Technical report No 49

COPERT III
Computer programme to calculate emissions from road transport

Methodology and emission factors (Version 2.1)

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1. Introduction

This report describes the methodology and relevant emission factors which are suggested to be used for the calculation of emission estimates from road transport. The methodology is fully incorporated in the computer programme COPERT III, which facilitates its application. The development of COPERT III was financed by the European Environment Agency, in the framework of the activities of the European Topic Centre on Air Emissions. It is proposed to be used by EEA member countries for the compilation of CORINAIR emission inventories. To that aim, a special function exists to export results from COPERT III directly to the CollectER format. In principle, COPERT III methodology can be applied for the calculation of traffic emission estimates at a relatively high aggregation level, both temporally and spatially, on a yearly basis for NUTS 0. However, it has been shown that the methodology can also be used with a sufficient degree of certainty at a higher resolution too, for the compilation of urban emission inventories with a spatial resolution of 1x1 km^2 and a temporal resolution of 1 hour.

This report is the third update of the initial version prepared in 1989 for the CORINAIR 1985 emissions inventory (Eggleston et al. ,1989) and firstly updated in 1991 for the CORINAIR 1990 inventory (Eggleston et al., 1993) and included in the Atmospheric Emission Inventory Guidebook (EMEP/CORINAIR, 1996). The second update of the methodology (Ahlvik et al., 1997) was introduced in the software tool COPERT II (Ntziachristos and Samaras, 1997) and a further update of the Guidebook was prepared.

Several input sources have been used in developing the methodology of COPERT III. The fundamentals of the methodology date back to the first version of the programme and several emission factors from older vehicles still remain unmodified since this first version. The previous version (COPERT II) introduced several methodological revisions, including extended vehicle classification and pollutant coverage, emission factors and corrections for road gradient and vehicle load, etc. The present version introduces both additional refinements of the COPERT II methodology and new calculation elements. Those revisions and extensions mainly originate from the following sources:

- finalisation of the COST 319 action on the Estimation of Emissions from Transport, (Joumard R. (ed.), 1999),
- completion of the MEET (Methodologies to Estimate Emissions from Transport); a European Commission (Directorate for Transport) sponsored project in the framework of the 4th Framework Programme in the area of Transport (Hickman et al., 1999),
- European Commission's Auto Oil II programme (Ntziachristos and Samaras, 1999b),
- the Inspection and Maintenance project (LAT/AUTh, 1998); a European Commission (Directorate Generals for Environment DGXI ,Transport DGVII, and Energy DGXVII) sponsored project,
- the EPEFE project; a programme conducted by the Association of European Automotive Manufacturers (ACEA) and the European Petroleum Industry Association (EUROPIA) (ACEA and EUROPIA, 1996).

- Continuation of the CONCAWE work on evaporation emissions (CONCAWE, 1992)
- In comparison with the COPERT II methodology, the following significant modifications have been introduced:
- Updated hot emission factors and consumption factors for Euro I gasoline and diesel passenger cars and light duty vehicles.
- Revised cold start over-emission ratios for Euro I gasoline vehicles.
- Proposal for an alternative evaporation losses modelling
- Modelling of the effect of vehicle age (mileage) on emissions and the effect of an enhanced Inspection and Maintenance scheme.
- Revised vehicle category split, including future emission technologies for different classes and updated, representative emission reduction factors over existing vehicle technologies.
- The effect of the use of improved fuels on the emissions of present and future vehicle technologies.
- Extended NMVOC species profile, providing values for 68 different components.
- Emission factors for 23 PAHs and POPs and additional toxicity equivalent emission factors for Dioxins and Furans.
- Revisited emission factors of non regulated pollutants (little modifications have been made).

Additional corrections / revisions have been incorporated according to the review of the methodology conducted by several Member States in the frame of national inventorying use of the programme. Such modifications include an improved unleaded allocation module, emission corrections for fuel consumption dependant pollutants, etc.

