for air pollution estimation. The use of a common set of emission data for these various applications goes some way to ensuring consistency between them. The emission functions are also available in the Emission Factor Toolkit produced by

Casella Stanger, which now underpins the DMRB Screening Method. The derivation of the vehicle emission functions is described in more detail below.

Emission functions for NO_x, PM, CO and HC

Petrol cars

2.16 The emission functions for Pre-Euro I (Regulation ECE 15), Euro I, Euro II vehicles were all derived from TRL measurements. The pre-Euro I functions were taken from the 1998 TRL database (unpublished), and Euro I and Euro II functions were drawn from Barlow *et al.* (2001). The Euro III and IV emission functions were based on emission reduction scaling factors applied to the equations for Euro II vehicles. These scaling factors were based partly on factors given in MEET (Methodologies for estimating emissions from transport, European Commission, 1999) and on a judgement of the extent (if any) that emissions from Euro II vehicles, calculated from the coefficients at the average speed of the Extra Urban Drive Cycle (EUDC) cycle, would need to be reduced in order to meet the Euro III and Euro IV emission limits. Some limited data from TRL on Euro III vehicles also aided the judgement. In this assessment, account was taken of the fact that the regulatory cycle for the Euro III and IV tests applies the moment the vehicle is switched on, and therefore includes a period of 'cold start' emissions. In the case of PM, there were no emission functions for pre-Euro I vehicles. An average value of 0.02 g/km, agreed some years ago for use in the NAEI and based on limited measurements, was retained, but the relative speed dependence around this value was assumed to be the same as for CO. Since PM emissions from petrol vehicles are not regulated, it was assumed that PM emissions from Euro III, IV vehicles would remain at Euro II levels (Annex 1).

Diesel cars

2.17 The emission functions for pre-Euro I, Euro I, and Euro II vehicles were all derived from TRL measurements. The pre-Euro I functions were taken from the 1998 TRL database, and the Euro I and Euro II functions were taken from Barlow *et al.* (2001). The Euro III and IV emission functions (including PM) were based on emission reduction scaling factors applied to the equations for Euro II vehicles. These scaling factors were estimated following much the same principles as for petrol cars.

Petrol LGVs

2.18 The emission functions for pre-Euro I vehicles were drawn from the 1998 TRL database for small and medium sized LGVs, with the Euro I functions being taken from Barlow *et al.* (2001). Emission functions for Euro II petrol LGVs were not available, and so they were assumed to be the same as for a medium-sized petrol car. The emission functions for Euro III and IV vehicles were based on emission reduction scaling factors applied to the equations for Euro II vehicles. The same scaling factors as those applied to petrol cars were assumed. No factors were available for PM emissions from petrol LGVs. For pre-Euro I vehicles, a bulk estimate of 0.04 g/km, agreed some years ago for use in the NAEI, was retained, but the relative speed dependence around this value was assumed to be the same as that for CO. PM emission functions for Euro I and II vehicles were assumed to be the same as for a medium sized petrol car. Since PM emissions from petrol vehicles are not regulated, it was assumed that PM emissions from Euro III and Euro IV vehicles would remain at Euro II levels.

Diesel LGVs

2.19 The emission functions for pre-Euro I vehicles were obtained from the 1998 TRL database for medium and large sized LGVs, and the Euro I emission functions were taken from Barlow *et al.* (2001). Factors for Euro II diesel LGVs were not available. For all pollutants except NO_x, the levels of emissions from Euro I vehicles appeared to be within the limits for Euro II. Hence, emission coefficients for Euro II diesel LGVs were assumed to be the same as for Euro I on the basis that no further reduction in emissions was necessary. For NO_x, a slight reduction in emissions was required from Euro I to meet the Euro II limits. Therefore, the Euro I coefficients were adopted with a 0.95 scaling factor for Euro II vehicles. The Euro III and IV emission functions (including PM) were based on emission reduction scaling factors applied to the functions for Euro II. These scaling factors were estimated following much the same principles as for petrol and diesel cars (ie based on the extent emissions needed to be reduced to meet the limit values), with information from MEET and some limited data from TRL on Euro III vehicles aiding the judgement.

HGVs and buses

2.20 The emission functions for pre-Euro I, Euro I, and Euro II vehicles were all drawn from TRL measurements. The pre-Euro I functions were from the 1998 TRL database, and the Euro I and Euro II functions were taken from the 2001 TRL Report. Drive-cycle factors for pre-1988 HGVs and buses, of which some remain in the fleet, have been used in the NAEI; these have corresponded to earlier measurements over the Warren Spring Laboratory (WSL) drive cycles. Speed-dependent emission equations were derived for this old category of HGVs from these existing WSL road-type factors, either assuming the relationship with speed is flat or has the same relative speed-dependence as the later pre-Euro I vehicles on the basis of the variation in the road-type factors with average cycle speed. In the latter case, the emission functions for these old HGVs were used, based on emission scaling factors applied to the factors for pre-Euro I vehicles. Euro III and IV emission functions were based on emission reduction scaling factors applied to the equations for Euro II. The scaling factors were drawn from COPERT III (Ntziachristos *et al.* 1999). It should be noted that data on heavy vehicle rates of emission are rather limited, even for current types of vehicle. It must be concluded, therefore, that there is more uncertainty in the emission functions used for heavy duty vehicles than those for light duty vehicles.

Emission functions for benzene and 1,3-butadiene

2.21 The emission coefficients for benzene and 1,3-butadiene were the same as those for total hydrocarbons, except for the use of a scaling coefficient reflecting the mass fraction of these two species in the total hydrocarbon emissions from different vehicle types. The mass fractions were based on the NMVOC emission speciation fractions for benzene and 1,3-butadiene in COPERT III. In deriving species fractions of the total hydrocarbon emission functions given by TRL, it was necessary to account for the amount of methane in the HC emissions, as the COPERT figures refer to fractions of non-methane volatile organic compounds. The methane components of the total HC emissions from each vehicle type were calculated from the COPERT III emission factors for methane.

Emission functions for carbon dioxide

2.22 Carbon dioxide emissions are not regulated under the EU emission standards. Nevertheless, for convenience, the vehicle classification used for the definition of CO_2 emission functions is the same as that for the regulated emissions, but in this case there are not significant, stepwise changes between the legislation classes. Carbon dioxide measurements were included in the test programs from which both the 1998 and 2001 TRL emission databases were compiled, and these were the sources used for pre-Euro I, Euro I, and Euro II cars, pre-Euro I and Euro I LGVs, and pre-Euro I, Euro I, and Euro II HGVs and buses, in the same way as for the NO_x, PM, CO and HC functions described above.

2.23 Emissions from vehicles in the Euro III and Euro IV classes will be influenced by the general improvements in technologies introduced to improve fuel economy (CO_2 emissions are very closely related to fuel consumption) and, for cars in particular, by a voluntary agreement between the European Automobile Manufacturers Association and the EU to reduce emissions (see paragraph 1.39). For cars and LGVs it was assumed that the baseline emissions of Euro III vehicles would be reduced from the Euro II levels by the same proportion that Euro II emissions were reduced from Euro I levels. The same proportional reduction was applied to Euro III emission levels to derive Euro IV levels. For petrol cars, diesel cars and petrol LGVs, an additional adjustment was made in order to take into account the voluntary agreement: emissions were reduced linearly to 140 g/km between 2000 and 2008, with no further improvement thereafter. Euro III and Euro IV buses and HGVs were assumed to have emission levels equivalent to those of Euro II vehicles.

Other fuel and technology factors affecting emissions

2.24 The emission function projections combined the effects of the penetration of improved fuels and other technologies influencing the baseline emissions from the fleet. The early introduction of ultra-low sulphur petrol and diesel (100% by 2001) into the national fleet is taken into account. Many bus fleets had converted to ultra-low sulphur diesel (ULSD) as early as 1997, and this is also accounted for. The impact these fuels would have on emissions from existing vehicles in the fleet was based on empirical formulae from EPEFE (European programme on emissions, fuels and engine technologies) on the relationship between emissions and fuel quality, combined with information drawn from MEET, the World-Wide Fuel Charter reports and various reports prepared by Millbrook and LT Buses on the effects of fuel quality on emissions from heavy duty vehicles (See Murrells (2000) UK road transport emission projections at http://www.naei.org.uk/reports.php for further details).

2.25 The retrofitting of particulate traps and oxidation catalyst on some heavy duty diesel vehicles is accounted for, on the basis of information from DTLR in 2001 on their likely uptake. Again, the assumptions on their effects on emissions and their fleet uptake is described in the Technical Annex of the Air Quality Strategy consultation document (DEFRA *et al.* 2001).

2.26 The effect of benzene content of petrol on exhaust emissions of benzene required particular attention. According to the UK Petroleum Industries Association (UKPIA), a very significant decrease in benzene content of UK petrol (76%) occurred in 2000 in order to meet the lower EU limit of 1% introduced that year. Equations from EPEFE and MEET were used to derive factors reflecting the effect of reduced benzene content on benzene emissions from catalyst cars. No such information is available for non-catalyst cars. However, on the basis of fundamental combustion chemistry modelling and the very significant declines in ambient benzene concentrations observed in early 2000 at a number of AURN monitoring sites, it was concluded that the reductions in benzene content of petrol led to a proportional reduction in benzene emissions from non-catalyst cars. This is represented with an emission reduction scaling factor for this class of vehicle.

Fleet composition projections

2.27 The expressions describing vehicle emission rates as a function of speed were combined with fleet composition data to produce weighted average emission rates for a number of broader vehicle categories. The vehicle fleet model that was used was compiled for the NAEI by NETCEN (Murrells, 2002). The model provides a classification of vehicle type by vehicle kilometres travelled (using a classification system by type, age and fuel as outlined above for cars), and covers the period from 1996 to 2025.

2.28 Where no local information on traffic composition is available to the user, the DMRB considers the traffic in two broad classes: light-duty vehicles and heavy-duty vehicles. For the DMRB, the dissaggregated functions for the NAEI vehicle classes were combined into traffic-weighted average functions for these two vehicle groups. In order that the approach taken was again consistent with other applications of emission calculations, data on the composition and operation of road traffic in the UK were taken from the database compiled for the NAEI in 2001 (Murrells, 2002). The proportions of the detailed vehicle classes in the LDV and HDV will vary according to location. This is taken into account in the DMRB via the use of different traffic compositions for three types of road:

- all motorways and A-roads,
- urban roads which are neither motorways nor A-roads,
- any other roads.

It was assumed that the detailed composition of the traffic on each road type would conform with national average statistics.

2.29 Where local information on traffic composition is available to the user, the DMRB allows for the division of the traffic into passenger cars, light goods vehicles, buses, rigid HGVs and articulated HGVs. Again, it was assumed that within each of these classes the distribution of vehicles according to fuel type, emission standard and engine size would conform with national average statistics.

2.30 The aggregated emission functions described above for the different vehicle types do not take into account any local variations in certain aspects of traffic composition (for example a specific road might carry an exceptionally high flow of old passenger cars). Nor do they reflect variations in emissions that might result from other local circumstances such as steep hills or the presence of vehicles with cold engines. Depending on the nature of any deviations from the basic emission functions used here, concentrations may be under- or overestimated.

2.31 The fleet model was based on a number of assumptions. For example, it was assumed that diesel car sales will equilibrate at 20% of new car registrations. Also, a catalyst failure rate of 5% per annum is assumed (failed catalyst cars are included in the non-catalyst class). For cars over three years old, which must pass an emissions test in the annual roadworthiness 'MOT' inspection, it is assumed that 98% of the failed catalysts are rectified, so these vehicles return to the catalyst class.

2.32 Vehicle survival rates were derived from DETR vehicle licensing statistics on new registrations and age distribution. Annual mileages, as a function of the vehicle's age, were also derived from DETR statistics based on information from the National Travel Survey. The growth of new vehicle sales was based on the DETR Vehicle Market Model. The composition of the UK fleet was defined in terms of the proportion of vehicle kilometres travelled in a year by vehicles in each of the different Euro emission classes (Euro I, II etc) and also the petrol/diesel mix in the case of cars and LGVs. For years up to 1999, composition data were based on DfT Vehicle Licensing Statistics, which give the age profile of the fleet each year from vehicle licensing records. These were combined with data from DfT on the changes in annual mileage with age to take account of the fact that, on average, newer vehicles travel a greater number of kilometres in a year than older vehicles. Figures from the Society of Motor Manufacturers and Traders (SMMT) were used to show the extent of early penetration of Euro III cars in the fleet before 2000. More details on the methods for deriving fleet composition can be found in the NAEI annual reports (eg Goodwin *et al.* 2001).

2.33 Projections in the composition of the vehicle fleet from 2000 were derived from the turnover in the vehicle fleet and forecasts in the number of new vehicle sales. Fleet turnover was based on survival rate functions implied by historic vehicle licensing statistics (ie how many vehicles of different ages survive). Forecasts in new vehicle sales were provided by DfT's Vehicle Market Model or linked to traffic growth projections (eg the National Road Traffic Forecast). A number of other key assumptions affecting the composition of the fleet were made. These include:

- the penetration of diesel car sales in the new car market,
- the early introduction of Euro IV standards in the petrol car market,
- the fitting of particulate traps to some new light duty diesel vehicles.

2.34 The assumptions were specified for the NAEI by DTLR in 2001, considering Government policy and most likely outcomes at the time. Further details on the NAEI fleet composition assumptions can be found in the Technical Annexe of the Air Quality Strategy for England, Scotland, Wales and Northern Ireland consultation document (DEFRA, 2002).

Atmospheric dispersion and reaction

2.35 An equation describing the characteristic decrease in pollutant concentrations with increasing distance from the road was derived from calculations using an atmospheric dispersion model developed at TRL. It was originally developed to forecast only carbon monoxide concentrations, and has been extensively validated for that purpose. It has been assumed that the dispersal of other pollutants will be equivalent to that of carbon monoxide, so that their concentrations will be in the same proportions as their rates of emission. This assumption is likely to be valid for non-reactive gases, including volatile hydrocarbons and total oxides of nitrogen. Because of their small size, exhaust particles also behave in a similar way to gases, though there may be some inaccuracies because of the deposition of some particles, their agglomeration in the atmosphere and their possible adsorption of other atmospheric constituents such as water vapour. These dispersion profiles were further reviewed in a series of field measurements (Hickman *et al.* 2002).

2.36 The contribution, in $\mu g/m^3$ per g/km, of a stream of traffic to pollutant concentrations at a distance *d* from the road centre is given by the equation below for distances up to 168m. It is shown graphically in Figure 3.

Traffic contribution = $0.17887 + 0.00024\,d - (0.295776/\,d) + (0.2596/\,d^{2}) - 0.0421\ln(d)$

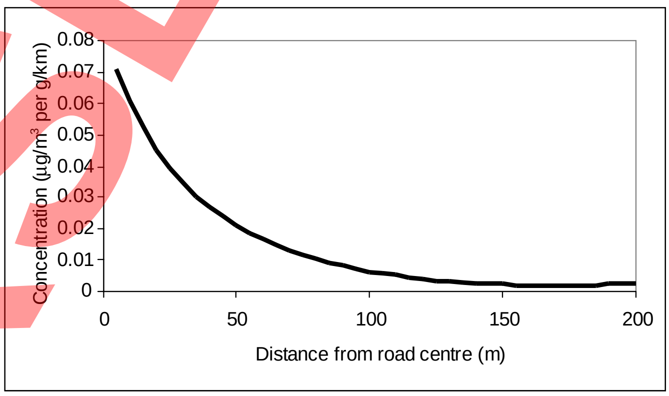

Figure 3 Traffic contribution to pollutant concentration at different distances from a road

2.37 The rate at which exhaust pollutants disperse depends on the atmospheric conditions, with the speed and direction of the wind being of particular importance. In deriving the equation above, a wind speed of 2 m/s was assumed, and no weighting for wind direction was used (it was assumed that winds were evenly distributed around the compass). The assumed speed is rather lower than typically found in the UK, and the equation will tend, therefore, to overestimate pollution concentrations. Independence of wind direction allows the procedure to be applied without any knowledge of local conditions, but may lead to under- or overestimates of concentrations depending on the relative positions of roads and receptor locations with reference to locally prevailing winds.

2.38 It should be noted that the dispersion equation represents the dispersion of the primary emissions from traffic on the road in question, and does not show the effects of chemical transformations or background contributions. When these are taken into account, different concentration profiles are produced for different pollutants.

Comparison with air quality criteria

2.39 The results at this stage are estimates of the annual mean traffic-derived concentrations of carbon monoxide, non-methane hydrocarbons, total oxides of nitrogen and PM_{10}. However, the air quality criteria against which the forecast concentrations may be assessed are often expressed in different terms - either for different pollutants (eg NO_2), different averaging periods (eg 8-hour average CO concentration), or different frequencies of occurrence (eg number of exceedences of a 24-hour standard for PM_{10}). Moreover, the local traffic contribution will be superimposed on an existing pollution background - from traffic outside the modelled area and other natural and anthropogenic sources. UK background pollution concentrations are estimated periodically by the NETCEN, on behalf of DEFRA. These maps are available with a spatial resolution of 1 km^2 for 2001. Scaling factors are provided for other assessment years between 1996 and 2025. Alternatively, measured background concentrations can be used if available and scaled for future years.

2.40 The final stage in the modelling procedure is therefore to apply conversions so that the final estimated concentrations are compatible with the air quality criteria against which they will be assessed. The procedures differ in detail for each pollutant, but were all derived empirically using data from the DEFRA network of air pollution monitoring stations and the roadside monitoring network operated by TRL for the Highways Agency. Conversions to other pollutants, averaging times and frequencies of occurrence, in accordance with the metrics specified in the air quality criteria, are outlined below.

Nitrogen dioxide

2.41 Although most of the oxides of nitrogen (NO_X) emissions from road traffic are in the form of NO, their impact must be evaluated in terms of their contribution to NO_2 levels in the air since these are subject to EU standards and Air Quality Strategy objectives, due to its effect on health. The NO_2 is formed primarily by reactions of NO in the atmosphere. An assumption that is implicit in the dispersion model used to derive this procedure is that there is no chemical interaction between pollutants or other atmospheric gases that will act to modify their concentrations differently from the physical dispersion processes. Oxides of nitrogen clearly do not conform with the requirement of chemical stability.

2.42 The main reaction by which NO is converted to NO_2 in the atmosphere is with O_3:

$$NO + O_3 = NO_2 + O_2$$

Where there is a large source of NO, such as the emissions from traffic on a road, the limiting factor on the production of NO_2 is the availability of O_3 with which the NO can react. At low concentrations of NO, there is sufficient O_3 in the air for its conversion to NO_2 to occur rapidly, but as the NO_2 concentration increases, the O_3 is depleted by the reaction until a stage is reached when none remains. After this stage, there is little effect on the concentration of NO_2, even at much higher NO concentrations. This is shown in Figure 4, where hourly average concentrations of NO_2 and O_3 have been plotted in order of increasing NO_X concentration. Ozone concentrations are highest when NO_X is low. They fall steadily as both NO_X and NO_2 levels increase. But, even though the highest NO_X concentrations approach 1000 ppb, the NO_2 limit is little higher than that of the O_3 at low NO_X concentrations. This means that the relationship between the annual mean concentrations of NO_X and NO_2 is non linear.

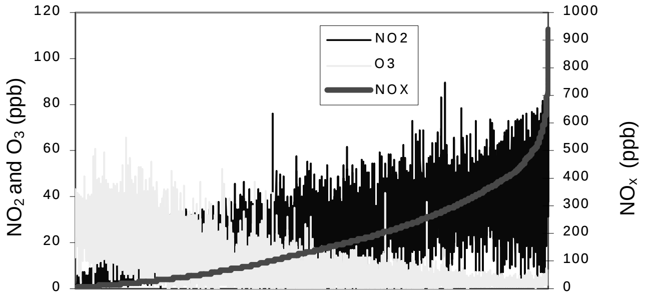

Figure 4 The relationship between near-road concentrations of O_3, NO_2 and NO_X

2.43 The implication of this is that increases in traffic flows will have a smaller effect on NO_2 concentrations than on NO_x. Near to a busy road, there is nearly always a large excess of NO compared with O_3, and production of NO_2 is therefore limited by the O_3 concentration rather than by the amount of emissions produced by the traffic. It should be noted that many other reaction mechanisms have been suggested to be important during episodes of extremely high pollution (QUARG 1993a). The meteorological conditions that produce such episodes are when the atmosphere is very stable, with very light, or no wind, and with a restricted mixing height so that pollutants cannot disperse into the upper layers of the air. For example, under those circumstances, the elevated concentrations of pollutants and their long residence in the local region can permit the formation of NO_2 by the reaction between NO and oxygen. Clearly, there is no effective limit on the availability of oxygen to take part in that reaction, and the limiting factors then become the concentration of NO and the kinetics of the reaction. A noteworthy pollution episode in December 1991 is thought to have resulted from these conditions, and in London, NO_2 concentrations exceeded all previous records, peaking at a level in excess of 400 ppb. However, conditions such as these occur very infrequently. Depending on the duration of the meteorological episode, many other reactions leading to the formation of NO_2 are possible.

2.44 The principles outlined above greatly simplify the true situation, in which many complex reaction mechanisms are involved. Ozone in the atmosphere is itself created by reactions involving exhaust pollutants, so as pollution patterns change in the future, there will be corresponding changes in typical O_3 concentrations that will, in turn, modify the processes through which NO_2 is produced. Recent measurements have indicated a tendency towards an increase in annual mean ozone concentrations, but a reduction in the frequency and magnitude of concentration peaks.

2.45 Because most NO_2 is formed through reactions of the type described, atmospheric NO_2 concentrations must be derived using a slightly different method to that used for the other pollutants. In previous versions of the DMRB, the method for deriving NO_2 concentrations near to roads involved the estimation of the background concentration of NO_x, adding to this a NO_x contribution from the road, then converting to NO_2 using a best-fit relationship between measured NO_2 and NO_x based on data from a wide variety of national monitoring sites. However, this method has now been replaced by a method proposed by Wilson and Laxen (2002). The revised approach assumes that concentrations near to roads are made up of two components:

- NO_2 from the road traffic,
- NO_2 from the background air.

2.46 The relationship between the atmospheric NO_2 and NO_x concentrations due to road traffic was examined by subtracting the corresponding background values of NO_2 and NO_x from the measured values at monitoring sites. The sites were predominantly from the AURN, together with one local authority site near the M60 (provided by Salford MBC) and four HA roadside sites for the years 1999-2001. Information was provided by NETCEN on local background NO_2 and NO_x for each monitoring location, using national 1x1 km grid square maps for each of the three years. The data is shown in Figure 5.

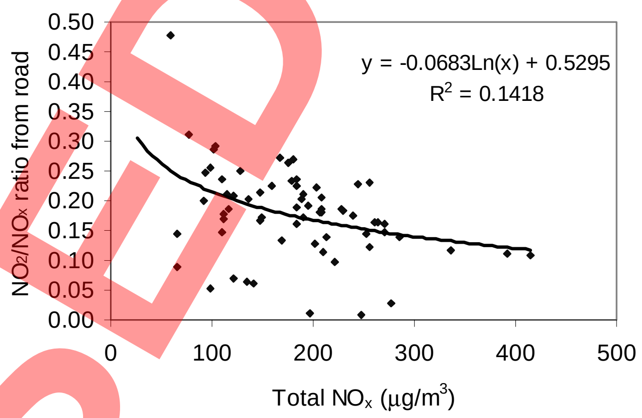

Figure 5 The relationship between the ratio of NO_x and NO_2 contributions from road traffic and total NO_x concentrations

The equation used to estimate total annual mean NO_2 is therefore:

$$NO_{2\ total} = NO_{2\ background} + NO_{2\ road}$$

Where $NO_{2\ road}$ is given by:

$$NO_{2\ road} = NO_{x\ road}\ [(-0.068 \ln (NO_{x\ total}) + 0.53]$$

The second equation is derived from the data shown in Figure 5.

2.47 The annual mean NO_2 concentration derived in this way is directly comparable to the annual mean air quality criteria for NO_2 (40 µg/m³). However, a conversion from the annual mean to the number of exceedences the hourly NO_2 standard (200 µg/m³) is not now used in the DMRB. There are two reasons for this:

(i) An evaluation of the monitoring data from the AURN sites revealed that the relationship between the number of hourly exceedences and the annual mean was very weak.

(ii) There are very few exceedences of the hourly criteria at annual mean concentrations below 40 µg/m³, and therefore the annual mean criteria will almost always be exceeded first.

These observations are illustrated graphically in Figure 6.

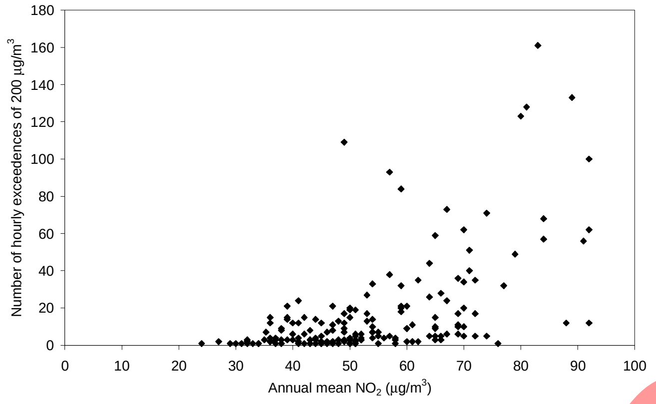

Figure 6 Relationship between annual mean NO_2 and number of hourly exceedences of 200 µg/m³ (1990 to 2001)

Carbon monoxide

2.48 In the case of CO, the road traffic contribution is added directly to the background concentration to give the absolute annual mean concentration. However, the air quality criteria for CO are defined in terms of a running 8-hour mean (10 mg/m³). As no exceedences of this standard are permitted, a relationship was required to relate the maximum 8-hour CO concentration during a year with the annual mean. Carbon monoxide is an inert gas (on the timescale of near-road dispersion processes) and is predominantly emitted by road traffic sources, so there are reasonably consistent relationships between the annual mean concentration and those for other averaging periods and frequencies. This is not the case, however when the absolute maximum 8-hour concentration is considered. The evaluation of the monitoring data from the AURN sites over a period of several years revealed that the relationship between the maximum 8-hour concentration and the annual mean was very weak, with a great deal of scatter (Figure 7). Consequently, only the annual mean CO concentration is reported. It should, however, be noted that exceedences of the CO standard have been extremely rare in recent years (although some exceedences of the CO standard in Figure 7 are apparent, the graph does include data going back to 1990), even at the busiest roadside sites, and if the annual mean is less than 2 mg/m³ then it is currently unlikely that the criteria will be exceeded (see 1998-2001 data in Figure 7). The evaluation of CO (as the annual mean) is included more for completeness than in the expectation of any exceedances of the criteria.

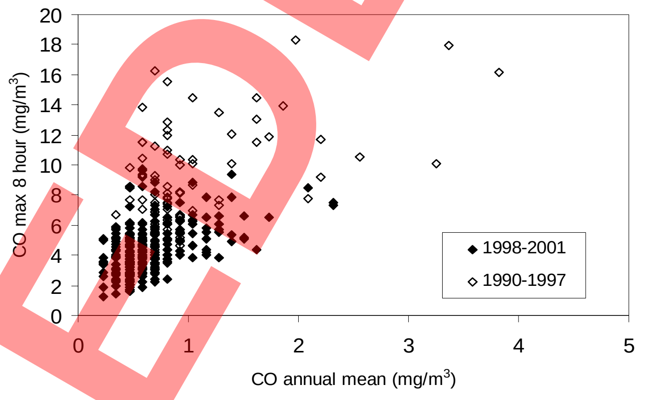

Figure 7 Relationship between maximum 8-hour CO and annual mean CO for 1990-2001

Particulate matter

2.49 The annual mean road traffic PM_{10} contribution calculated by the DMRB is added directly to the background concentration to give the absolute annual mean concentration. The annual mean PM_{10} can then be compared directly with the annual mean standards. Information on the size distribution of vehicle exhaust particles shows them predominantly to be much smaller than 10 µm in diameter, with most (by mass) in the size fraction less than 1 µm. It is therefore acceptable to regard the total particle emissions conventionally measured in vehicle tests as equivalent to PM_{10}. There is also a 24-hour mean standard for PM_{10} of 50 µg/m³, not to be exceeded more than a specified number of times a year. The evaluation of the monitoring data from the AURN sites revealed that the relationship between the number of exceedences of the 24-hour standard and the annual mean was good (Figure 8). The equation to derive the number of exceedences (N) from the annual mean (a) is:

$$N = -18.5 + 0.00145a^3 + (206/a)$$

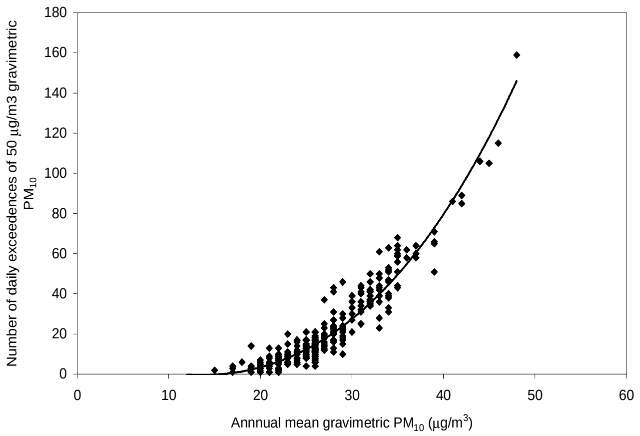

Figure 8 Relationship between annual mean and number of exceedences of 50 µg/m³ gravimetric PM_{10}

2.50 Of all of the pollutants considered, PM_{10} has the lowest direct contribution from road transport emissions. A significant proportion of airborne particles is secondary (derived in part from vehicle emissions, but generated by large-scale atmospheric processes and adding, therefore, to the general regional pollution background), non-transport combustion, and non-combustion sources such as mining, quarrying and construction also produce primary particles and the precursors of secondary particles, and there are natural sources such as fungal spores and sea salt. Furthermore, it has been shown that some episodes of high particle pollution are dominated by material transported over very large distances and that, on average in 1996, between a quarter and a half of the sulphate pollution in the UK was derived from sources in mainland Europe. For these reasons, the effects of a road scheme on PM_{10} concentrations are less marked than those on concentrations of other pollutants.

Benzene and 1,3-butadiene

2.51 For each of these pollutants, the road traffic contribution calculated by the DMRB Screening Method is added directly to the background concentration to give the absolute annual mean concentration. This can then be compared directly with the appropriate air quality criterion.

Calibration of the local assessment method

2.52 The DMRB Screening Method was modified to include the latest information on emission factors, fleet composition, background concentrations, the relationship between NO_X and NO_2, and the relationships between the annual mean concentrations and the metrics specified in the air quality criteria.

2.53 Data were assembled detailing pollutant concentrations and traffic conditions at a selection of roadside measurement sites from the AURN, local authority, and HA networks. Using these data and the new DMRB spreadsheet, estimates were made of annual mean concentrations of CO, NO_X, NO_2, PM_{10}, benzene and 1,3-butadiene. A comparison between these estimates and the corresponding measured concentrations revealed that there remained significant differences.

2.54 Further investigation showed that the ratio of the predicted road traffic contribution to the concentrations of CO, NO_x and PM_{10} can be described as a function of traffic flow (weighted for distance from the receptor where more than one road is being considered). The application of these functions to the road traffic component substantially improved the prediction accuracy of the method, and they have been incorporated into the DMRB spreadsheet. Nitrogen dioxide concentrations were derived from the adjusted NO_x concentrations using the method described in paragraph 2.46. A comparison of modelled with measured values showed that there was good agreement at the majority of AURN and HA monitoring sites. Further information is given in Boulter et al (2002). For benzene and 1,3-butadiene, no adjustments could be made due to the lack of measurement data. There remains a great deal of uncertainty in both the emissions factors and the estimated concentrations for these two pollutants. In particular, it is likely that the 1,3-butadiene concentration is significantly overpredicted.

Contribution to regional pollution

2.55 The procedure for local impact assessment is intended primarily to determine the likelihood of pollution concentrations arising that might be harmful to human health, as assessed by comparison with health-based air quality criteria. The pollutants also contribute to more widespread deterioration of air quality and impacts such as the formation of photochemical oxidants, acid deposition and the greenhouse effect. Phenomena of this type depend more

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on the total amount of pollution in the atmosphere than on concentrations in a particular locality. The estimation of total pollutant emissions from traffic on a network is therefore included in the DMRB.

2.56 The DMRB Screening Method calculates area-wide emissions of the following compounds: CO, VOC, NO_X, PM_{10} and CO_2. As the method for estimating total emissions is based on the same data and assumptions as that for local impact assessment, it is subject to the same uncertainties and approximations. An additional problem may arise in cases where a road scheme exerts an influence on traffic over a very large area. In the case of localised evaluations, the effects of traffic changes on roads that are further than a few hundred metres from the location studied will be negligible, but they may be significant in terms of the scheme's effects on total emissions. Care should therefore be taken to ensure that all of a scheme's area of influence is taken into account in the regional impact assessment.

3. ASSESSMENT PROCEDURE

Introduction

3.1 This chapter describes the stages of work that should be carried out when assessing the emissions and air quality impacts of a road scheme. This work is consistent with that required for multi-modal studies and for local authority review and assessment of air quality. The DMRB Screening Method described in this chapter is common to all three assessments. However, there are some slight differences in some of their requirements, and where this is the case the differences are noted in the appropriate sections of this chapter.

3.2 Unlike earlier versions of the Screening Method, this revision does not follow a paper-based graphical procedure, but has been produced in the form of an Excel spreadsheet. The spreadsheet can be downloaded from the Highways Agency website (http://highways.gov.uk/contracts/index.htm#2 in the DMRB section). The opportunity has also been taken to revise many of the basic data and relationships on which the method is based, so that it uses the most up-to-date information. Its performance has been assessed by comparing its results with measurements conducted at a wide range of roadside locations, and empirical corrections have been incorporated that significantly improve its accuracy.

3.3 The remainder of this chapter sets out the stages to be followed when assessing a road scheme and describes how to use the Screening Method. Throughout the assessment process, consideration should be given as to how to minimise any negative impact of the scheme on air quality. Information on how this can be achieved is given in Annex 4.

Stages in the assessment of a road scheme

3.4 The assessments should both inform and take account of developments in scheme design and route alignment. Assessment and design are part of an iterative process. The following levels of detail will generally be appropriate at the key stages. A report must be completed for each stage that is required in the assessment.

Stage 1

3.5 The objective at this stage is to indicate whether there are likely to be significant air quality impacts associated with particular broadly defined routes or corridors, as developed by the design organisation and the Overseeing Department's project manager.

3.6 The steps to be taken are:

I. Mark on a 1/25,000 or 1/10,000 scale map all properties where people might possibly be subjected to a change in air quality. Only properties within 200 m of the affected route or corridor need be considered. Particular attention should be paid to locations where susceptible people may be located, judged in terms of their sensitivity to pollution and the likely duration of their exposure to it. In addition, areas likely to experience higher than average pollution concentrations, such as tunnel portals, roundabouts and junctions, should be identified.

II. Count the number of properties within the vicinity of the proposed scheme, and split into the following distance bands for each road expected to be affected by the proposals:

- Roadside to 50 m from roadside
- 50 m - 100 m from roadside
- 100 m - 150 m from roadside
- 150 m - 200 m from roadside

III. Identify areas where it is likely that air quality will be improved or will deteriorate as a result of changes to traffic flows and traffic speed, or as a result of reduced congestion or queuing times.

IV. Identify the location of any AQMAs in areas that potentially could be affected by a change in air quality as a result of the proposals.

3.7 The results of the air quality assessment at this stage, to be included in the Stage 1 Report, should consist of:

- A constraints map showing the properties that might possibly be affected by a change in air pollution.
- A table listing the number of properties by distance band from each road that is likely to be

affected by the proposals and indicating which are likely to have an improvement or deterioration in air quality.

- The location and nature of any AQMAs that could be affected by the proposals.

Stage 2

3.8 As the choice of possible routes is narrowed down, taking potential air pollution impacts into account, a more detailed air quality assessment of the remaining options should be made. The steps to take are:

I. Revise as necessary the constraints maps produced during Stage 1 for the various route options under consideration to take account of any scheme changes and further traffic information.

II. Estimate pollutant concentrations at the properties that are likely to be the most affected by the proposals. If monitoring has been carried out in the area affected by the proposals, estimates should also be made at the monitoring sites and compared with the measurements to give an indication of the confidence that should be placed in the results. The estimates should be made using the 'Local' application of the DMRB spreadsheet. The years assessed should be the base year and the opening year with and without the proposals. In addition, the years 2005 and 2010 should be evaluated both with and without the proposals if the proposals would be operational at these times. If concentrations are expected to exceed the air quality criteria in any of the years in which they apply, further calculations should be carried out to determine the first year in which they will be achieved. If the estimated concentrations with the scheme are above the air quality criteria, detailed modelling should be carried out for these areas in the Stage 3 assessment.

III. Estimate the overall change in people's exposure to concentrations of nitrogen dioxide and PM_{10}. These pollutants are identified as of particular concern with respect to compliance with the objectives in the Air Quality Strategy. This specific assessment must be undertaken for the Strategy pollutant specific objective years, or, where a scheme opens after these dates, for the scheme opening year. This assessment is the same as that required for completing the Appraisal Summary Table in GOMMMS (DETR, 2000). The following steps are required:

a. For each affected road, calculate the difference in roadside PM_{10} and NO_2 levels between the do minimum and with proposal scenarios for either AQS objective years or opening year. Concentrations should be estimated using the 'Local' application of the DMRB spreadsheet. A positive value should be assigned where an increase in concentration has been identified due to the proposal and a negative value for a decrease in concentration.

b. For each affected route, obtain the banded property counts from the Stage 1 assessment. Four distance bands, up to 200 m from the roadside are specified. The bands closely relate to the diminishing contribution that vehicle emissions make to the local air pollution. Beyond 200 m, the contribution of vehicle emissions from the roadside to the local pollution levels is not significant. These property counts should be weighted, calculated through the use of the factors in Table 8. This weighting compensates for the reduction in pollutant concentration with distance from the road. The total number of 'weighted' properties for each affected road and pollutant, should be recorded.

Table 8 Pollutant weightings

Bands	PM_{10}	NO_2
Roadside to 50 m from roadside	1.00	1.00
50 m to 100 m from roadside	0.65	0.80
100 m to 150 m from roadside	0.55	0.65
150 m to 200 m from roadside	0.50	0.55

c. For each affected route the following values are to be calculated:

- (Difference in PM_{10} on the route) x (number of weighted properties on route)

- (Difference in NO_2 on the route) x (number of weighted properties on route)

The PM_{10} and NO_2 assessment value may subsequently be calculated by the aggregation of these values across all affected roads, separately for each pollutant. These values are required in the Appraisal Summary Table.

d. The number of properties with an improvement or deterioration in air quality with the scheme should also be recorded These values are also required in the Appraisal Summary Table.

e. This quantitative assessment procedure may be supported by a qualitative comment. In particular, a qualitative comment must be provided if any of the following situations applies:

- The proposed scheme leads to an increase in annual mean PM_{10} of at least 2 µg/m^3.
- The proposed scheme leads to an increase in NO_2 levels of at least 4 µg/m^3, and where concentrations are above the AQS NO_2 objective of 40 µg/m^3.
- The proposed scheme is likely to affect air quality in an AQMA, and state what the effect is.