2. Vehicle category split

The vehicle category split required for reporting in CORINAIR, presented in Table 2.1 (EMEP/CORINAIR, 1999)is not sufficient for calculating road transport emissions. This is the outcome of the deficiency in reflecting the year of vehicle production and, subsequently, the engine and aftertreatment technology which is implemented for achieving the emission standards. Thus, for the purpose of COPERT, a more detailed vehicle category split has been developed, presented in Table 2.2.

In order to help identifying the vehicle categories, Table 2.3 gives the classification of vehicles according to the UN-ECE. The main COPERT categories can be allocated to the UN-ECE classification as follows:

- Passenger Cars M1
- Light Duty Vehicles N1
- Heavy Duty Vehicles N2, N3
- Urban Buses & Coaches M2, M3
- Two Wheelers L1, L2, L3, L4, L5

In order to provide assistance in distributing national fleets to different levels of emission legislation, a description of each class is given in the following sections.

2.1. Legislation classes of gasoline passenger cars <2,5 tonnes

The production year of vehicles in this category has been taken into account by introducing different classes, which reflect legislative steps (ECE, Euro) or technology steps ('Improved Conventional', 'Open Loop').

From 1970 and until 1985 all EC member states followed the UN ECE R15 (United Nations Economic Committee for Europe Regulation 15) amendments as regards the emissions of pollutants from vehicles less than 3,5 tonnes. According to the relevant EC Directives, the implementation dates of these regulations were as follows:

- pre ECE vehicles up to 1971
- ECE 15 00 & 01 1972 to 1977
- ECE 15 02 1978 to 1980
- ECE 15 03 1981 to 1985
- ECE 15 04 1985 to 1992

However, the above implementation dates are 'average' for the EU 15 member states. They are different from one member state to another as the directives had to be ratified by the national parliaments. Even more important these regulations were applicable on the vehicles – either produced in the member state or imported from elsewhere in the world – registered in the member state. By default, vehicles classified in ECE categories are considered to operate on leaded gasoline.

After 1985 new technologies appeared, imposed by the EC legislation and national schemes applying to vehicles <2,5 t. Those technologies are described in the following paragraphs.

2.1.1. Gasoline passenger cars <1,4l

a. Improved Conventional: It takes into account German and Dutch incentive programmes:

- Anl.XXIVC (only relevant for Germany). Effective date: 1.7.1985.
- NLG 850 (only relevant for the Netherlands). Effective date: 1.1.1986

It is assumed that the required emission standards can be met by applying improved conventional technology, that is without the use of a catalytic converter. This type of emission control technology also started to appear in Denmark from 1.1.1988. Consumption of leaded gasoline is considered for such vehicles because of no particular aftertreatment requirements.

b. Open Loop: It takes into account German, Danish, Greek and Dutch incentive programmes. It is assumed that the required emission standards can be met by applying open loop three way catalysts. Effective dates: Denmark 1.1.1989, F.R.Germany 1.7.1985, Greece 1.1.1990, The Netherlands 1.1.1987. Because of the introduction of the catalyst, unleaded fuel is by default considered.

c. Euro I: It takes into account national incentive programmes (e.g. voluntary programmes in F.R.Germany carried out after 1.7.1985), where compliance with US 83 limits is required. However, directive 91/441/EEC introduced this emission standard at a European level for all vehicles introduced in the market between 1992 and 1996. The obligatory introduction of three-way catalysts in this vehicle class makes mandatory the use of unleaded fuel.

2.1.2. Gasoline passenger cars 1,4-2,0 l

a. Improved conventional. It takes into account vehicles which meet the limit values of the Directive 88/76/EEC by means of open loop catalysts. In practice relevant only for the national incentive programmes. Effective dates of implementation are: Denmark 1.1.1987, F.R.Germany 1.7.1985, The Netherlands 1.1.1987. As in the previous category, leaded gasoline is considered.

b. Open Loop. It takes into account vehicles which meet the limit values of the Directive 88/76/EEC by means of open loop catalysts. In practice relevant only to the national incentive programmes. Effective dates of implementation are: Denmark 1.1.1987, F.R.Germany 1.7.1985, Greece 1.1.1990, The Netherlands 1.1.1986. Again, unleaded fuel is by default considered.

c. Euro I: It takes into account national incentive programmes where compliance with US 83 limits is required However, directive 91/441/EEC introduced this emission standard for all vehicles introduced in the market between 1992 and 1996. The use of unleaded fuel is mandatory.