3.9 The results of the assessment at this stage, to be included in the Stage 2 Report, should consist of:

- A constraints map showing the properties which might possibly be affected by changes in air quality.
- A statement explaining the air quality implications of the route options. This should include, where relevant, an explanation of why certain areas were selected for investigation of localised pollution effects, the estimated concentrations and an assessment of the results. Any areas requiring detailed modelling in Stage 3 should be identified.
- A quantitative assessment of the change in people's exposure to PM_{10} and NO_2 and an estimate of the number of properties that are likely to have an improvement or deterioration in air quality. This may be accompanied by a qualitative comment indicating that the proposal would affect air quality in an AQMA or would cause a significant increase in concentrations.

Stage 3

a. Total Emissions

3.10 Calculations should be made of the change in total emissions that will result from the scheme, as compared with the do-minimum alternative. The 'Regional' application of the DMRB spreadsheet is designed for this purpose.

b. Local Impacts

3.11 Where parts of the preferred route have changed significantly from those assessed at Stage 2 or the traffic data has been revised, the estimated pollutant concentrations should be revised.

3.12 If, after the Screening Method assessment already carried out, the localised air pollution effects of the preferred route are thought likely to be significant, a detailed air quality assessment should be carried out by someone with relevant expertise. This situation may arise because the results of the initial local impact assessment indicate that there is a reasonable risk of the AQS objectives being exceeded, or because the proposal includes significant features not examined by this Screening Method. Examples of this latter type might include schemes where car parking is a major feature (the effects of cold starting could be important), schemes with features that would affect the dispersion of pollution (eg tunnels) or where concentrations are estimated to be close to the objectives and the proposals would significantly affect peak hour congestion. It is not possible to give an exact specification for this assessment, as the precise requirements will depend on the individual circumstances of the scheme. However, the following issues should be addressed in the detailed air quality report:

I. The reason why detailed modelling is required (for example, the possibility of exceeding the AQS objectives, the proposals affecting an AQMA or features of the proposals that cannot be addressed by the Screening Method).

II. The results of any calculations already made.

III. The method used to calculate existing and predicted air pollution levels. The fundamentals of dispersion modelling are discussed briefly in Annex 3. Additional advice on air pollution modelling is available from a variety of sources including the Technical Guidance Note TG(02) (DEFRA, 2002). The assumptions and procedures used in making the forecasts should be clearly stated (eg changes in vehicle technology and their effect on emissions, assumptions about traffic levels and speeds, the key features of the dispersion model used), as should the sources of any supplementary data used (eg exhaust emission rate data, meteorological data, pollution measurements). The traffic forecast used should be that for the high growth assumption

IV. An assessment of the existing air quality in relation to the air quality criteria and a comparison of modelled with measured concentrations to verify the model results.

V. An assessment of the significance of the changes in air quality. The assessment should bring together the earlier conclusions about existing and forecast pollution levels in relation to air quality criteria.

Using the local and regional Screening Methods

3.13 The ‘Local’ Screening Method is to be used in Stage 2 road assessments, local authority review and assessment, and in multi-modal studies. The ‘Regional’ Screening Method is to be used in Stage 3 road assessments and multi-modal studies.

Input data requirements

Years for assessment

3.14 The years for which assessments are required depend on the application (road scheme assessment or review and assessment) and on the pollutant (because the target dates for the AQS objectives differ).

I. For the local impact of a road scheme, the assessment should be for the base year and opening year. If the proposals would be operational in 2005 or 2010, then these years should also be assessed.

II. For the generalised local impact assessment of a road scheme, the instructions given in paragraph 3.8 should be followed.

III. For Local Authority Review and Assessment, the calculations should be made for the appropriate target dates for the AQS objectives (Table 4).

Receptor locations

3.15 For the local application, pollutant concentrations should be estimated at locations where the Air Quality Strategy objectives apply. These are locations where members of the public will be exposed to the pollution over the appropriate timescale for the objective. Further information is given in the Technical Guidance (DEFRA, 2002). Some of the locations likely to be chosen are:

I. Where the impact of the scheme is expected to be greatest because of significant changes in the nearby traffic conditions.

II. Where pollution levels are expected to be highest because of large traffic flows or operating conditions conducive to high rates of emission (eg low-speed congested traffic, road junctions where vehicles must stop and start).

III. Properties where there are likely to be vulnerable occupants, such as schools, hospitals or nursing homes.

IV. At roadside locations appropriate for the generalised local assessment of road schemes (see 3.8).

V. Where air pollution concentrations are measured, which will help to quantify uncertainties in estimates at other locations.

The road network

3.16 For a local assessment, the roads included in the calculation should be all those expected to make a significant contribution to pollution at the receptor location in question. In practice, roads more than 200 m away from the receptor can be excluded. Minor roads can also be excluded even when they are closer to the receptor than 200 m, since their relatively small contributions will be represented in the local background concentration. The selection of roads can often be made using a large-scale map, together with basic traffic flow data. Where there is uncertainty as to the likely impact of roads in the area, a site inspection is recommended.

3.17 For the regional assessment of a road scheme, the network should take into account all of the roads where there will be a change in the traffic flow, either in numbers of vehicles or a change in operation that will affect the mean traffic speed. Often, some of the roads in the network will not be directly involved in any proposed infrastructure change, but their traffic may nevertheless be influenced by the scheme. For some major schemes, the area of influence can be extensive.

Road type

3.18 A road type definition must be given for each road included in the assessment. The DMRB Screening Method has been configured with three broad road categories. These are:

Category A	=	All Motorways or A-roads
Category B	=	Urban roads which are neither motorways nor A-roads
Category C	=	Any other roads

3.19 This classification is related to the composition of the traffic characterising each of these road types. In the case of motorways and A-roads, they are associated with a higher proportion of the heaviest goods vehicles. In urban areas these large articulated vehicles are often restricted to relatively small areas and specific routes. The traffic classification by road type is compatible with the defaults used within the NAEI.

3.20 Where the user has information on the composition of the traffic, this should be used in preference to the default values. In this case, the road type definition is not appropriate (labelled category 'D').

Traffic data

3.21 Traffic characteristics must be specified for each road in the network under consideration. The revised DMRB Screening Method allows the traffic to be described in two ways.

I. In terms of the AADT flow and the proportion of light-duty and heavy duty vehicles (defined respectively as those vehicles with a gross vehicle weight below and above 3.5 tonnes). Depending on the assessment year and road type, the model will refer to a database to derive a more detailed composition for each broad vehicle type. The resulting subdivision will give the national average composition with respect to type (car, light goods vehicle, bus, coach, rigid lorry or articulated lorry), size (engine capacity or weight), fuel (petrol or diesel) and the emission standard.

II. Where local traffic classification data are available, these should be used in preference, as it is possible for the local traffic composition to differ significantly from the national average. Data should be given as individual percentages of cars, light goods vehicles, buses/coaches, rigid lorries and articulated lorries. Because it is not simple to observe many of the other variables used in the detailed classification (such as fuel type or emission standard), the model again performs that subdivision using national data.

3.22 Vehicle emission rates are calculated as a function of average speed. The highest emissions are normally associated with slow speed, congested driving conditions, with the lowest emissions during steady speed operation at an average speed of around 60-80 km/h. The DMRB Screening Method uses annual average vehicle speed as an input parameter. Where no information is available on average speeds and no estimate can be made, then the speed limit may be used as a default. However, given that changes in average speed may have significant impacts on the estimated rates of emission, sensitivity tests using various speeds should be carried out to determine if detailed investigation of the speed is warranted.

Definition of road links

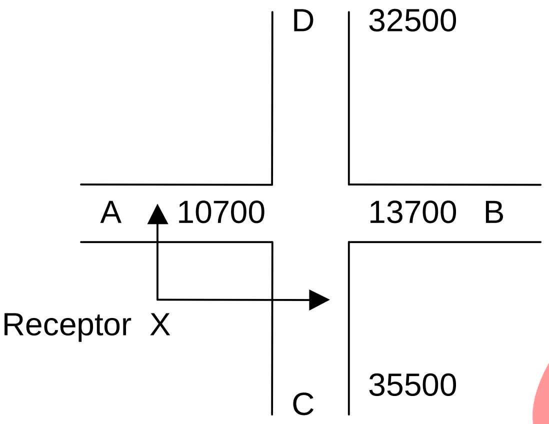
3.23 The process of link definition is undertaken by dividing the network of roads within the study area into sections where traffic conditions (flow, composition and average speed) are reasonably homogeneous. The road network should be divided into as few continuous roads as possible to avoid overestimation by including contributions separately from different parts of the same road. This is true even when a road is not straight or is interrupted by a roundabout, crossroad or other feature. There will be situations where a short section of road is not part of a longer continuous road and it must be considered as a separate contributor. The data necessary for each link are essentially those described above, but there are slight differences in the approaches for local and regional assessments.

I. For local assessments, it is necessary to consider the traffic characteristics at the point nearest to the receptor. Thus, for example, the average speed over a whole link is likely be higher than that on the same link, but near to a roundabout. If the receptor in close to the roundabout, the lower, localised average speed should be used. This applies to all other traffic data. It is also necessary to specify the distance between the receptor and the centre of each link.

II. For regional assessments, which take into account each link in its entirety, the average properties should be used. The length of the link is also required.

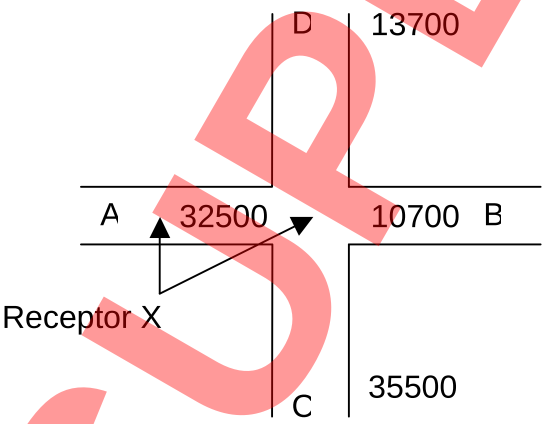
The principles of link definition for local assessments are illustrated in the examples given below.

Example 1



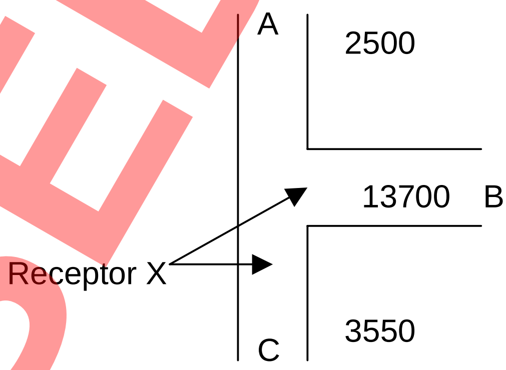
This simple network should be divided into 2 links, AB and CD. For the receptor at X, the distances would be as shown by the arrows. The traffic flows (and other data) would be those on the arms of the crossroad nearest to X. Thus, for link AB, the appropriate flow would be 10700, and for CD 35500.

Example 2



This is the same network as for example 1, but now it has been assumed that the major flow of traffic takes the route AC. Because road designations are based on homogeneous traffic characteristics rather than geometry, the two links in this case are AC and BD. The closest position to the receptor on link BD is now at the centre of the crossroad, as shown. This point is common to both arms of the link, so the traffic data should be the average, rather than that specific to either of them. Thus, the appropriate flow would be 12200.

Example 3



Again, this simple network reduces to two links. On the basis of the traffic flows, arms A and C are most similar (a difference of 10500 compared with a difference of 11300 between A and B). The continuous link is therefore designated AC, with the remaining arm, B, becoming the second link. The arrows show the closest distances between the links and the receptor. The appropriate flow for Link AC is 35500 because the receptor is closer to arm C than arm A. That for link B would be 13700.

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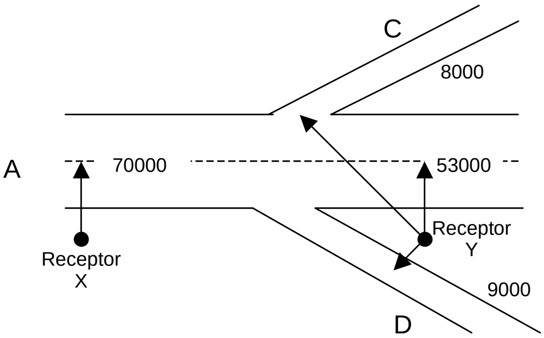
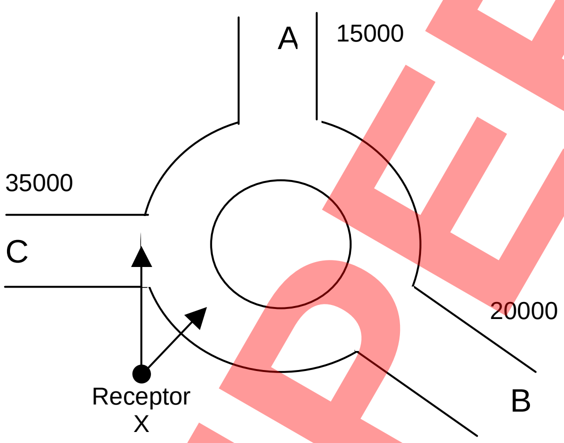
Example 4



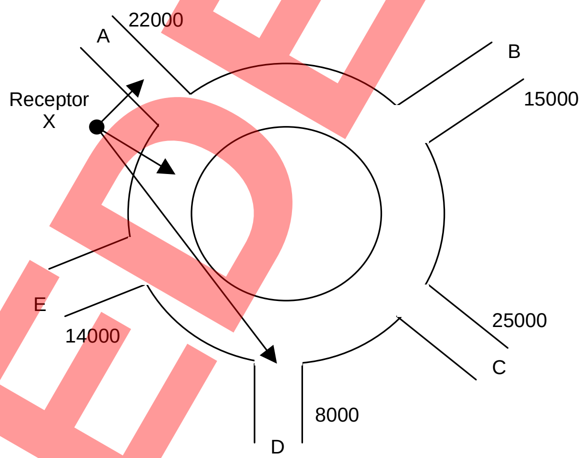
This example represents a motorway or dual-carriageway road (AB) with entry and exit slip roads. AB has a traffic flow of 70000 west of the junction, and a flow of 53000 east of the junction. The flow on the northern slip road (C) is 8000, and the flow on the southern slip road is 9000. At a receptor located away from the junction (X), only the flow on the main link need be considered. For a receptor located within the area bounded by the junction, all three links (AB east of the junction, and both slip roads) need to be considered as shown.

Example 5



Even though this network includes a roundabout, it is similar to the three-arm junction in Example 3. The two arms with the most similar traffic conditions are considered as one link and the remaining arm forms the second. Thus, the first link is AB, and the second is C. However, the presence of the roundabout influences the positions on the roads to which measurements are taken as it has the effect of bringing some of the traffic nearer to the receptor. The distance to link C is measured normally, but that to AB is taken to a point on the roundabout. The flow on AB is taken to be the average of that on arms A and B.

Example 6



This example shows a five-arm roundabout. This can be reduced to three links as follows. On the basis of the traffic flows, arms A and C are similar, and therefore AC becomes a link, with the distance being measured to the nearest point on arm A. Arms B and E are also similar, and so BE also becomes a link, with the distance being measured to the nearest point on the roundabout and the flow being the average of those on the two arms. The remaining arm, D, becomes the third link. The distance to arm D is measured to the point at which arm D joins the roundabout.

Local background concentrations

3.24 For local impact assessments it is necessary to specify background concentrations upon which the local, traffic derived pollution is superimposed. They may be derived through local long term ambient measurements at background sites, remote from immediate sources of air pollution, but such data are rarely available.

3.25 Alternatively, background concentrations may be obtained from a series of default concentration maps produced periodically by NETCEN, on behalf of DEFRA. The maps provide data with a resolution of 1km x 1km. Users may obtain these background pollution data from LAQM section of the NETCEN website at www.airquality.co.uk.

3.26 The mapping procedure has made use of ambient measurements recorded from a combination of the

DEFRA background rural and urban networks (supplemented by other monitoring network data for some pollutants) and NAEI emission inventory estimates. The methodology is described in Stedman *et al.*, 2001; Bush *et al.*, 2001a and 2001b. Background maps, are now available with a 2001 base year for PM_{10}, SO_2, NO_X, NO_2 CO, benzene and 1,3-butadiene. For other years, between 1996 and 2025, correction factors are available to estimate the likely change in background concentrations. Because there are contributions from non-traffic sources to the general background concentrations, changes will not be in direct proportion to the changes in traffic emissions.

3.27 While the mapped background concentrations may be directly appropriate for most urban situations, for which several monitoring sites have been used for verification, there are few measurements available for rural locations. An analysis of the rural background concentrations allocated to individual grid squares containing road links indicates that they may be unduly influenced by the road. It is then inappropriate to add a second contribution from the road. Where this issue is considered significant, it is recommended that concentrations are used derived from the average background concentration up to four grid squares away from either side of the road where there are no other significant sources of pollution.

Property count

3.28 For the generalised local impact assessment, it is necessary to provide a banded count of properties within 200 m of the road network, as detailed in paragraph 3.6.

Preparation of input tables

3.29 The data assembled in the way described above should now be assembled into tables in preparation for their input to the spreadsheet. There are small differences between the tables for local impact assessment and those for regional impact assessment.

I. For local assessments data should be provided for each link under the headings shown below, and include the distance from the link to the receptor in addition to the traffic flow and composition details. One such table is needed for each receptor location to be evaluated, and for each year under consideration.

		Traffic flow & speed		Traffic composition							
					Vehicles <3.5t GVW (LDV)			Vehicles >3.5t GVW (HDV)			
Link number	Distance from link centre to receptor (m)	AADT (combined) veh/day	Annual average speed (km/h)	Road type (A,B,C,D)	% cars	% light goods vehicles	Total % LDV	% buses and coaches	% rigid HGV	% articulated HGV	Total % HDV

Figure 9 Input Data for Local Assessment

II. For regional impact assessment, most of the necessary data are identical, but, since this evaluation is not made with respect to any individual location, the distance to receptor column is replaced by the link length. An option is also provided to give a title to each link (the street name, for example). This may be helpful in identifying the contributions made by particular parts of the network.

			Traffic flow & speed		Traffic composition							
						Vehicles <3.5t GVW (LDV)			Vehicles >3.5t GVW (HDV)			
Link number	Link title	Link length (km)	AADT (combined) veh/day	Annual average speed (km/h)	Road type (A,B,C,D)	% cars	% light goods vehicles	Total % LDV	% buses and coaches	% rigid HGV	% articulated HGV	Total % HDV

Figure 10 Input Data for Regional Assessment

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Instructions for spreadsheet operation

3.30 The DMRB Screening Method Spreadsheet has been developed in Microsoft Excel 97. It contains several macros written in Visual Basic for Applications (VBA). These macros are activated via buttons which will be identified in the following text.

Appearance of the spreadsheet

3.31 The method is contained in a multi-sheet spreadsheet, with five of these sheets immediately accessible by the user. These sheets are as follows:

I.	*Title*	This is the title page of the spreadsheet, indicating the version number of the method and the release date.
II.	*Local*	This is the sheet to be used for inputting data for the assessment of local air quality in relation to both road scheme appraisal and local authority review and assessment.
III.	*Local output*	This sheet presents the results of the assessment of local air quality. The concentrations of pollutants are stated as annual means, and according to the metrics specified in the air quality criteria. In addition, a table is included to show the contribution of each separate link to the annual mean concentrations estimated for a receptor point.
IV.	*Regional*	This is the sheet to be used for inputting data for the regional impact assessment of road schemes on road transport emissions.
V.	*Regional output*	This sheet presents the results of the regional assessment of the impact of road schemes on road transport emissions.

In addition to these five sheets, a sixth sheet, entitled *Calc*, is visible whenever any calculations are being made by one of the macros. This sheet is not visible at any other time.

In order to assist the user, comment boxes are linked to some of the cells to provide definitions and details of the required input data. The presence of a comment box is indicated by a red triangle in the top right-hand corner of a cell.

Method for assessment of local air quality

3.32 The procedure in the DMRB Screening Method spreadsheet for the assessment of local air quality involves seven steps. These steps are highlighted on the *Local* sheet, and are as follows:

Step 1 Enter the receptor name and number (1 for first receptor, 2 for second, and so on). Up to 20 different receptors can be assessed, with each one requiring a unique identification number. If the results for a specified receptor number are already present on the Local output sheet, the program will ask for a different receptor number.

Step 2 Enter the assessment year (1996 to 2025).

Step 3 Enter the number of links to be assessed for the current receptor. Up to 15 different links can be assessed. Carriageways on the same road must not be entered separately.

Step 4 Enter the background concentrations which are relevant to the locality of the assessment for the assessment year. If there is no requirement to assess a particular pollutant, a zero can be entered as the background value. A result will still be presented for the pollutant on the Local output sheet, but this can be ignored.

Step 5 Enter the distance and traffic data for each link. The number of links specified here must match that defined in Step 3, and the following input data are required:

- The distance in metres from the link centre to the receptor. The minimum distance allowed is 2 m.
- The combined annual average total daily traffic flow (AADT). Carriageways must not be treated separately.
- The annual average traffic speed in km/h. This must be between 5 km/h and 130 km/h.

- The road type

Enter either A, B, C or D in upper case or lower case, but not a mixture of both. If information on the traffic composition on the link is not available, enter either ‘A’, ‘B’, or ‘C’, where

A = Motorways or A-roads
B = Urban roads which are not motorways or A-roads
C = All other roads

If either ‘A’, ‘B’, or ‘C’ is entered in a cell, the cell shading will change to light grey to indicate which type of traffic composition must be used (see below).

Where information on actual traffic composition is available from classified counts, this may be used in place of the pre-set traffic compositions by entering ‘D’ in the road type cell. If ‘D’ is entered in a cell, the cell shading will change to dark grey.

- *The traffic composition*

If either ‘A’, ‘B’, or ‘C’ has been entered in the road type cell, then only the total percentages of heavy-duty vehicles (HDVs) and light-duty vehicles (LDVs) need to be entered in the appropriate light grey cells. The dark grey cells must be left blank.

If ‘D’ has been entered in the road type cell, the percentage of vehicles in each of the following five classes must then be entered:

i. Passenger cars
ii. Light goods vehicles
iii. Buses and coaches
iv. Rigid heavy goods vehicles (>3.5 tonnes gross vehicle weight)
v. Articulated heavy goods vehicles (>3.5 tonnes gross vehicle weight)

The appropriate values are entered in the corresponding dark grey cells. The light grey cells must be left blank.

Step 6 Place the cursor over the CALCULATE button and click on the left mouse button. The amount of time required for the calculation varies according to the number of links involved. During the calculation a message will appear on the screen to indicate the percentage of the calculation which has been completed. When the calculation has been completed, a ‘RUN COMPLETE’ message appears, and the results for the current receptor can then be viewed on the Local output sheet. If only one receptor is to be assessed, the procedure ends at this point. The Local output sheet displays the details of the current receptor (name, number, and assessment year), the predicted concentrations for the receptor. The results for CO, benzene, 1,3-butadiene, NO_x, NO_2 and PM_{10} are presented as annual mean concentrations, and in addition for PM_{10} the number of days with concentrations above 50 mg/m^3 [4].

Step 7 In some assessments, there may be a need to look at several receptors. If this is the case, the results for the current receptor can be stored on the Local output sheet by pressing the STORE RESULTS FOR THIS RECEPTOR button on the Local sheet. Enter data for the next receptor by overwriting the input data already present, or start from scratch by pressing the CLEAR INPUT DATA button.

Method for regional impact assessment

3.33 The regional impact assessment method involves five steps. These steps are highlighted on the Regional sheet, and are as follows:

Step 1 Enter the identifying name for the assessment.

Step 2 Enter the assessment year (1996-2025).

Step 3 Enter the number of links to be assessed. Up to 1,000 different links can be assessed.

[4] For CO the air quality criteria are for a running 8-hour mean of 10 mg/m^3. However, as there is no strong relationship between the CO annual mean and the running 8-hour mean it is not possible to calculate the latter from the annual mean with a high degree of confidence. Therefore only the annual mean value is reported. The NO_2 criteria are defined in terms of both the annual mean of 40 µg/m^3, and the number of exceedances of a 1-hour mean of 200 µg/m^3. Whilst the annual mean NO_2 value is calculated, the number of exceedances of the hourly standard cannot be calculated from the annual mean with a high degree of confidence. Therefore, as with CO, only the annual mean NO_2 value is reported.

Step 4 Either:

Enter the data for each link. The number of links specified here must match that defined in Step 3, and the following input data are required:

- Title of the link (optional).
- Length of the link in km.
- Combined annual average total daily traffic flow (AADT).
- Annual average traffic speed in km/h. This must be between 5 km/h and 130 km/h.
- Road type defined in the same way as in the local air quality assessment.
- Traffic composition defined in the same way as in the local air quality assessment.

Or:

Import the link data as an Excel spreadsheet or a tab-delimited text file. In order to import link data, click on the IMPORT LINK DATA (.xls or .txt) button. This will open the 'Data File to Import' dialogue box. Locate the data file and click on 'Open'. In order to be imported correctly the data file must be in the following format:

Excel data file:

The Excel data file must take the format shown below, with a header line at Row 1. The header line may be left blank.

Alternatively, if the data file is in the correct Excel format, the data from Row 2 onwards can simply be copied into the Regional sheet at Cell at the Link title position for link number 1.

Text data file:

The tab-delimited text data file is essentially the same and must be defined in the following way:

Line 1: [Identifying name]

Following lines: [Link title]{TAB}[Link length] {TAB} [AADT] {TAB} [Speed] {TAB} [Road type] {TAB} [%PC] {TAB} [%LGV] {TAB} [Total %LDV] {TAB} [%Buses] {TAB} [%Rigid HGV] {TAB} [%Artic HGV] {TAB} [Total %HDV]

Where an entry is not required (eg %PC is not required for road types A, B or C) the field is left blank.

Step 5 Place the cursor over the CALCULATE button and click on the left mouse button (<u>Warning</u>: this clears any existing output). Again, the amount of time required for the calculation varies according to the number of links involved. The calculation may take a few hours if there are several hundred links to process. During the calculation a message will appear on the screen to indicate the percentage of the calculation which has been completed. When the calculation has been completed, a 'RUN COMPLETE' message appears, and the results for the current receptor can then be viewed on the Regional output sheet. The Regional output sheet displays the summarised details of the current assessment (name, assessment year, and number of links), and the predicted total emissions of CO, THC, NO_x, PM_{10} and CO_2 on the defined network.

Worked examples

Local assessment

3.34 This section shows how the DMRB Screening Method should appear during the local and regional assessments. The network used in the local assessment is taken to be Example 1 from paragraph 3.23.

3.35 The image below illustrates the input sheet for the local air quality assessment with the appropriate details entered for Example 1. Some typical traffic speeds, traffic composition, and background concentrations have been used.

DMRB: Assessment of Local Air Quality **INPUT SHEET**

Step 1	Receptor name	example 1-house at crossroads	Receptor number	1
Step 2	Year	2005		
Step 3	Number of links	2		

Step 6

Step 7

Step 4

Background concentrations for 2005					
CO (mg/m^3)	Benzene (µg/m^3)	1,3-butadiene (µg/m^3)	NO_x (µg/m^3)	NO_2 (µg/m^3)	PM_{10} (µg/m^3)
0.29	0.4	0.17	33.4	21.6	14

Step 5

Link number	Distance from link centre to receptor (m)	Traffic flow & speed: AADT (combined, veh/day)	Traffic flow & speed: Annual average speed (km/h)	Traffic composition: Road type (A,B,C,D)	Vehicles <3.5t GVW (LDV): % passenger cars	Vehicles <3.5t GVW (LDV): % light goods vehicles	Vehicles <3.5t GVW (LDV): Total % LDV	Vehicles>3.5t GVW (HDV): % buses and coaches	Vehicles>3.5t GVW (HDV): % rigid HGV	Vehicles>3.5t GVW (HDV): % articulated HGV	Vehicles>3.5t GVW (HDV): Total % HDV
1	10	10700	36	A			90				10
2	25	35500	15	D	82	6		1	8	3	
3											
4											
5											
6											
7											

Figure 11 Example Spreadsheet for Input to Local Assessment

3.36 The CALCULATE button is then pressed, and the program checks for errors in the input data. As the program executes, it displays messages showing how much of the calculation has been completed, and indicates when the calculation is complete.

3.37 Once the calculation is complete, the results for the current receptor can be viewed on the output sheet for the local assessment. In the example below, the user has also stored the results for the current receptor:

DMRB: Assessment of Local Air Quality **OUTPUT SHEET**

Current receptor

Receptor Name	example 1-house at crossroads	Receptor number	1
Assessment year	2005		

Results

Pollutant	Annual mean				For comparison with Air Quality Standards		
	Background concentration	Road traffic component	Total	Units	Metric	Value	Units
CO	0.29	0.38	0.67	mg/m^3	Annual mean*	0.67	mg/m^3
Benzene	0.40	0.41	0.81	µg/m^3	Annual mean	0.81	µg/m^3
1,3-butadiene	0.17	0.70	0.87	µg/m^3	Annual mean	0.87	µg/m^3
NO_x	33.4	105.6	139.0	µg/m^3	Not applicable		
NO_2	21.6	20.3	41.9	µg/m^3	Annual mean*	41.9	µg/m^3
PM_{10}	14.0	17.5	31.5	µg/m^3	Annual mean	31.5	µg/m^3
					Days >50µg/m^3	33	Days

* See Footnote 4 in DMRB Volume 11 Chapter 3

Contribution of each link to annual mean

Link number	CO (mg/m^3)	Benzene (µg/m^3)	1,3-butadiene (µg/m^3)	NOx (µg/m^3)	PM_{10} (µg/m^3)
1	0.07	0.08	0.12	22.50	3.51
2	0.31	0.33	0.57	83.09	13.96
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

All receptors

Receptor number	Name	Year	Pollutant concentrations at receptor						
			CO *	Benzene	1,3-butadiene	NO_x	NO_2 *	PM_{10}	
			Annual mean mg/m^3	Annual mean µg/m^3	Annual mean µg/m^3	Annual mean µg/m^3	Annual mean µg/m^3	Annual mean µg/m^3	Days >50µg/m^3
1	example 1-house at crossroads	2005	0.7	0.8	0.9	138.98	41.9	31.5	33

Figure 12 Example Spreadsheet for Output from Local Assessment

Regional assessment

The regional assessment is very similar to the local assessment in appearance. Typical input and output sheets are illustrated below:

DMRB: Regional Impact Assessment **INPUT SHEET**

Step 1	Name	motorway widening	(Step 4)
Step 2	Year	2005	Step 5
Step 3	Number of links	5	RUN COMPLETE
Step 4			

Link number	Link title	Link length (km)	Traffic flow & speed		Road type (A,B,C,D)	Traffic composition						
						Vehicles <3.5t GVW (LDV)			Vehicles>3.5t GVW (HDV)			
			AADT (combined,veh/day)	Annual average speed (km/h)		% passenger cars	% light goods vehicles	Total % LDV	% buses and coaches	% rigid HGV	% artic-ulated HGV	Total % HDV
1	motorway J4-5	10.60	120,000	112	A			90				10
2	motorway J5-6	8.20	110,000	112	A			89				11
3	Argyll Rd	3.20	30,000	50	A			93				7
4	Barnwood Rd	2.50	15,000	40	B			94				6
5	Market St	1.00	22000	35	D	78	15		3	4	0	
6												
7												
8												
9												
10												
11												

Figure 13 Example Spreadsheet for Input to Regional Assessment

DMRB: Regional Impact Assessment **OUTPUT SHEET**

Summary

Name	motorway widening		
Year	2005	Number of links	5
Pollutant		Total emission	Units
CO		1,055,839	kg/year
THC		136,608	kg/year
NO_x		1,214,987	kg/year
PM_{10}		43,654	kg/year
CO_2		179,109	tonnes/year

All links

Link number	Link title	Emissions				
		CO (kg/year)	THC (kg/year)	NO_x (kg/year)	PM_{10} (kg/year)	CO_2 (tonnes/year)
1	motorway J4-5	576,606	72,545	666,026	24,177	99,047
2	motorway J5-6	409,713	53,294	498,254	17,711	70,236
3	Argyll Rd	39,900	6,354	32,629	1,094	5,881
4	Barnwood Rd	17,920	2,571	9,951	352	2,445
5	Market St	11,701	1,844	8,128	320	1,500
6						
7						
8						

Figure 14 Example Spreadsheet for Output to Regional Assessment

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5. ENQUIRIES

All technical enquiries or comments on this Standard should be sent in writing as appropriate to:

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Chief Road Engineer Scottish Executive Development Department Victoria Quay Edinburgh EH6 6QQ	J HOWISON Chief Road Engineer

Chief Highway Engineer Transport Directorate Welsh Assembly Government Llywodraeth Cynulliad Cymru Crown Buildings Cardiff CF10 3NQ	J R REES Chief Highway Engineer Transport Directorate

Director of Engineering Department for Regional Development Roads Service Clarence Court 10-18 Adelaide Street Belfast BT2 8GB	G W ALLISTER Director of Engineering

ANNEX 1 EMISSION CONTROL LEGISLATION FOR ROAD VEHICLES

Emission limits to which new vehicles must comply, are presented in Tables A1.1 to A1.4.

Table A1.1 Vehicles with at least four wheels used for the carriage of passengers not exceeding 2.5 tonnes laden with up to 6 seats

EU Directive	Reference mass or engine size	Engine fuel type	Limit values (g/km)[1]					Implementation dates	
			CO	HC	NO_x	$HC+NO_x$	PM	Type Approval	In-use
70/220/EEC	<751 kg to >2150 kg	P	24.68 to 54.29	1.97 to 3.16				01/09/1971	01/09/1972
74/290/EEC	<751 kg to >2150 kg	P	19.74 to 43.44	1.68 to 2.69				01/10/1975	01/10/1976
77/102/EEC	<751 kg to >2150 kg	P	19.74 to 43.44	1.68 to 2.69	2.47 to 3.95			01/10/1997	01/10/1980
78/665/EEC	<751 kg to >2150 kg	P	16.04 to 35.29	1.48 to 2.37	2.10 to 3.36			01/10/1979	01/10/1981
83/351/EEC[2]	<751 kg to >2150 kg	All	14.31 to 27.15			4.69 to 6.91		01/10/1984	01/10/1986
88/76/EEC[3]	>2000 cc	P	6.17		0.86	1.6		01/10/1988	01/10/1989
		D	7.40			2.0			
	1400-2000 cc	P	7.40			2.0		01/10/1991	01/10/1993
		IDI	7.40			2.0			
		DI	7.40			2.0		01/10/1994	01/10/1996
	<1400 cc	P	11.11		1.48	3.7		01/10/1990	01/10/1991
		D	11.11		1.48	3.7			
88/436/EEC	>2000 cc	IDI	6.17		0.86	1.6	0.27	01/10/1989	01/10/1990
		DI	6.17		0.86	1.6	0.27	01/10/1994	01/10/1996
	1400-2000 cc	IDI	7.40			2.0	0.27	01/10/1989	01/10/1990
		DI	7.40			2.0	0.27	01/10/1994	01/10/1996
	<1400 cc	IDI	11.11		1.48	3.7	0.27	01/10/1989	01/10/1990
		DI	11.11		1.48	3.7	0.27	01/10/1994	01/10/1996
89/458/EEC	<1400 cc	P	4.69			1.2		01/07/1992	31/12/1992
91/441/EEC[4] (Euro I)		P	2.72			1.0		01/07/1992	31/12/1992
		IDI	2.72			1.0	0.14		
		DI	2.72			1.4	0.20		
		DI	2.72			1.0	0.14	01/07/1994	31/12/1994
94/12/EC (Euro II)		P	2.20			0.5		01/01/1996	01/01/1997
		IDI	1.00			0.7	0.08		
		DI	1.00			0.9	0.10		
		DI	1.00			0.7	0.08	01/10/1999	01/10/1999

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EU Directive	Reference mass or engine size	Engine fuel type	Limit values (g/km)[1]					Implementation dates	
			CO	HC	NO_x	$HC+NO_x$	PM	Type Approval	In-use
98/69/EC (Euro III)[5]		P	2.30	0.20	0.15			01/01/2000	01/01/2001
		D	0.64		0.5	0.56	0.05		
	Cold Test (-7ºC)								
		P	*15.00*	*1.80*				01/01/2000	01/01/2001
98/69/EC (Euro IV)		P	1.00	0.10	0.08			01/01/2005	01/01/2006
		D	0.50		0.25	0.3	0.025		
	Cold Test (-7ºC)								
		P	*15.00*	*1.80*				01/01/2005	01/01/2006

1 Limits were expressed in units of g/test until Directive 91/441. Values have been divided by 4 (the length of the test cycle in km) for inter-comparison.
2 The analytical method for HC measurements was changed. Results using the new method are approximately 2.3 times higher than those previously. Thus, HC + NO_x limits for 83/351 and later Directives are more severe than might appear from comparison with earlier standards.
3 Standards changed to be based on engine capacity, rather than on vehicle weight category. Introduction of the urban test cycle.
4 Introduction of a new test cycle, the combined urban and extra-urban test referred to as the EUDC (extra urban drive cycle). In addition the legislation defined a limit for idle CO_2 emissions, zero emissions from the crankcase and a limit on evaporative emissions of hydrocarbons from petrol vehicles.
5 Revision to the 91/441 test cycle to exclude the initial 40 sec idle, thus tightening the cold start performance requirements.
Glossary: P – petrol, D – diesel, DI – direct injection, IDI – indirect direction

Table A1.2 Vehicles with at least four wheels used for the carriage of goods not exceeding 3.5 tonnes laden (includes car greater than 2.5 tonnes laden weight and/or with 7 to 9 seats)