2.1.3. Gasoline passenger cars >2,0 l

a. Euro I. It takes into account EC legislation and national incentive programmes:

- 88/76/EEC (relevant for all countries). Effective date for new vehicles: 1.1.1990.
- US 83 (only relevant for Denmark, F.R.Germany, Greece, The Netherlands). Effective date: Denmark 1.1.1987, F.R.Germany 1.7.1985, Greece 1.1.1989, The Netherlands 1.1.1987. It is assumed that the required emission standards can be met by applying closed loop three way catalysts.
- Directive 91/441/EEC introduced this emission standard for all vehicles introduced in the market between 1992 and 1996.

In any case, unleaded fuel is considered to be used for Euro I vehicles.

2.1.4. Recent and future legislation steps

Current emission standards for passenger cars have been adopted in the EU since 1997 (Directive 94/12/EC - Euro II) and are valid until the end of 2000. Compared to 91/441/EEC the current emission standards impose a 30 % and 55 % reduction in CO and HC+NO_x respectively. Moreover, additional legislation steps have been decided to be introduced up to year 2005 (Directive 98/69/EC implemented in Stage 2000 - Euro III and Stage 2005 - Euro IV). The Stage 2000 requirements impose a 30 % CO reduction, 40 % NO_x and 40 % VOC reduction over the current 94/12/EC emission standards and additional reductions are foreseen for year 2005. All those technologies make use af closed-loop three way catalytic converters for the reduction of pollutant emissions. Further requirements of the new legislation is the introduction of on-board diagnostic systems (OBD) and emission conformity in tests at low ambient temperature (-7°C).

2.2. Legislation classes of diesel passenger cars <2,5 tonnes

2.2.1. Conventional vehicles

The ‘Conventional’ vehicle class applies to diesel passenger cars of all capacities and includes vehicles prior to the introduction of the ‘Consolidated Emissions Directive’ 91/441/EEC. Therefore, cases included are non regulated vehicles launched prior to 1985 and vehicles complying with directive ECE 15/04 (up to 1992). In principle diesel vehicles of this class are equipped with indirect injection engines with no exhaust aftertreatment.

2.2.2. Improved diesel technologies

Improved diesel technologies include vehicles complying with directives 91/441/EEC (Euro I, 1992-1996), 94/12/EC (Euro II, valid from 1996 for indirect injection and 1997 for direct injection up to 2000) and the new regulations 98/69/EC Stage 2000 (Euro III) and 98/69/EC Stage 2005 (Euro IV). Euro I were the first vehicles to be consecutively regulated for CO, HC+ NO_x and PM emissions. Few of those vehicles were equipped with oxidation catalysts. Directive 94/12/EC brought reductions over the former Directive of 68 % for CO, 38 % for HC+ NO_x and 55 % for PM and oxidation catalysts were used in almost all vehicles. Additional reductions are brought for Euro III and Euro IV vehicles.

2.3. Legislation classes of LPG passenger cars <2,5 tonnes

Legislation classes provided for LPG passenger cars, as in the case of diesel passenger ones, include a ‘Conventional’ class where vehicles up to 91/441/EEC are grouped together. After this, legislation classes are introduced according to the Directives as adopted in the case of gasoline and diesel passenger cars.

2.4. Legislation classes of 2 stroke passenger cars <2,5 tonnes

This type of vehicles is relevant mainly for some Eastern European countries (and to some extent for Germany). A very limited fleet of such vehicles is still in circulation and no particular emission standards are applicable. Therefore all such vehicles are grouped in a common 'Conventional' class.