EU Directive	Reference mass or engine size	Engine fuel type	Limit values (g/km)[1]					Implementation dates	
			CO	HC	NO_x	$HC+NO_x$	PM	Type Approval	In-use
70/220/EEC	<751 kg to >2150 kg	P	24.68 to 54.29	1.97 to 3.16				01/09/1971	01/09/1972
74/290/EEC	<751 kg to >2150 kg	P	19.74 to 43.44	1.68 to 2.69				01/10/1975	01/10/1976
77/102/EEC	<751 kg to >2150 kg	P	19.74 to 43.44	1.68 to 2.69	2.47 to 3.95			01/10/1997	01/10/1980
78/665/EEC	<751 kg to >2150 kg	P	16.04 to 35.29	1.48 to 2.37	2.10 to 3.36			01/10/1979	01/10/1981
83/351/EEC	<751 kg to >2150 kg	All	14.31 to 27.15			4.69 to 6.91		01/10/1984	01/10/1986
88/76/EEC	>2000 cc	P	6.17		0.86	1.6		01/10/1988	01/10/1989
	>2000 cc	D	7.40			2.0			
	1400-2000 cc	P	7.40			2.0		01/10/1991	01/10/1993
	1400-2000 cc	IDI	7.40			2.0			
	1400-2000 cc	DI	7.40			2.0		01/10/1994	01/10/1996
	<1400 cc	P	11.11		1.48	3.7		01/10/1990	01/10/1991
	<1400 cc	D	11.11		1.48	3.7			

EU Directive	Reference mass or engine size	Engine fuel type	Limit values (g/km)[1]					Implementation dates	
			CO	HC	NO_x	$HC+NO_x$	PM	Type Approval	In-use
88/436/EEC	>2000 cc	IDI	6.17		0.86	1.6	0.27	01/10/1989	01/10/1990
	>2000 cc	DI	6.17		0.86	1.6	0.27	01/10/1994	01/10/1996
	1400-2000 cc	IDI	7.40			2.0	0.27	01/10/1989	01/10/1990
	1400-2000 cc	DI	7.40			2.0	0.27	01/10/1994	01/10/1996
	<1400 cc	IDI	11.11		1.48	3.7	0.27	01/10/1989	01/10/1990
	<1400 cc	DI	11.11		1.48	3.7	0.27	01/10/1994	01/10/1996
89/458/EEC	<1400 cc	P	4.69			1.2		01/07/1992	31/12/1992
91/441/EEC (Euro I)	<1021 kg	All	14.31			4.7		01/07/1992	31/12/1992
	1021-1250 kg	All	16.54			5.1			
	1251-1470 kg	All	18.76			5.4			
	1471-1700 kg	All	20.73			5.8			
	1701-1930 kg	All	22.95			6.2			
	1931-2150 kg	All	24.93			6.5			
	>2150 kg	All	27.15			6.9			
93/59/EEC (Euro I supplement)	<1251 kg	P&IDI	2.72			1.0	0.14	01/10/1993	01/10/1994
	<1251 kg	DI	2.72			1.4	0.20		
	<1251 kg	DI	2.72			1.0	0.14	01/10/1994	01/10/1995
	1250-1700 kg	P&IDI	5.17			1.4	0.19	01/10/1993	01/10/1994
	1250-1700 kg	DI	5.17			2.0	0.27		
	1250-1700 kg	DI	5.17			1.4	0.19	01/10/1994	01/10/1995
	1701-3500 kg	P&IDI	6.90			1.7	0.25	01/10/1993	01/10/1994
	1701-3500 kg	DI	6.90			2.4	0.35		
	1701-3500 kg	DI	6.90			1.7	0.25	01/10/1994	01/10/1995
96/69/EC (Euro I supplement)	<1251 kg	P	2.20			0.5		01/01/1997	01/10/1997
	<1251 kg	IDI	1.00			0.7	0.80		
	<1251 kg	DI	1.00			0.9	0.10		
	<1251 kg	DI	1.00			0.7	0.08	01/10/1999	01/10/1999
	1250-1700 kg	P	4.00			0.6		01/01/1998	01/10/1998
	1250-1700 kg	IDI	1.25			1.0	0.12		
	1250-1700 kg	DI	1.25			1.3	0.14		
	1250-1700 kg	DI	1.25			1.0	0.12	01/10/1999	01/10/1999
	1701-3500 kg	P	5.00			0.7		01/01/1998	01/10/1998
	1701-3500 kg	IDI	1.50			1.2	0.17		
	1701-3500 kg	DI	1.50			1.6	0.20		
	1701-3500 kg	DI	1.50			1.2	0.17	01/10/1999	01/10/1999
98/69/EC (Euro III)	<1251 kg	P	2.30	0.20	0.15			01/01/2000	01/01/2001
	<1251 kg	D	0.64		0.5	0.56	0.05		
	1250-1700 kg	P	4.17	0.25	0.15			01/01/2001	01/01/2002
	1250-1700 kg	D	0.80		0.65	0.72	0.07		
	1701-3500 kg	P	5.22	0.29	0.21			01/01/2001	01/01/2002
	1701-3500 kg	D	0.95		0.78	0.86	0.1		
	Cold Test (-7ºC)								
	<1251 kg	P	15.00	1.80				01/01/2000	01/01/2001

EU Directive	Reference mass or engine size	Engine fuel type	Limit values (g/km)[1]					Implementation dates	
			CO	HC	NO_x	$HC+NO_x$	PM	Type Approval	In-use
98/69/EC (Euro IV)	<1251 kg	P	1.00	0.10	0.08			01/01/2005	01/01/2006
	<1251 kg	D	0.50		0.25	0.3	0.025		
	1250-1700 kg	P	1.81	0.13	0.1			01/01/2006	01/01/2007
	1250-1700 kg	D	0.63		0.33	0.39	0.04		
	1701-3500 kg	P	2.27	0.16	0.11			01/01/2006	01/01/2007
	1701-3500 kg	D	0.74		0.39	0.46	0.06		
	Cold Test (-7ºC)								
	<1251 kg	P	15.00	1.80				01/01/2005	01/01/2006
2001/100/EC (Euro III & IV supplement)	*Cold Test (-7ºC)*								
	<1251 kg	P	15.00	1.80				01/01/2003	
	1250-1700 kg	P	24.00	2.70					
	1701-3500 kg	P	30.00	3.20					

Table A1.3 Vehicles used for the carriage of goods and exceeding 3.5 tonnes laden

EU Directive	Vehicle category	Test	Limit values g/kWh					m^{-1}	Implementation dates	
			CO	HC	NO_x	CH_4 [2]	PM	Smoke	Type Approval	In-use
72/306/EEC		FAS	Nominal Flow: 42 litres/sec					2.260	within 18 months of 02/08/1972	
			Nominal Flow: 100 litres/sec					1.495		
			Nominal Flow: 200 litres/sec					1.065		
88/77/EEC		13-Mode	11.20	2.40	14.40				01/07/1988	01/10/1990
91/542/EEC (Euro I)	> 86kW	13-Mode	4.50	1.10	8.00		0.36		01/07/1992	01/10/1993
	>= 86kW		4.50	1.10	8.00		0.612			
91/542/EEC (Euro II)			4.00	1.10	7.00		0.15		01/10/1995	01/10/1996
1999/96/EC (Euro III)[1]	>= 0.75dm^3 per cylinder	ESC/ELR	2.10	0.66	5.00		0.1	0.8	01/10/2000	01/10/2001
		ETC	5.45	0.78	5.00	1.6	0.16			
	< 0.75dm^3 per cylinder	ESC/ELR	2.10	0.66	5.00		0.13	0.8		
		ETC	5.45	0.78	5.00	1.6	0.21			
1999/96/EC (Euro IV)		ESC/ELR	1.50	0.46	3.50		0.02	0.5	01/10/2005	01/10/2006
		ETC	4.00	0.55	3.50	1.1	0.03			
1999/96/EC (Euro V)		ESC/ELR	1.50	0.46	2.00		0.02	0.5	01/10/2008	01/10/2009
		ETC	4.00	0.55	2.00	1.1	0.03			
1999/96/EC (EEV)		ESC/ELR	1.50	0.25	2.00		0.02	0.15	Voluntary	
		ETC	3.00	0.40	2.00	0.65	0.02			

1 Test cycles: ESC - cycle consisting of 13 steady state modes, ELR - cycle consisting of a sequence of load steps at constant engine speeds, ETC - cycle consisting of 1800 second-by-second transient modes. Smoke opacity as determined on the ELR test.

2 For natural gas engines only.

Glossary: EEV, Environmentally enhanced vehicle, operating on alternative fuels; FAS, Free Acceleration Smoke test; CH_4, methane.

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Table A1.4 Motorcycles (two-wheel, three-wheel and light quadricycles)

EU Directive	Vehicle category	Type or engine size	Engine fuel type	Limit values (g/km)				Implementation dates	
				CO	HC	NO_x	$HC+NO_x$	Type Approval	In-use
97/24/EC Ch 5	Moped	2 wheel	P	6.00			3.0	17/06/1999	17/06/2003
		3 & 4 wheel		12.00			6.0		
	Motorcycles 2-stroke	2 wheel		8.00	4	0.1			
		3 & 4 wheel		12.00	6	0.15			
	Motorcycles 4-stroke	2 wheel		13.00	3	0.3			
		3 & 4 wheel		19.50	4.5	0.45			
	Moped	2 wheel		1.00			1.2	17/06/2000	
		3 & 4 wheel		3.50			1.2		
Proposal COM(2000) 314	Motorcycles	2 wheel	P	5.50	1.2	0.3		01/01/2003	01/01/2004
		<= 150 cc		2.00	0.8	0.2		Voluntary	
		> 150 cc		2.00	0.3	0.1			
		3 & 4 wheel	P	7.00	1.5	0.4		01/01/2003	01/01/2004
			D	2.00	1	0.65			

ANNEX 2 EXHAUST EMISSION FACTORS

A2.1 The following tables provide coefficients of equations expressing pollutant emission rates as a function of average vehicle speed. The equations for tables A2.1 - A2.7 are in the standard form:

$$E = (a + b.v + c.v^2 + d.v^e + f.\ln(v) + g.v^3 + h/v + i/v^2 + j/v^3).x$$

Where: E is the emission rate expressed in g/km
v is the average vehicle speed in km/h
a to j, and x are coefficients

A2.2 These coefficients are tabulated for the pollutants CO, NO_X, PM, HC, benzene, 1,3-butadiene and CO_2 for a wide range of vehicle types.

A2.3 These emission factors are derived from studies by TRL on behalf of the DfT, and are incorporated into the NAEI. This process is described in Chapter 2. The DMRB emission rates are the same as those in the NAEI for all pollutants except carbon dioxide.

Table A2.1 Carbon monoxide

Legislation class	Engine size or vehicle configuration	Coefficients a	b	c	d	e	f	g	h	i	j	x	Valid speed range (km/h)
Petrol car													
Pre-ECE	< 1.4 l	13.6	-0.169	0	0	0	0	0.00000926	158	0	0	2.62	5 - 130
	1.4 - 2.0 l	9.53	-0.118	0	0	0	0	0.0000062	179	0	0	2.62	
	> 2.0 l	9.71	-0.243	0.0018	0	0	0	0	244	0	0	2.62	
ECE 15.00	< 1.4 l	13.6	-0.169	0	0	0	0	0.00000926	158	0	0	1.87	
	1.4 - 2.0 l	9.53	-0.118	0	0	0	0	0.0000062	179	0	0	1.87	
	> 2.0 l	9.71	-0.243	0.0018	0	0	0	0	244	0	0	1.87	
ECE 15.01	< 1.4 l	13.6	-0.169	0	0	0	0	0.00000926	158	0	0	1.87	
	1.4 - 2.0 l	9.53	-0.118	0	0	0	0	0.0000062	179	0	0	1.87	
	> 2.0 l	9.71	-0.243	0.0018	0	0	0	0	244	0	0	1.87	
ECE 15.02	< 1.4 l	13.6	-0.169	0	0	0	0	0.00000926	158	0	0	1.55	
	1.4 - 2.0 l	9.53	-0.118	0	0	0	0	0.0000062	179	0	0	1.55	
	> 2.0 l	9.71	-0.243	0.0018	0	0	0	0	244	0	0	1.55	
ECE 15.03	< 1.4 l	13.6	-0.169	0	0	0	0	0.00000926	158	0	0	1.62	
	1.4 - 2.0 l	9.53	-0.118	0	0	0	0	0.0000062	179	0	0	1.62	
	> 2.0 l	9.71	-0.243	0.0018	0	0	0	0	244	0	0	1.62	
ECE 15.04	< 1.4 l	13.6	-0.169	0	0	0	0	0.00000926	158	0	0	1	
	1.4 - 2.0 l	9.53	-0.118	0	0	0	0	0.0000062	179	0	0	1	
	> 2.0 l	9.71	-0.243	0.0018	0	0	0	0	244	0	0	1	
Euro I	< 1.4 l	4.23	-0.0867					0.00000801		360		1	
	1.4 - 2.0 l	0.612						0.00000184		980	-2383	1	
	> 2.0 l	0.0423		0.000145					112			1	
Euro II	< 1.4 l	0.385	-0.0007						44.2			1	
	1.4 - 2.0 l	0.51							8.01			1	
	> 2.0 l	-0.241	0.00166						12.8			1	
Euro III	< 1.4 l	0.385	-0.0007						44.2			0.9	
	1.4 - 2.0 l	0.51							8.01			0.9	
	> 2.0 l	-0.241	0.00166						12.8			0.9	
Euro IV	< 1.4 l	0.385	-0.0007						44.2			0.6	
	1.4 - 2.0 l	0.51							8.01			0.6	
	> 2.0 l	-0.241	0.00166						12.8			0.6	
Diesel cars													
Pre-Euro I	< 2.0 l	0.478	-0.0068	0.000045	0	0	0	0	16.9	0	0	1	5 - 130
	> 2.0 l	0.599	-0.0056	0.000026	0	0	0	0	12	0	0	1	
Euro I	< 2.0 l	0.499	-0.0098	0.000065						200	-777	1	
	> 2.0 l	0.0373		-0.000034				3.16e-07	8.82			1	
Euro II	< 2.0 l	0.632	-0.0135	0.000075					2.38			1	
	> 2.0 l	0.624	-0.0128	0.0000697					0.139			1	
Euro III	< 2.0 l	0.632	-0.0135	0.000075					2.38			0.6	
	> 2.0 l	0.624	-0.0128	0.0000697					0.139			0.6	
Euro IV	< 2.0 l	0.632	-0.0135	0.000075					2.38			0.6	
	> 2.0 l	0.624	-0.0128	0.0000697					0.139			0.6	
Petrol LGV													
Pre-Euro I		20.52	-0.141	-0.005328	0	0	0	0.0000674	143.2	77.4	0	1	5 - 130
Euro I		-0.447						9.29e-07	140			1	
Euro II		0.51							8.01			1	
Euro III		0.51							8.01			0.9	
Euro IV		0.51							8.01			0.6	

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Legislation class	Engine size or vehicle configuration	Coefficients											Valid speed range (km/h)
		a	b	c	d	e	f	g	h	i	j	x	
Diesel LGV													
Pre-Euro I		1.642	-0.0191	0.000005	0	0	0	0.0000012	4.312	0	0	1	5 - 130
Euro I		-1.49	0.0181						52.5	-140		1	
Euro II		-1.49	0.0181						52.5	-140		1	
Euro III		-1.49	0.0181						52.5	-140		0.6	
Euro IV		-1.49	0.0181						52.5	-140		0.6	
HGV													
Pre-1988 models	rigid	1.61	0	0	0	0	0	0	26.2	686	-2514	1.30	5 - 100
	artic	0.93	0	0.000078	0	0	0	0	81.1	0	-161	1.31	
1988 - 1993 models	rigid	1.61	0	0	0	0	0	0.00e+00	26.2	686	-2514	1	
	artic	0.93	0	0.000078	0	0	0	0	81.1	0	-161	1	
Euro I	rigid	0.66		0.0000214					28.6	171	-671	1	
	artic	1.84		0.00006					80.2	479	-1882	1	
Euro II	rigid	0.74							12	314	-1150	1	
	artic	1.98							32.2	844	-3092	1	
Euro III	rigid	0.74							12	314	-1150	0.7	
	artic	1.98							32.2	844	-3092	0.7	
Euro IV	rigid	0.74							12	314	-1150	0.51	
	artic	1.98							32.2	844	-3092	0.51	
Euro IV+ (2008)	rigid	0.74							12	314	-1150	0.51	
	artic	1.98							32.2	844	-3092	0.51	
Buses													
Pre-1988 models		0.28	0	0	0	0	0	0.00000294	137	0	0	2.25	5 - 60
1988 - 1993 models		0.28	0	0.00e+00	0	0	0	0.00000294	137	0	0	1	
Euro I		0.612		0.00002					26.7	160	-627	1	
Euro II		0.691							11.2	294	-1079	1	
Euro III		0.691							11.2	294	-1079	0.7	
Euro IV		0.691							11.2	294	-1079	0.51	
Euro IV+ (2008)		0.691							11.2	294	-1079	0.51	
Motorcycles													
Pre-2000	moped (2-stroke)	6.48	0.404	0				0	0	0	0	1	20 - 30
	<250 cc 2-stroke	20.7	0.0719	0				0	-17.6	0	0	1	5 - 130
	<250 cc 4-stroke	2.05	0	0.00285				0	770	-2360	0	1	
	250-750 cc 4-stroke	9.29	0	0.00113				0	490	-1436	0	1	
	>750 cc 4-stroke	4.97	0	0.0015				0	414	-1196	0	1	
97/24/EC	moped (2-stroke)	6.48	0.404	0				0	0	0	0	0.10	20 - 30
	<250 cc 2-stroke	20.7	0.0719	0				0	-17.6	0	0	0.52	5 - 130
	<250 cc 4-stroke	2.05	0	0.00285				0	770	-2360	0	0.29	
	250-750 cc 4-stroke	9.29	0	0.00113				0	490	-1436	0	0.31	
	>750 cc 4-stroke	4.97	0	0.0015				0	414	-1196	0	0.43	