2.5. Legislation classes of gasoline light duty vehicles <3,5 tonnes

In the EU the emissions of these vehicles were covered by the different ECE steps up to 1993 and all such vehicles are introduced with the term 'Conventional'. Vehicles in the 'Conventional' class are considered to operate on leaded gasoline. From 1993 up to 1997 new emission standards are applicable (Euro I - Directive 93/59/EEC), which ask for catalytic converters on gasoline powered vehicles. The Directive 96/69/EC (Euro II) has introduced stricter emission standards for light duty trucks since 1997 and it is valid up to 2001. Two more legislation steps have been introduced in COPERT III, namely Euro III - 98/69/EC (valid 2001-2006) and Euro IV - 98/69/EC (valid 2006 onwards) which introduce even stricter emission standards. All new technologies operate on unleaded fuel due to the mandatory use of three way catalysts.

2.6. Legislation classes of diesel light duty vehicles <3,5 tonnes

Legislation classes valid for gasoline light duty vehicles are also applicable in the case of diesel ones (with different emission standards though). In general, engine technology of diesel light duty vehicles follows the one of respective diesel passenger cars.

2.7. Legislation classes of gasoline heavy duty vehicles >3,5 tonnes

Heavy duty gasoline vehicles >3,5 tonnes play a negligible role in European emissions from road traffic. Any such vehicles are included in the 'Conventional' class without further distinction in legislation steps because no specific emission standards have been set for such vehicles.

2.8. Legislation classes of diesel heavy duty vehicles >3,5 tonnes

Emissions from diesel engines used in vehicles of gross weight over 3,5 tonnes were first regulated in 1988 with the introduction of the original ECE 49 Regulation. Vehicles (or, better, engines) complying with ECE 49 and earlier are all classified as 'Conventional'. Directive 91/542/EEC, implemented in two stages, brought two additional standards of reduced emission limits valid from 1992 to 1995 (Stage 1) and 1995 up to date (Stage 2). Directive 1999/96/EC adopted by the Council of Environment Ministers on Dec. 13, 1999 aims at the reduction of gaseous and particulate pollutants from diesel heavy duty vehicles by 30 % starting in year 2000 up to 2005. This proposal has been introduced in COPERT III as Euro III. Two additional vehicle classes have been introduced according to proposal COM(1998) 776 (adopted by the Council on Dec. 20, 1998) which aim at the introduction of even more stringent emission standards for gaseous and particulate pollutants. Euro IV (valid from 2005 to 2008) and Euro V (starting in year 2008) classes have been introduced in COPERT III to cover those requirements.

2.9. Legislation classes for 2 stroke mopeds <50 cm³

No emission standards were agreed in the Europe for emissions of two wheelers but only national legislation was valid in a few countries (Austria, Switzerland). Since June 1999, directive 97/24/EC has introduced emission standards, which for the case of two-stroke mopeds <50cm^3, are applied to CO (6 g/km) and HC+ NO_x (3 g/km). An additional stage of the legislation will come into force for mopeds in June 2000 (CO: 1 g/km, HC+ NO_x: 1,2 g/km).

Therefore, mopeds are classified into three classes, namely 'Conventional', '97/24/EC Stage 1' and '97/24/EC Stage 2'.

2.10. Legislation classes for 2 stroke and 4 stroke motorcycles >50 cm³

Emissions from two and four stroke motorcycles > 50 cm^3 were first introduced in June 1999 when directive 97/24/EC came into force. The directive imposes different emission standards for two and four stroke vehicles respectively, and separate limits are set for HC and NO_x to allow for a better distinction in the different technologies (2-stroke : CO 8 g/km, HC 4 g/km, NO_x 0,1 g/km; 4-stroke : CO 13 g/km, HC 3 g/km, NO_x 0,3 g/km).

For both two and four stroke vehicles, two emission legislation classes are proposed, 'Conventional' and '97/24/EC'.

3. Pollutants covered

COPERT III methodology covers exhaust emissions of CO, NO_x, VOC, CH_4, CO_2, N_2O, NH_3, SO_x, diesel exhaust particulates (PM), PAHs and POPs, Dioxins and Furans and heavy metals contained in the fuel (Lead, Cadmium, Copper, Chromium, Nickel, Selenium and Zinc). A detailed NMVOC split is also included to distinguish hydrocarbon emissions as alkanes, alkenes, alkynes, aldehydes, ketones and aromatics.