Table A2.2 Total oxides of nitrogen

Legislation class	Engine size or vehicle configuration	Coefficients											Valid speed range (km/h)
		a	b	c	d	e	f	g	h	i	j	x	
Petrol car													
Pre- ECE	< 1.4 l	1.173	0.0225	-0.00014	0	0	0	0	0	0	0	1	5 - 130
	1.4 - 2.0 l	1.36	0.0217	-0.00004	0	0	0	0	0	0	0	1	
	> 2.0 l	1.5	0.03	0.0001	0	0	0	0	0	0	0	1	
ECE 15.00	< 1.4 l	1.173	0.0225	-0.00014	0	0	0	0	0	0	0	1	
	1.4 - 2.0 l	1.36	0.0217	-0.00004	0	0	0	0	0	0	0	1	
	> 2.0 l	1.5	0.03	0.0001	0	0	0	0	0	0	0	1	
ECE 15.01	< 1.4 l	1.173	0.0225	-0.00014	0	0	0	0	0	0	0	1	
	1.4 - 2.0 l	1.36	0.0217	-0.00004	0	0	0	0	0	0	0	1	
	> 2.0 l	1.5	0.03	0.0001	0	0	0	0	0	0	0	1	
ECE 15.02	< 1.4 l	1.479	-0.0037	0.00018	0	0	0	0	0	0	0	1	
	1.4 - 2.0 l	1.663	-0.0038	0.0002	0	0	0	0	0	0	0	1	
	> 2.0 l	1.87	-0.0039	0.00022	0	0	0	0	0	0	0	1	
ECE 15.03	< 1.4 l	1.616	-0.0084	0.00025	0	0	0	0	0	0	0	1	
	1.4 - 2.0 l	E.F. = 1.29.exp(.0099*v)										1	
	> 2.0 l	2.784	-0.0112	0.000294	0	0	0	0	0	0	0	1	
ECE 15.04	< 1.4 l	1.12	0.001	0.000145	0	0	0	-1.57e-07	0	0	0	1	
	1.4 - 2.0 l	1.35	0.00433	0.000137	0	0	0	0	0	0	0	1	
	> 2.0 l	1.91	0	0.000089	0	0	0	5.95e-07	0	0	0	1	
Euro I	< 1.4 l	0.161						4.11e-07	2.82			1	
	1.4 - 2.0 l	-0.375	0.008						12.5	-51.5	81.1	1	
	> 2.0 l	0.389		-0.000092				9.2e-07			70	1	
Euro II	< 1.4 l	0.25	-0.00283					1.72e-07	0.182			1	
	1.4 - 2.0 l	0.302						1.99e-07				1	
	> 2.0 l	0.265	-0.0028					3.53e-07				1	
Euro III	< 1.4 l	0.25	-0.00283					1.72e-07	0.182			0.6	
	1.4 - 2.0 l	0.302						1.99e-07				0.6	
	> 2.0 l	0.265	-0.0028					3.53e-07				0.6	
Euro IV	< 1.4 l	0.25	-0.00283					1.72e-07	0.182			0.32	
	1.4 - 2.0 l	0.302						1.99e-07				0.32	
	> 2.0 l	0.265	-0.0028					3.53e-07				0.32	
Diesel car													
Pre-Euro I	< 2.0 l	0.88	-0.0115	0.000086	0	0	0	0	1.67	0	0	1	5 - 130
	> 2.0 l	0.638	0	0	0	0	0	2.04e-07	6.02	-10.6	0	1	
Euro I	< 2.0 l	0.514		-0.000064				7.07e-07		119	-408	1	
	> 2.0 l	-0.378						4.98e-07	47	-327	790	1	
Euro II	< 2.0 l	0.844	-0.00884					7.08e-07				1	
	> 2.0 l	0.358						2.51e-07	11.5			1	
Euro III	< 2.0 l	0.844	-0.00884					7.08e-07				1	
	> 2.0 l	0.358						2.51e-07	11.5			1	
Euro IV	< 2.0 l	0.844	-0.00884					7.08e-07				0.5	
	> 2.0 l	0.358						2.51e-07	11.5			0.5	
Petrol LGV													
Pre-Euro I		1.596	-0.00672	0.000124	0	0	0	0	0	0	0	1	5 - 130
Euro I		0.414		-0.000054				5.77e-07	0	0	0	1	
Euro II		0.302						1.99e-07				1	
Euro III		0.302						1.99e-07				0.6	
Euro IV		0.302						1.99e-07				0.33	

Legislation class	Engine size or vehicle configuration	Coefficients a	b	c	d	e	f	g	h	i	j	x	Valid speed range (km/h)
Diesel LGV													
Pre-Euro I		0.9552		-3.16e-05				6.24e-07	15.692		-27.52	1	5 - 130
Euro I		1.31		-0.00025		0	0	2.32e-06	0	0	0	1	
Euro II		1.31		-0.00025		0	0	2.32e-06	0	0	0	0.95	
Euro III		1.31		-0.00025		0	0	2.32e-06	0	0	0	0.71	
Euro IV		1.31		-0.00025		0	0	2.32e-06	0	0	0	0.37	
HGV													
Pre-1988 models	rigid	13.5	0	0	0	0	0	0	0	0	0	1	5 - 100
	artic	20.7	0	0	0	0	0	0	0	0	0	1	
1988 - 1993 models	rigid	4.34	-0.0464	0	0	0	0	5.64e-06	133	-107	0	1	
	artic	6.86	0	0	0	0	0	0	441	-1118	639	1	
Euro I	rigid	4.4	0	0				1.87e-06	126	0	-805	1	
	artic	11.7	0	0				4.99e-06	334	0	-2141	1	
Euro II	rigid	4.66	-0.0303	0.000356				0.00e+00	106	-178	0	1	
	artic	10	-0.0651	0.000764				0.00e+00	227	-381	0	1	
Euro III	rigid	4.66	-0.0303	0.000356				0.00e+00	106	-178	0	0.69	
	artic	10	-0.0651	0.000764				0.00e+00	227	-381	0	0.69	
Euro IV	rigid	4.66	-0.0303	0.000356				0.00e+00	106	-178	0	0.49	
	artic	10	-0.0651	0.000764				0.00e+00	227	-381	0	0.49	
Euro IV+ (2008)	rigid	4.66	-0.0303	0.000356				0.00e+00	106	-178	0	0.28	
	artic	10	-0.0651	0.000764				0.00e+00	227	-381	0	0.28	
Buses													
Pre-1988 models		0	0	0	23.9196	-0.128837	0	0	0	0	0	1	5 - 60
1988 - 1993 models		17.1	-0.323	2.21e-03	0	0	0	0	0	277	0	1	
Euro I		3.96	0	0				1.69e-06	113	0	-725	1	
Euro II		4.46	-0.0291	0.000341				0	101	-170	0	1	
Euro III		4.46	-0.0291	0.000341				0	101	-170	0	0.69	
Euro IV		4.46	-0.0291	0.000341				0	101	-170	0	0.49	
Euro IV+ (2008)		4.46	-0.0291	0.000341				0	101	-170	0	0.28	
Motorcycles													
Pre-2000	moped (2-stroke)	0.03	0	0				0	0	0	0	1	20 - 30
	<250 cc 2-stroke	0.0151	0	9.24e-06				0	0	0	0	1	5 - 130
	<250 cc 4-stroke	0.055	0.00226	0				-5.89e-08	0	0	0	1	
	250-750 cc 4-stroke	0.096	0	0				2.58e-07	0	0	0	1	
	>750 cc 4-stroke	0.16	0	0.000022				0	0.738	0	0	1	
97/24/EC	moped (2-stroke)	0.03	0	0				0	0	0	0	0.33	20 - 30
	<250 cc 2-stroke	0.0151	0	9.24e-06				0	0	0	0	0.78	5 - 130
	<250 cc 4-stroke	0.055	0.00226	0				-5.89e-08	0	0	0	1.43	
	250-750 cc 4-stroke	0.096	0	0				2.58e-07	0	0	0	1.37	
	>750 cc 4-stroke	0.16	0	0.000022				0	0.738	0	0	1.26	

Table A2.3 Particulate matter

Legislation class	Engine size or vehicle configuration	Coefficients											Valid speed range (km/h)
		a	b	c	d	e	f	g	h	i	j	x	
Petrol car													
Pre-Euro I	< 1.4 l	0.0324	-0.00040	0	0	0	0	2.21e-08	0.377	0	0	1	5 - 130
	1.4 - 2.0 l	0.0227	-0.00028	0	0	0	0	1.48e-08	0.427	0	0	1	
	> 2.0 l	0.0232	-0.00058	4.29e-06	0	0	0	0	0.582	0	0	1	
Euro I	< 1.4 l	0.00244		-8.53e-07				8.72e-09	0.00795			1	
	1.4 - 2.0 l	0.00307						8.35e-09				1	
	> 2.0 l	0.00672		-1.54e-06				1.52e-08				1	
Euro II	< 1.4 l	0.00356	-0.00013	1.38e-06								1	
	1.4 - 2.0 l	0.0024	-0.000046					5.59e-09				1	
	> 2.0 l	0.0024		-1.64e-06				1.73e-08				1	
Euro III	< 1.4 l	0.00356	-0.00013	1.38e-06								1	
	1.4 - 2.0 l	0.0024	-0.000046					5.59e-09				1	
	> 2.0 l	0.0024		-1.64e-06				1.73e-08				1	
Euro IV	< 1.4 l	0.00356	-0.00013	1.38e-06								1	
	1.4 - 2.0 l	0.0024	-0.000046					5.59e-09				1	
	> 2.0 l	0.0024		-1.64e-06				1.73e-08				1	
Diesel car													
Pre-Euro I	< 2.0 l	0.131	0	-0.000014	0	0	0	1.54e-07	2.16	0	0	1	5 - 130
	> 2.0 l	0.282	-0.00399	0.000026	0	0	0	2.53e-08	1.32	0	0	1	
Euro I	< 2.0 l	0.189	-0.00176					8.93e-08	-3.84	60.4	-191	1	
	> 2.0 l	0.0857	-0.000901					7.56e-08	1.02		-4.5	1	
Euro II	< 2.0 l	0.0722		-0.000018				1.51e-07				1	
	> 2.0 l	0.113		-2.24e-05				2e-07			30.4	1	
Euro III	< 2.0 l	0.0722		-0.000018				1.51e-07				0.7	
	> 2.0 l	0.113		-2.24e-05				2e-07			30.4	0.7	
Euro IV	< 2.0 l	0.0722		-0.000018				1.51e-07				0.35	
	> 2.0 l	0.113		-2.24e-05				2e-07			30.4	0.35	
Petrol LGV													
Pre-Euro I		0.03472		-1.46e-05				1.56e-07	0.39335			1	5 - 130
Euro I		0.00307	0	0	0	0	0	8.35e-09	0	0	0	1	
Euro II		0.0024	-0.000046	0	0	0	0	5.59e-09	0	0	0	1	
Euro III		0.0024	-0.000046	0	0	0	0	5.59e-09	0	0	0	1	
Euro IV		0.0024	-0.000046	0	0	0	0	5.59e-09	0	0	0	1	
Diesel LGV													
Pre-Euro I		0.553	-0.006604	0.00002				2.54e-07	-0.526	13.36		1	5 - 130
Euro I		0.127		-0.000038				4.15e-07	0	0	0	1	
Euro II		0.127		-0.000038				4.15e-07	0	0	0	1	
Euro III		0.127		-0.000038				4.15e-07	0	0	0	0.8	
Euro IV		0.127		-0.000038				4.15e-07	0	0	0	0.49	
HGV													
Pre-1988 models	rigid	0.174	0	0	0	0	0	1e-07	14.4	0	0	2.09	5 - 100
	artic	0.283	0	0	0	0	0	0	20.9	-12.8	0	1.14	
1988 - 1993 models	rigid	0.174	0	0	0	0	0	1.00e-07	14.4	0	0	1	
	artic	0.283	0	0	0	0	0	0	20.9	-12.8	0	1	
Euro I	rigid	0.0896	0	0				5.16e-08	7.43	0	0	1	
	artic	0.236	0	0				1.36e-07	19.5	0	0	1	
Euro II	rigid	0.111	-0.00145	1.26e-05				0	4.05	-6.7	0	1	
	artic	0.288	-0.00379	0.000033				0	10.6	-17.5	0	1	

Legislation class	Engine size or vehicle configuration	a	b	c	d	e	f	g	h	i	j	x	Valid speed range (km/h)
		Coefficients											
Euro III	rigid	0.111	-0.00145	1.26e-05				0	4.05	-6.7	0	0.72	
	artic	0.288	-0.00379	0.000033				0	10.6	-17.5	0	0.72	
Euro IV	rigid	0.111	-0.00145	1.26e-05				0	4.05	-6.7	0	0.15	
	artic	0.288	-0.00379	0.000033				0	10.6	-17.5	0	0.15	
Euro IV+ (2008)	rigid	0.111	-0.00145	1.26e-05				0	4.05	-6.7	0	0.15	
	artic	0.288	-0.00379	0.000033				0	10.6	-17.5	0	0.15	
Buses													
Pre-1988 models		0.128	0	0	0	0	0	0	14.4	0	0	2.31	5 - 60
1988 - 1993 models		0.128	0	0	0	0	0	0	14.4	0	0	1	
Euro I		0.0843	0	0				4.85e-08	6.98	0	0	1	
Euro II		0.104	-0.00137	0.000012				0	3.81	-6.3	0	1	
Euro III		0.104	-0.00137	0.000012				0	3.81	-6.3	0	0.72	
Euro IV		0.104	-0.00137	0.000012				0	3.81	-6.3	0	0.15	
Euro IV+ (2008)		0.104	-0.00137	0.000012				0	3.81	-6.3	0	0.15	
Motorcycles													
Pre-2000	moped (2-stroke)	0.04	0	0	0	0	0	0	0	0	0	1	20 - 30
	<250 cc 2-stroke	0.04	0	0	0	0	0	0	0	0	0	1	5 - 130
	<250cc 4-stroke	0.12	0	0	0	0	0	0	0	0	0	1	
	250-750 cc 4-stroke	0.12	0	0	0	0	0	0	0	0	0	1	
	>750 cc 4-stroke	0.12	0	0	0	0	0	0	0	0	0	1	
97/24/EC	moped (2-stroke)	0.04	0	0	0	0	0	0	0	0	0	1	20 - 30
	<250 cc 2-stroke	0.04	0	0	0	0	0	0	0	0	0	1	5 - 130
	<250 cc 4-stroke	0.12	0	0	0	0	0	0	0	0	0	1	
	250-750 cc 4-stroke	0.12	0	0	0	0	0	0	0	0	0	1	
	>750 cc 4-stroke	0.12	0	0	0	0	0	0	0	0	0	1	

Table A2.4 Hydrocarbons

Legislation class	Engine size or vehicle configuration	Coefficients											Valid speed range (km/h)
		a	b	c	d	e	f	g	h	i	j	x	
Petrol car													
Pre- ECE	< 1.4 l	1.85	-0.0197	0	0	0	0	6.8e-07	18.5	0	0	1.58	5 - 130
	1.4 - 2.0 l	2.13	-0.0317	0.00017	0	0	0	0	16.7	0	0	1.58	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.4e-07	25.8	0	0	1.58	
ECE 15.00	< 1.4 l	1.85	-0.0197	0	0	0	0	6.8e-07	18.5	0	0	1.23	
	1.4 - 2.0 l	2.13	-0.0317	0.00017	0	0	0	0	16.7	0	0	1.23	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.4e-07	25.8	0	0	1.23	
ECE 15.01	< 1.4 l	1.85	-0.0197	0	0	0	0	6.8e-07	18.5	0	0	1.23	
	1.4 - 2.0 l	2.13	-0.0317	0.00017	0	0	0	0	16.7	0	0	1.23	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.4e-07	25.8	0	0	1.23	
ECE 15.02	< 1.4 l	1.85	-0.0197	0	0	0	0	6.8e-07	18.5	0	0	1.25	
	1.4 - 2.0 l	2.13	-0.0317	0.00017	0	0	0	0	16.7	0	0	1.25	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.4e-07	25.8	0	0	1.25	
ECE 15.03	< 1.4 l	1.85	-0.0197	0	0	0	0	6.8e-07	18.5	0	0	1.25	
	1.4 - 2.0 l	2.13	-0.0317	0.00017	0	0	0	0	16.7	0	0	1.25	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.4e-07	25.8	0	0	1.25	
ECE 15.04	< 1.4 l	1.85	-0.0197	0	0	0	0	6.8e-07	18.5	0	0	1	
	1.4 - 2.0 l	2.13	-0.0317	0.00017	0	0	0	0	16.7	0	0	1	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.4e-07	25.8	0	0	1	
Euro I	< 1.4 l	-0.52	0.00492						18.7	-92.3	186	1	
	1.4 - 2.0 l	0.14	-0.0054	4.7e-05					3.47			1	
	> 2.0 l	-0.0487	0.00076						7.16		-42	1	
Euro II	< 1.4 l	0.185	-0.0033	1.9e-05								1	
	1.4 - 2.0 l	0.0501								12.1		1	
	> 2.0 l	-0.0017	-2e-05						1.2			1	
Euro III	< 1.4 l	0.185	-0.0033	1.9e-05								0.7	
	1.4 - 2.0 l	0.0501								12.1		0.7	
	> 2.0 l	-0.0017	-2e-05						1.2			0.7	
Euro IV	< 1.4 l	0.185	-0.0033	1.9e-05								0.53	
	1.4 - 2.0 l	0.0501								12.1		0.53	
	> 2.0 l	-0.0017	-2e-05						1.2			0.53	
Diesel car													
Pre-Euro I	< 2.0 l	0.00641	0	0	0	0	0	0	6.23	-3.88	0	1	5 - 130
	> 2.0 l	0.104	-0.0019	0.00001	0	0	0	0	4.12	-8.01	0	1	
Euro I	< 2.0 l	0.0157							2.64			1	
	> 2.0 l	0.139	-0.0023					1.1e-07	0.663			1	
Euro II	< 2.0 l	0.0784	-0.0012					4.6e-08	1.04			1	
	> 2.0 l	0.0473	-0.0003						2.06			1	
Euro III	< 2.0 l	0.0784	-0.0012					4.6e-08	1.04			0.7	
	> 2.0 l	0.0473	-0.0003						2.06			0.7	
Euro IV	< 2.0 l	0.0784	-0.0012					4.6e-08	1.04			0.64	
	> 2.0 l	0.0473	-0.0003						2.06			0.64	
Petrol LDV													
Pre-Euro I		2.624	-0.0477	0.00023	0	0	0	3.4e-07	18.44	8.1	0	1	5 - 130
Euro I		0.0626							1.41			1	
Euro II		0.0501								12.1		1	
Euro III		0.0501								12.1		0.7	
Euro IV		0.0501								12.1		0.53	

Legislation class	Engine size or vehicle configuration	Coefficients											Valid speed range (km/h)
		a	b	c	d	e	f	g	h	i	j	x	
Diesel LDV													
Pre-Euro I		0.602	-0.00878	1.9e-05	0	0	0	2.2e-07	0.0678	11.44	-36.24	1	5 - 130
Euro I		0.071							2.36			1	
Euro II		0.071							2.36			1	
Euro III		0.071							2.36			0.78	
Euro IV		0.071							2.36			0.41	
HGV													
Pre-1988 models	rigid	0.756	0	2.7e-05	0	0	0	0	33.3	381	-1416	2.01	5 - 100
	artic	0.259	0	0	0	0	0	-6e-08	56.7	-9.01	0	2.52	
1988 - 1993 models	rigid	0.756	0	2.7e-05	0	0	0	0.00e+00	33.3	381	-1416	1	
	artic	0.259	0	0	0	0	0	-6e-08	56.7	-9.01	0	1	
Euro I	rigid	0.284	1e-05						12.5	143	-532	1	
	artic	0.736	2.6e-05						32.5	371	-1379	1	
Euro II	rigid	0.0366	0.002						16.8		-118	1	
	artic	0.0984	0.0054						45.5		-320	1	
Euro III	rigid	0.0366	0.002						16.8		-118	0.7	
	artic	0.0984	0.0054						45.5		-320	0.7	
Euro IV	rigid	0.0366	0.002						16.8		-118	0.49	
	artic	0.0984	0.0054						45.5		-320	0.49	
Euro IV+ (2008)	rigid	0.0366	0.002						16.8		-118	0.49	
	artic	0.0984	0.0054						45.5		-320	0.49	
Buses													
Pre-1998 models		0.448	0	0	0	0	0	0	0	430	-1093	4.13	5 - 60
1988 - 1993 models		0.448	0	0	0	0	0	0	0	430	-1093	1	
Euro I		0.267	9.6e-06						11.8	135	-501	1	
Euro II		0.0341	0.00187						15.8		-111	1	
Euro III		0.0341	0.00187						15.8		-111	0.7	
Euro IV		0.0341	0.00187						15.8		-111	0.49	
Euro IV+ (2008)		0.0341	0.00187						15.8		-111	0.49	
Motorcycles													
Pre-2000	moped (2-stroke)	3.81	0.198	0				0	0	0	0	1	20 - 30
	<250 cc 2-stroke	5.78	0	0				7.7e-07	168	-436	0	1	5 - 130
	<250 cc 4-stroke	0.0844	0	0				6.8e-07	63.3	0	-657	1	
	250-750 cc 4-stroke	0.131	0	0				3.4e-07	55	0	-517	1	
	>750cc 4-stroke	0.466	0	0					90.1	0	-1064	1	
97/24/EC	moped (2-stroke)	3.81	0.198	0				0	0	0	0	0.22	20 - 30
	<250 cc 2-stroke	5.78	0	0				7.7e-07	168	-436	0	0.69	5 - 130
	<250 cc 4-stroke	0.0844	0	0				6.8e-07	63.3	0	-657	0.49	
	250-750 cc 4-stroke	0.131	0	0				3.4e-07	55	0	-517	0.55	
	>750 cc 4-stroke	0.466	0	0					90.1	0	-1064	0.29	

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Table A2.5 Benzene

Legislation class	Engine size or vehicle configuration	Coefficients											Valid speed range (km/h)
		a	b	c	d	e	f	g	h	i	j	x	
Petrol car													
Pre-ECE	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.1026	5 - 130
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.1026	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.1026	
ECE 15.00	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0804	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0804	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0804	
ECE 15.01	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0804	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0804	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0804	
ECE 15.02	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0811	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0811	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0811	
ECE 15.03	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0811	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0811	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0811	
ECE 15.04	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0651	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0651	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0651	
Euro I	< 1.4 l	-0.52	0.00492						18.7	-92.3	186	0.0401	
	1.4 - 2.0 l	0.14	-0.00541	0.000047					3.47			0.0401	
	> 2.0 l	-0.0487	0.000762						7.16		-42	0.0401	
Euro II	< 1.4 l	0.185	-0.00331	1.89e-05								0.0401	
	1.4 - 2.0 l	0.0501								12.1		0.0401	
	> 2.0 l	-0.00167	-1.57e-05						1.2			0.0401	
Euro III	< 1.4 l	0.185	-0.00331	1.89e-05								0.0281	
	1.4 - 2.0 l	0.0501								12.1		0.0281	
	> 2.0 l	-0.00167	-1.57e-05						1.2			0.0281	
Euro IV	< 1.4 l	0.185	-0.00331	1.89e-05								0.0213	
	1.4 - 2.0 l	0.0501								12.1		0.0213	
	> 2.0 l	-0.00167	-1.57e-05						1.2			0.0213	
Diesel car													
Pre-Euro I	< 2.0 l	0.00641	0	0	0	0	0	0	6.23	-3.88	0	0.0171	5 - 130
	> 2.0 l	0.104	-0.00193	0.00001	0	0	0	0	4.12	-8.01	0	0.0171	
Euro I	< 2.0 l	0.0157							2.64			0.0171	
	> 2.0 l	0.139	-0.00234					1.1e-07	0.663			0.0171	
Euro II	< 2.0 l	0.0784	-0.00115					4.62e-08	1.04			0.0171	
	> 2.0 l	0.0473	-0.00027						2.06			0.0171	
Euro III	< 2.0 l	0.0784	-0.00115					4.62e-08	1.04			0.0119	
	> 2.0 l	0.0473	-0.00027						2.06			0.0119	
Euro IV	< 2.0 l	0.0784	-0.00115					4.62e-08	1.04			0.0109	
	> 2.0 l	0.0473	-0.00027						2.06			0.0109	
Petrol LGV													
Pre-Euro I		2.624	-0.0477	0.000234	0	0	0	3.42e-07	18.44	8.1	0	0.0639	5 - 130
Euro I		0.0626							1.41			0.0380	
Euro II		0.0501								12.1		0.0380	
Euro III		0.0501								12.1		0.0266	
Euro IV		0.0501								12.1		0.0202	

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Legislation class	Engine size or vehicle configuration	Coefficients a	b	c	d	e	f	g	h	i	j	x	Valid speed range (km/h)
Diesel LGV													
Pre-Euro I		0.602	-0.00878	1.88e-05	0	0	0	2.18e-07	0.0678	11.44	-36.24	0.0193	
Euro I		0.071							2.36			0.0193	
Euro II		0.071							2.36			0.0193	
Euro III		0.071							2.36			0.0150	
Euro IV		0.071							2.36			0.0079	
HGV													
Pre-1988 models	rigid	0.756	0	0.000027	0	0	0	0	33.3	381	-1416	0.0014	5 - 100
	artic	0.259	0	0	0	0	0	-5.57e-08	56.7	-9.01	0	0.0016	
1988 - 1993 models	rigid	0.756	0	0.000027	0	0	0	0.00e+00	33.3	381	-1416	0.0007	
	artic	0.259	0	0	0	0	0	-5.57e-08	56.7	-9.01	0	0.0006	
Euro I	rigid	0.284	1.02e-05						12.5	143	-532	0.0007	
	artic	0.736	0.000026						32.5	371	-1379	0.0006	
Euro II	rigid	0.0366	0.002						16.8		-118	0.0007	
	artic	0.0984	0.0054						45.5		-320	0.0006	
Euro III	rigid	0.0366	0.002						16.8		-118	0.0005	
	artic	0.0984	0.0054						45.5		-320	0.0004	
Euro IV	rigid	0.0366	0.002						16.8		-118	0.0003	
	artic	0.0984	0.0054						45.5		-320	0.0003	
Euro IV+ (2008)	rigid	0.0366	0.002						16.8		-118	0.0003	
	artic	0.0984	0.0054						45.5		-320	0.0003	
Buses													
Pre-1988 models		0.448	0	0	0	0	0	0	0	430	-1093	0.0026	5 - 60
1988 - 1993 models		0.448	0	0	0	0	0	0	0	430	-1093	0.0006	
Euro I		0.267	9.58e-06						11.8	135	-501	0.0006	
Euro II		0.0341	0.00187						15.8		-111	0.0006	
Euro III		0.0341	0.00187						15.8		-111	0.0004	
Euro IV		0.0341	0.00187						15.8		-111	0.0003	
Euro IV+ (2008)		0.0341	0.00187						15.8		-111	0.0003	
Motorcycles													
Pre-2000	moped (2-stroke)	3.81	0.198	0				0	0	0	0	0.0673	20 - 30
	<250 cc 2-stroke	5.78	0	0				7.69e-07	168	-436	0	0.0673	5 - 130
	<250 cc 4-stroke	0.0844	0	0				6.75e-07	63.3	0	-657	0.0673	
	250-750 cc 4-stroke	0.131	0	0				3.37e-07	55	0	-517	0.0673	
	>750 cc 4-stroke	0.466	0	0					90.1	0	-1064	0.0673	
97/24/EC	moped (2-stroke)	3.81	0.198	0				0	0	0	0	0.0148	20 - 30
	<250 cc 2-stroke	5.78	0	0				7.69e-07	168	-436	0	0.0466	5 - 130
	<250 cc 4-stroke	0.0844	0	0				6.75e-07	63.3	0	-657	0.0328	
	250-750 cc 4-stroke	0.131	0	0				3.37e-07	55	0	-517	0.0370	
	>750 cc 4-stroke	0.466	0	0					90.1	0	-1064	0.0199	

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Table A2.6 1,3-butadiene

Legislation class	Engine size or vehicle configuration	Coefficients a	b	c	d	e	f	g	h	i	j	x	Valid speed range (km/h)
Petrol car													
Pre-ECE	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0213	5 - 130
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0213	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0213	
ECE 15.00	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0167	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0167	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0167	
ECE 15.01	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0167	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0167	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0167	
ECE 15.02	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0169	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0169	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0169	
ECE 15.03	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0169	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0169	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0169	
ECE 15.04	< 1.4 l	1.85	-0.0197	0	0	0	0	6.77e-07	18.5	0	0	0.0135	
	1.4 - 2.0 l	2.13	-0.0317	0.000169	0	0	0	0	16.7	0	0	0.0135	
	> 2.0 l	1.22	-0.0108	0	0	0	0	3.42e-07	25.8	0	0	0.0135	
Euro I	< 1.4 l	-0.52	0.00492						18.7	-92.3	186	0.0065	
	1.4 - 2.0 l	0.14	-0.00541	0.000047					3.47			0.0065	
	> 2.0 l	-0.0487	0.000762						7.16		-42	0.0065	
Euro II	< 1.4 l	0.185	-0.00331	1.89e-05								0.0065	
	1.4 - 2.0 l	0.0501								12.1		0.0065	
	> 2.0 l	-0.00167	-1.57e-05						1.2			0.0065	
Euro III	< 1.4 l	0.185	-0.00331	1.89e-05								0.0046	
	1.4 - 2.0 l	0.0501								12.1		0.0046	
	> 2.0 l	-0.00167	-1.57e-05						1.2			0.0046	
Euro IV	< 1.4 l	0.185	-0.00331	1.89e-05								0.0035	
	1.4 - 2.0 l	0.0501								12.1		0.0035	
	> 2.0 l	-0.00167	-1.57e-05						1.2			0.0035	
Diesel car													
Pre-Euro I	< 2.0 l	0.00641	0	0	0	0	0	0	6.23	-3.88	0	0.0084	5 - 130
	> 2.0 l	0.104	-0.00193	0.00001	0	0	0	0	4.12	-8.01	0	0.0084	
Euro I	< 2.0 l	0.0157							2.64			0.0084	
	> 2.0 l	0.139	-0.00234					1.1e-07	0.663			0.0084	
Euro II	< 2.0 l	0.0784	-0.00115					4.62e-08	1.04			0.0084	
	> 2.0 l	0.0473	-0.00027						2.06			0.0084	
Euro III	< 2.0 l	0.0784	-0.00115					4.62e-08	1.04			0.0058	
	> 2.0 l	0.0473	-0.00027						2.06			0.0058	
Euro IV	< 2.0 l	0.0784	-0.00115					4.62e-08	1.04			0.0053	
	> 2.0 l	0.0473	-0.00027						2.06			0.0053	
Petrol LGV													
Pre-Euro I		2.624	-0.0477	0.000234	0	0	0	3.42e-07	18.44	8.1	0	0.0133	5 - 130
Euro I		0.0626							1.41			0.0062	
Euro II		0.0501								12.1		0.0062	
Euro III		0.0501								12.1		0.0043	
Euro IV		0.0501								12.1		0.0033	

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Legislation class	Engine size or vehicle configuration	Coefficients a	b	c	d	e	f	g	h	i	j	x	Valid speed range (km/h)
Diesel LGV													
Pre-Euro I		0.602	-0.00878	1.88e-05	0	0	0	2.18e-07	0.0678	11.44	-36.24	0.0094	5 - 130
Euro I		0.071							2.36			0.0094	
Euro II		0.071							2.36			0.0094	
Euro III		0.071							2.36			0.0074	
Euro IV		0.071							2.36			0.0039	
HGV													
Pre-1988 models	rigid	0.756	0	0.000027	0	0	0	0	33.3	381	-1416	0.0637	5 - 100
	artic	0.259	0	0	0	0	0	-5.57e-08	56.7	-9.01	0	0.0761	
1988 - 1993 models	rigid	0.756	0	0.000027	0	0	0	0.00e+00	33.3	381	-1416	0.0317	
	artic	0.259	0	0	0	0	0	-5.57e-08	56.7	-9.01	0	0.0302	
Euro I	rigid	0.284	1.02e-05						12.5	143	-532	0.0317	
	artic	0.736	0.000026						32.5	371	-1379	0.0302	
Euro II	rigid	0.0366	0.002						16.8		-118	0.0317	
	artic	0.0984	0.0054						45.5		-320	0.0302	
Euro III	rigid	0.0366	0.002						16.8		-118	0.0222	
	artic	0.0984	0.0054						45.5		-320	0.0212	
Euro IV	rigid	0.0366	0.002						16.8		-118	0.0155	
	artic	0.0984	0.0054						45.5		-320	0.0148	
Euro IV+ (2008)	rigid	0.0366	0.002						16.8		-118	0.0155	
	artic	0.0984	0.0054						45.5		-320	0.0148	
Buses													
Pre-1988 models		0.448	0	0	0	0	0	0	0	430	-1093	0.1209	5 - 60
1988 - 1993 models		0.448	0	0	0	0	0	0	0	430	-1093	0.0293	
Euro I		0.267	9.58e-06						11.8	135	-501	0.0293	
Euro II		0.0341	0.00187						15.8		-111	0.0293	
Euro III		0.0341	0.00187						15.8		-111	0.0205	
Euro IV		0.0341	0.00187						15.8		-111	0.0143	
Euro IV+ (2008)		0.0341	0.00187						15.8		-111	0.0143	
Motorcycles													
Pre-2000	moped (2-stroke)	3.81	0.198	0				0	0	0	0	0.0140	20 - 30
	<250 cc 2-stroke	5.78	0	0				7.69e-07	168	-436	0	0.0140	5 - 130
	<250 cc 4-stroke	0.0844	0	0				6.75e-07	63.3	0	-657	0.0140	
	250-750 cc 4-stroke	0.131	0	0				3.37e-07	55	0	-517	0.0140	
	>750 cc 4-stroke	0.466	0	0					90.1	0	-1064	0.0140	
97/24/EC	moped (2-stroke)	3.81	0.198	0				0	0	0	0	0.0031	20 -30
	<250 cc 2-stroke	5.78	0	0				7.69e-07	168	-436	0	0.0097	5 - 130
	<250 cc 4-stroke	0.0844	0	0				6.75e-07	63.3	0	-657	0.0068	
	250-750 cc 4-stroke	0.131	0	0				3.37e-07	55	0	-517	0.0077	
	>750 cc 4-stroke	0.466	0	0					90.1	0	-1064	0.0041	

Table A2.7 Carbon dioxide

Legislation class	Engine size or vehicle configuration	Coefficients											Valid speed range (km/h)
		a	b	c	d	e	f	g	h	i	j	x	
Petrol car													
Pre-ECE	< 1.4 l	68.19	-0.751	0.005				5.3E-06	98	6282	-19055	3.957	5 - 130
	1.4 - 2.0 l	53.70	-0.572	0.004				3.1E-06	901	0	0	3.899	
	> 2.0 l	75.46	-1.059	0.008				3.5E-07	1215	0	0	3.971	
ECE 15.00	< 1.4 l	68.19	-0.751	0.005				5.34E-06	98	6282	-19055	3.495	
	1.4 - 2.0 l	53.70	-0.572	0.004				3.12E-06	901	0	0	3.416	
	> 2.0 l	75.46	-1.059	0.008				3.46E-07	1215	0	0	3.138	
ECE 15.01	< 1.4 l	68.19	-0.751	0.005				5.34E-06	98	6282	-19055	3.495	
	1.4 - 2.0 l	53.70	-0.572	0.004				3.12E-06	901	0	0	3.416	
	> 2.0 l	75.46	-1.059	0.008				3.46E-07	1215	0	0	3.138	
ECE 15.02	< 1.4 l	68.19	-0.751	0.005				5.34E-06	98	6282	-19055	3.254	
	1.4 - 2.0 l	53.70	-0.572	0.004				3.12E-06	901	0	0	3.166	
	> 2.0 l	75.46	-1.059	0.008				3.46E-07	1215	0	0	3.278	
ECE 15.03	< 1.4 l	68.19	-0.751	0.005				5.34E-06	98	6282	-19055	3.254	
	1.4 - 2.0 l	53.70	-0.572	0.004				3.12E-06	901	0	0	3.166	
	> 2.0 l	75.46	-1.059	0.008				3.46E-07	1215	0	0	3.278	
ECE 15.04	< 1.4 l	68.19	-0.751	0.005				5.34E-06	98	6282	-19055	2.933	
	1.4 - 2.0 l	53.70	-0.572	0.004				3.12E-06	901	0	0	2.933	
	> 2.0 l	75.46	-1.059	0.008				3.46E-07	1215	0	0	2.933	
Euro I	< 1.4 l	54.40	-0.544	0.004				4.01E-06	400	87	7005	2.933	
	1.4 - 2.0 l	34.81	-0.005	0.000				1.3E-05	979	490	-1191	2.933	
	> 2.0 l	38.47	0.001	0.000				1.34E-05	1468	0	-42	2.933	
Euro II	< 1.4 l	29.33	-0.004	0.000				1.38E-05	542	0	0	2.933	
	1.4 - 2.0 l	36.25	0.000	0.000				1.32E-05	655	12.2	0	2.933	
	> 2.0 l	80.36	-1.049	0.008				2.02E-08	612	0	0	2.933	
Euro III	< 1.4 l	29.33	-0.004	0.000				1.38E-05	542	0	0	2.918	
	1.4 - 2.0 l	36.25	0.000	0.000				1.32E-05	655	12.2	0	2.918	
	> 2.0 l	80.36	-1.049	0.008				2.02E-08	612	0	0	2.918	
Euro IV	< 1.4 l	29.33	-0.004	0.000				1.38E-05	542	0	0	2.563	
	1.4 - 2.0 l	36.25	0.000	0.000				1.32E-05	655	12.2	0	2.563	
	> 2.0 l	80.36	-1.049	0.008				2.02E-08	612	0	0	2.563	
Diesel car													
Pre-Euro I	< 2.0 l	76.43	-1.063	7.04E-03				1.80E-07	253	-3.92	0	2.933	5 - 130
	> 2.0 l	86.94	-0.836	5.34E-05				4.46E-05	273	-8.10	0	2.933	
Euro I	< 2.0 l	60.93	-0.386	3.25E-05				2.68E-05	-1.81	5688	-19570	2.933	
	> 2.0 l	43.84	-0.00342	-8.77E-03				9.45E-05	962	0	-9421	2.933	
Euro II	< 2.0 l	43.74	-0.246	1.65E-05				2.73E-05	428	0	0	2.933	
	> 2.0 l	48.53	-0.0067	-5.72E-03				5.91E-05	612	0	35	2.933	
Euro III	< 2.0 l	43.74	-0.246	1.65E-05				2.73E-05	428	0	0	2.918	
	> 2.0 l	48.53	-0.0067	-5.72E-03				5.91E-05	612	0	35	2.918	
Euro IV	< 2.0 l	43.74	-0.246	1.65E-05				2.73E-05	428	0	0	2.563	
	> 2.0 l	48.53	-0.0067	-5.72E-03				5.91E-05	612	0	35	2.563	
Petrol LGV													
Pre-Euro I		90.8	-0.879	-0.00244				8.87E-05	229.1	2404	0	2.933	5 - 130
Euro I		103.5	-0.773	0				5.55E-05	71.4	4632	0	2.933	
Euro II		99.0	-0.736	0				5.24E-05	4.00	4422	0	2.933	
Euro III		99.0	-0.736	0				5.24E-05	4.00	4422	0	2.918	
Euro IV		99.0	-0.736	0				5.24E-05	4.00	4422	0	2.563	

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Legislation class	Engine size or vehicle configuration	Coefficients											Valid speed range (km/h)
		a	b	c	d	e	f	g	h	i	j	x	
Diesel LGV													
Pre-Euro I		81.22	-0.4766	4.48E-05				5.87E-05	483	-1264	2215	2.933	5 - 130
Euro I		79.96	0.0090	-0.0160				1.61E-04	535	-70.0	0	2.933	
Euro II		77.43	0.0090	-0.0155				1.56E-04	519	-70.0	0	2.933	
Euro III		77.43	0.0090	-0.0155				1.56E-04	519	-70.0	0	2.842	
Euro IV		77.43	0.0090	-0.0155				1.56E-04	519	-70.0	0	2.754	
HGV													
Pre-1988 models	rigid	128	0	-0.0223				3.10E-04	2884	1220	-4511	2.933	5 - 100
	artic	648	-7.16	5.11E-05				4.74E-04	225	12147	-105	2.933	
1988 - 1993 models	rigid	127	0	-0.0224				3.10E-04	2828	728	-2688	2.933	
	artic	647	-7.16	3.90E-05				4.74E-04	122	12163	-80.5	2.933	
Euro I	rigid	150	1.03E-05	1.07E-05				6.56E-05	2104	19467	-90259	2.933	
	artic	395	2.63E-05	3.00E-05				1.72E-04	5533	51194	-237418	1.907	
Euro II	rigid	210	0.000331	-0.0164				1.84E-04	27.7	30591	-117427	2.933	
	artic	491	0.00104	-0.0381				4.29E-04	74.4	71340	-274171	2.288	
Euro III	rigid	210	0.000331	-0.0164				1.84E-04	27.7	30591	-117427	2.933	
	artic	491	0.00104	-0.0381				4.29E-04	74.4	71340	-274171	2.288	
Euro IV	rigid	210	0.000331	-0.0164				1.84E-04	27.7	30591	-117427	2.933	
	artic	491	0.00104	-0.0381				4.29E-04	74.4	71340	-274171	2.288	
Euro IV+ (2008)	rigid	210	0.000331	-0.0164				1.84E-04	27.7	30591	-117427	2.933	
	artic	491	0.00104	-0.0381				4.29E-04	74.4	71340	-274171	2.288	
Buses													
Pre-1988 models		26.8	0	0				1.69E-04	6516	-9753	-4560	2.933	5 - 60
1988 - 1993 models		25.0	0	0				1.67E-04	6408	-11113	-1105	2.933	
Euro I		141.3	9.68E-06	1.00E-05				6.15E-05	1977	18283	-84801	2.933	
Euro II		200.3	2.93E-04	-0.0156				1.75E-04	26.0	29113	-111672	2.933	
Euro III		200.3	2.93E-04	-0.0156				1.75E-04	26.0	29113	-111672	2.933	
Euro IV		200.3	2.93E-04	-0.0156				1.75E-04	26.0	29113	-111672	2.933	
Euro IV+ (2008)													
Motorcycles													
Pre-2000	moped (2-stroke)	25										2.933	20 - 30
	<250 cc 2-stroke	45.80	-0.76	0.011				-4.55E-05	0	0	0	2.933	5 - 130
	<250 cc 4-stroke	70.78	-2.25	0.032				-1.31E-04	0	0	0	2.933	
	250-750 cc 4-stroke	102.10	-3.32	0.045				-1.86E-04	0	0	0	2.933	
	>750 cc 4-stroke	119.63	-3.63	0.048				-1.95E-04	0	0	0	2.933	
97/24/EC	moped (2-stroke)	25	0	0				0	0	0	0	1.291	20 -30
	<250 cc 2-stroke	18.01	0.19	-0.001				3.28E-06	0	0	0	2.933	5 - 130
	<250 cc 4-stroke	79.90	-2.46	0.034				-1.40E-04	0	0	0	2.933	
	250-750 cc 4-stroke	79.90	-2.46	0.034				-1.40E-04	0	0	0	2.933	
	>750 cc 4-stroke	79.90	-2.46	0.034				-1.40E-04	0	0	0	2.933	

ANNEX 3 DETAILED AIR QUALITY MODELLING

Introduction

A3.1 The DMRB Screening Method is not intended to provide an accurate forecast of air quality in the vicinity of a road. It was developed to indicate whether or not such forecasts were necessary, by determining approximate concentrations in a simple and relatively straightforward way. If possible exceedances are identified, the conclusion reached is that a more detailed study is necessary.

A3.2 One major difference between the Screening Method given and a more detailed study is that the latter should take into account special and unusual features of the scheme. That is not the case in the screening procedure, which is based largely on average statistics (concerning, for example, the composition of the traffic and the site dispersion characteristics) and is universally applicable. It is specifically the unusual aspects of a scheme that determine the size and nature of those differences between the air quality impacts it forecasts and those determined in a more accurate assessment. It is not possible, therefore, to give specific or comprehensive guidance on how the more accurate assessment should be done. The methodology and data used, and the factors that are taken into account should be based on the properties of each individual scheme. The intention of this Annex is to draw attention to some features of road traffic pollution that can be of significance in the planning of an air quality impact assessment. The details of the assessment itself need to be given careful attention by a specialist in air pollution, who is able to make the specific decisions needed in each individual case.

A3.3 There are two fundamental elements involved in the prediction of air pollution concentrations. It is necessary first to determine the sources of the pollution and the rates at which it is emitted, and secondly, to determine how it is dispersed and transformed in the atmosphere after its release.

Pollutant emissions

A3.4 A road network is a complex source of pollution. The emissions it produces vary significantly in space and time in response to a large number of factors. The accuracy with which emission estimates can be made depends on how many of those factors are taken into account and, importantly, on the extent and quality of available input information. A model that includes a large number of parameters can give a better representation of the processes leading to the emission of pollutants, but the potential for error and uncertainty in the model and its input data is increased.

A3.5 The most widely used approximations for estimating road traffic emissions are based on two parameters only: the type of vehicle and its average speed. In many cases, this is the only practical approach as data for a more complex evaluation are not available. However, in determining the methodology to use for a particular application, some attention should be given to the exact nature of the scheme and its likely consequences on vehicle emissions.

A3.6 Table A3.1 presents a list of factors that are known to affect emissions from road vehicles, together with comments on the nature of their effects and on situations in which they might be important. Before a decision is made on a method for estimating emission rates, it is useful to consider whether any features of the scheme in question suggest that the use of basic, speed related emission factors is inappropriate. The judgement must be based also on the practicality and likely increase in accuracy that might be derived from the inclusion of additional parameters. For example, the temperature of an engine has a large influence on emissions and the effects are reasonably well quantified, but it is rare that information on a scheme includes the engine temperature profile of the traffic. In many cases, the potential gain in accuracy through the use of engine temperature in the calculation of emission rates may be offset by the lack of realistic data on vehicle operating temperatures.

Other sources of emission

A3.7 It is likely in most cases that the most important source of emissions near to a scheme will be the traffic it carries. The resulting pollution concentrations will, however, be superimposed on the existing background and in some circumstances that can be an important contribution. In urban areas, background levels of pollution are often relatively high because of the many traffic and non-traffic sources found in towns and cities. In other areas there may be significant individual sources of pollution such as power stations and industrial premises. Where locally elevated levels of pollution exist, it is important that they be recognised in an assessment since they may combine with the scheme's traffic emissions to create a worse situation than indicated through consideration of the traffic alone.

A3.8 It is possible to treat contributions from other sources in two ways: their impact may be modelled, or based on pollution measurements. The choice of approach will depend on the details of the scheme and on the availability of data - either as input for a model evaluation, or air quality data.

A3.9 A few general comments may, however, be made:

The Department of the Environment, Food and Rural Affairs operates a nationwide network of air pollution monitoring stations. It may often be possible to obtain air quality data from a location with similar characteristics to that being studied.

In addition to these permanent monitoring exercises, many ad hoc pollution surveys are carried out (for example by Local Authorities). They too may provide useful information.

Where non-traffic sources of pollution are not expected to vary, a comparison between various scheme options can be carried out without reference to them. Relative impacts of the options will be properly evaluated even though forecast concentrations may be incorrect in absolute terms. Note that this is also true where a general change in background pollution is anticipated (owing, for example, to future reductions in vehicle emissions). Any widespread changes will take place independently of the scheme and will thus be applicable to all options.

Table A3.1 Factors that influence vehicle emission rates

	Factor
Vehicle type	Emissions from different types of vehicle vary significantly. There is often a mismatch between vehicle classes used in traffic observation and modelling and those used in emissions studies. The basic vehicle properties that are distinguishable in terms of emissions are the engine type, the type of emission control system, the weight, the engine capacity and the emission standard to which the vehicle was certified. Often, some of these are approximated by a vehicle's age, since that determines the level of technology to which it was built. The classes often used in traffic studies are based on more directly observable vehicle characteristics such as the body style (eg car, taxi, bus). Where there are no special features of a scheme that influence the traffic composition, it is often satisfactory to base emission factors on the composition of the UK vehicle fleet. There are many cases, though, where this will not be so: there are more buses and taxis than average in urban areas, lorries on motorways tend to have a higher average weight than those in towns, etc. Emission data for some types of vehicle are very limited, and it is sometimes necessary to equate them to vehicle types about which more is known. For example, London taxis may be considered equivalent to large diesel engined cars, or buses to lorries of about the same gross weight.
Fuel type	The emission rates of petrol engined vehicles are quite different from those of diesels. In the future, it is possible that a wider range of fuels will be used for road transport. There is growing interest in gaseous fuels (eg CNG) and alternative liquid fuels (eg methanol), and they too exhibit different emission properties. In some cases, there is little doubt as to the type of fuel used by a certain type of vehicle (it can be assumed, for example, that all HGVs use diesel), but for some classes, such as cars and light vans, it is almost impossible to determine the precise split between fuel types. Unless there is a good reason to do otherwise, it is sufficient to base estimates on national statistics. It should be recognised that future events may alter the balance between fuels and forecasts of future emission rates may need to consider social, economic and political factors in addition to technological trends.

Factor	
Vehicle operation	Many operational features influence a vehicle's emissions. Some of the better known factors are:
Speed	There is a well known correspondence between rates of emission and the average speed at which a vehicle is driven. It should normally be taken into account in an emission model.
Variation of speed	Emission rates tend to increase under variable operating conditions, compared with those during steady state driving. The effect is implicitly considered in most speed related emission factors since the variability of speed during a trip is closely related to the average speed. Slow speed journeys in towns involve frequent speed changes in response to the traffic conditions, while higher speed trips are normally driven more smoothly. Nevertheless, for two trips at the same average speed, emissions can vary substantially depending on speed variability. If a scheme has features that suggest speeds may vary more than average a more complex treatment may be warranted, though the availability of input data may be a limiting factor.
Road geometry	The emissions from a vehicle negotiating a twisting road, or from a vehicle climbing a steep slope, will be increased because of the need to use lower gears and the extra load on the engine. Little is known quantitatively about these effects, and it may be that their influence on a vehicle's average speed makes implicit allowance for them in a basic, speed related emission model. Perhaps the largest of these effects is on the emissions from lorries climbing steep slopes, so where roads have significant gradients and are expected to carry large numbers of HGVs, it may be necessary to make an allowance for it.
Engine temperature	Cold engines produce higher emissions than hot engines and emission control catalysts do not operate efficiently until they are warmed by the hot exhaust gases. Thus, where the number of vehicles starting from cold may be significant, the emission model should take this into account. Examples of where this could be important are locations near to car parks where engines may cool while vehicles are parked, or near to housing developments where the morning traffic may contain a large number of cars making their first journey of the day.
Evaporative emissions	Hydrocarbons are emitted by the evaporation of fuel as well as being emitted in a vehicle's exhaust. Because diesel is less volatile than petrol, it is usually only evaporative emissions derived from petrol that are considered. Emissions occur during the production and distribution of fuel and from vehicles in use. Vehicle evaporative emissions are of three main types: some vapour escapes from the fuel system when the vehicle is in operation and when it is parked with a warm engine, some is displaced from the fuel tank by liquid fuel when it is refilled, and some is emitted during the expansion of vapour in the fuel tank under the influence of ambient temperature variations. Quantitative data on evaporative emissions are very scarce, though some estimates suggest them to be a significant proportion of total hydrocarbon emissions. Their inclusion in an assessment should be considered if a scheme is likely to produce a change in local emissions. Such a case might be, for example, if a new petrol filling station is to be built.

Pollutant dispersion

A3.10 In the same way that the emission of pollutants is influenced by local conditions, so is its dispersion in the atmosphere after release. This is normally simulated by using a standard dispersion model. Care should be exercised in the choice of an appropriate model and in the input data that are used.

A3.11 Many of the currently available dispersion models were developed some years ago. Some have been maintained and improved, but usually their basic principles remain unaltered. Thus, while there have been scientific advances in the understanding of atmospheric dispersion processes, and very major gains in the power of computers, allowing more complex models to be operated routinely using standard equipment, few applications have taken advantage of them. Considered in the overall context of air pollution forecasting, though, this limitation may not be as serious as it seems. It has already been noted that the use of a complex model only provides improved results if appropriately detailed and accurate input data are available, and in many cases that is not the case. There are uncertainties, imprecisions and shortages of data for most of the stages of an air quality forecast.

A3.12 The models that are available are of several basic types. The simplest and most common are based on the Gaussian dispersion theory. This assumes that a pollutant emission develops into a plume, under the influence of the wind, and that the profile of concentrations in the plume has a Gaussian distribution in the horizontal and vertical directions. The concentration at any point in the plume can be calculated from the standard deviation of the concentration distribution, which can be expressed in turn as a function of the downwind distance from source and a number of atmospheric parameters. Special adaptations are needed when this principle is applied to traffic pollution (it was developed on the basis of emissions from fixed point sources).

A3.13 Other models have been developed empirically, from the analysis of air pollution data in relation to measured meteorological, traffic, site layout and other relevant variables. Given sufficient data for a thorough statistical analysis, these models can give accurate results. Important limitations are, however, that they apply strictly only to the location at which the measurements were made and that there is considerable uncertainty if the models are extrapolated beyond the range of the data on which they were based. They are, therefore, of limited use in making pollution forecasts for future years when vehicle emission characteristics will be very different.

A3.14 Two other types of model take as their basis the principle of conservation of mass of a pollutant as it spreads in the air. The Eulerian, or box, type of model calculates the change in concentration in a finite ‘box’ of air as the balance between material flowing into the box and that flowing out, with an allowance for any emissions occurring within the box. The second mass conservation type, the Lagrangian model, determines concentrations by following the movement of a ‘parcel’ of polluted air under the influence of the wind. Both of these types of model can be developed to be considerably more complex than the Gaussian or empirical models and can, in theory at least, provide more accurate pollution estimates. The Gaussian model, for example, assumes that pollution is transported uniformly in the direction of the wind, while a Lagrangian model can simulate the effects of complex wind patterns.

A3.15 Allowances can be made in most of these models for concentration changes produced by chemical reactions in the air. This is of significance in this context mainly with regard to the oxides of nitrogen. It is again the case, though, that few fully developed models are available that provide an adequate treatment of chemical interactions. Most consider only the dispersion of inert gases.

A3.16 A choice of a specific dispersion model is largely dependent on the specific characteristics of the scheme under investigation. General guidance on the choice of a particular dispersion model has been published by several bodies (*e.g.* DEFRA, 2002). As in other cases, the decision must be based on the circumstances of the scheme and the practicality of obtaining satisfactory input data. For a rural scheme in uncomplicated surroundings, there is probably little to be gained from the use of complex modelling techniques, and standard Gaussian models are likely to be appropriate. Where the terrain is not simple, in a mountainous area or the centre of a town, for example, there may be some advantage from the use of other types of model and their application should be considered, always bearing in mind that the input data requirements will be considerably greater.

A3.17 Dispersion models of all classes need, in principle, common types of input data. They vary in the level of detail that is necessary. In addition to information on rates of emission, the essential requirements concern the site layout and meteorology. The physical layout of a scheme will normally be available from drawings made during its design process. Meteorological data can be obtained from the Meteorological Office's extensive network of meteorological monitoring stations. It is important that the data used be representative for the area, so they should be from the nearest possible location, and they should be taken from records covering a reasonable length of time (several years) in order that short term fluctuations are not given undue weight. Even so, there will inevitably be a measure of uncertainty as influences in the immediate locality of the scheme may be important. For example, wind data for London are available from measurements made at the London Weather Centre, at a height of 70 m above the ground. Those measurements will be quite different from the conditions at ground level.

Sources of information

A3.18 A number of Government Departments and associated establishments have policy and research responsibilities in the field of air pollution. Primary contacts are as follows:

(a) Standards, Safety and Research: Environmental Policy
Highways Agency
Romney House
43 Marsham Street
London, SW1P 3HW

The Highways Agency has the responsibility for the planning, construction and network management of trunk roads in England. It develops assessment procedures, commissions research on air pollution relating to roads and prepares guidance on these matters for inclusion in the DMRB on behalf of the administrations in England, Scotland, Wales and Northern Ireland.

(b) Air and Environment Quality Division
DEFRA
Ashdown House
123 Victoria Street
London SW1E 6DE

The AEQ develops UK policy on air quality, operates an extensive network of air pollution monitoring stations in the UK and commissions research on air pollution.

(c) Vehicle, Standards and Engineering Division
DfT
Great Minster House
76 Marsham Street
London, SW1P 4DR

VSE represents the UK in the development of vehicle emission control policies and commissions research on exhaust emissions.

(d) Health and Safety Commission and Executive
Baynards House
1 Chepstow Place
Westbourne Grove
London W2 4TF

HSC and HSE promote and enforce the protection of people at work and the public from industrial hazards, including environmental concerns.

(e) Department of Health
Hannibal House
Elephant and Castle
London SE1 6TE

Cover all aspects of the health impacts of environmental pollution.

(f) Meteorological Office
London Road
Bracknell
Berkshire RG12 2SZ

The Meteorological Office provides a comprehensive service of meteorological information and carries out research on air quality and pollutant dispersion.

A3.19 There are also many research organisations, in the UK and elsewhere in Europe, that study traffic produced air pollution. The following are only a few examples.

(a) TRL Ltd
Old Wokingham Road
Crowthorne
Berkshire RG45 6AU

TRL carries out research and consultancy work on all aspects of vehicle derived air pollution.

(b) National Environmental Technology Centre
Culham
Abingdon
Oxfordshire OX14 3DB

NETCEN is a UK centre for environmental research.

A3.20 The motor and oil industries may provide information on aspects of fuels and vehicles that influence air pollution.

(a) Society of Motor Manufacturers and Traders
Forbes House
Halkin Street
London SW1X 7DS

(b) UK Petroleum Industry Association
9 Kingsway
London WC2B 6XH

A3.21 Some international bodies are involved in policy, research and development. Examples are:

Commission of the European Communities
rue de la Loi 200
1049 Brussels
Belgium

Recommend and implement standards for vehicle emissions and air quality for EU Member States, and commission extensive research.

European Environment Agency
Kongens Nytorv 6
DK-1050
Copenhagen
Denmark

European environmental policy.

World Health Organisation
Geneva
Switzerland

Studies of the health effects of air pollutants and recommendation of air quality standards.

A3.22 Many of these and other organisations publish information from time to time. A number of recent and relevant publications are listed in Chapter 4, but this list is not an exhaustive compilation of what is available. Additional reference material, and up to date supplements to the listed works, may often be obtained by standard literature review procedures.

ANNEX 4 POTENTIAL MITIGATION MEASURES

4.1 The air quality assessment of a road scheme must include any mitigation measures as agreed with the Overseeing Department's project manager.

A4.2 It must be recognised that the scope for mitigation of any adverse effect on air quality through route choice, design or operation is limited in comparison with reductions in emission rates achievable through improved vehicle technology. However, possible mitigation measures might include:

- Increasing the distance between the road and a sensitive location. Concentrations of primary pollutants fall rapidly with distance from the road, and realignment by only a few tens of metres may provide significant benefits.

- Carefully siting tunnel portals and ventilation shafts. The build-up of pollution in tunnels means that the air expelled from them contains higher concentrations than that near an open road.

- Siting junctions and intersections away from sensitive receptors. Slow traffic negotiating intersections generally produces greater amounts of pollution than freely flowing traffic.

- Special traffic management near to sensitive receptors (DoT, 1996; Abbot *et al.*, 1995; Cloke *et al.*, 1998). Priority schemes, speed limits and other control procedures might be used to modify the traffic behaviour so that vehicles are operating in a mode that produces low emissions. Free-flow conditions at a speed around 60 - 80 km/h are optimum.

- The use of dense vegetation screens or barriers. There is some evidence that concentrations are slightly reduced in a small area on the leeward side of a large screen or barrier.

- Orientation of the road relative to locally prevailing winds. If a route can be chosen so that a sensitive location is upwind, average concentrations at that location will be lower.

A4.3 The impact of a road network or scheme on air quality is just one of the factors to be considered in route choice and design, and conflicts can occur. Any mitigation measure must also perform to an acceptable level in road safety and economic terms.