According to the detail of information available and the approach adopted by the methodology to calculate emissions, the above mentioned pollutants can be distinguished into the following groups:

Group 1: Pollutants for which a detailed methodology exists, based on specific emission factors and covering different traffic situations and engine conditions. The pollutants included in this group are given in Table 3.1.

Group 2: Emissions dependent on fuel consumption. Fuel consumption is calculated with specific consumption factors and calculations are of the same quality as of pollutants of Group 1. Emissions of pollutants of this Group are produced as a fraction of fuel consumption. Pollutants included in this group are quoted in Table 3.2.

Group 3: Pollutants for which a simplified methodology is applied mainly due to the absence of detailed data. This Group contains the pollutants given in Table 3.3

Group 4: NMVOC profiles which are derived as a fraction of the of total NMVOC emissions. A small fraction of NMVOC remaining is considered to be PAHs. Speciation includes the categories given in Table 3.4. Details on the speciation of NMVOC exhaust emissions are given in § 4.12.

4. Methodology outline

Total emission estimates are calculated with combination of firm technical data (e.g. emission factors) and activity data (e.g. total vehicle kilometres) provided by the user. All technical data depend on control variables which may be modified by the user, to provide an accurate estimate depending on the type of application of the methodology. The following provide an outline of the application of the methodology. Details on the technical parameters can be found in the respective chapters.

4.1. Emission types

In principle, total emissions are calculated by summing emissions from three different sources, namely the thermal stabilised engine operation (hot), the warming-up phase (cold start) and the fuel evaporation. It is clarified that the word 'engine' is used in place of the actual 'engine and any exhaust aftertreatment devices'. Distinction in emissions during the stabilised and warming-up phase is necessary because of the substantial difference in vehicle emission performance during those two conditions. Concentrations of most pollutants during the warming-up period are many times higher than during hot operation and a different methodological approach is required to estimate over-emissions during this period. Also, evaporation of fuel (gasoline) during the day (with or without the vehicle in operation) results in emissions of non-methane hydrocarbons by a different mechanism than exhaust emissions. In that respect, total emissions can be calculated by means of the equation:

$$\mathbf{E_{TOTAL} = E_{HOT} + E_{COLD} + E_{EVAP}} \quad \mathbf{(1)}$$

Where,

- $\mathbf{E_{TOTAL}}$: total emissions (g) of any pollutant for the spatial and temporal resolution of the application,
- $\mathbf{E_{HOT}}$: emissions (g) during stabilised (hot) engine operation,
- $\mathbf{E_{COLD}}$: emissions (g) during transient thermal engine operation (cold start),
- $\mathbf{E_{EVAP}}$: emissions (g) from fuel evaporation. Emissions from evaporation are only relevant for NMVOC species from gasoline powered vehicles.

4.2. Emissions under different driving conditions

Vehicle emissions are heavily dependent on the engine operation conditions. Different driving situations impose different engine operation conditions and therefore a distinct emission performance. In that respect, a distinction is made in urban, rural and highway driving to account for variations in driving performance. Typical speed ranges for each driving situation are given in Table 4.1, while actual data for each country can be found in Table 4.3. The distinction in different driving situations is consistent to the EMEP/CORINAIR approach (Table 2.1).

As will be later demonstrated, different activity data and emission factors are attributed to each driving situation. Also, by definition, cold start emissions are attributed to urban driving because the assumption is made that the large majority of vehicles starts any trip in urban areas. More details on the exact attribution of cold start emissions in different driving situations can be found in the relevant chapter (§ 4.6.). Therefore, as far as driving conditions are concerned, total emissions can be calculated by means of the equation:

$$\mathbf{E_{TOTAL} = E_{URBAN} + E_{RURAL} + E_{HIGHWAY}} \quad \mathbf{(2)}$$

Where,

- $\mathbf{E_{URBAN}}$, $\mathbf{E_{RURAL}}$, $\mathbf{E_{HIGHWAY}}$: total emissions (g) of any pollutant for the respective driving situation.

4.3. Calculation outline

Calculation of total emissions is made by combining activity data for each vehicle category with appropriate emission factors. Those emission factors vary according to input data (driving situations, climatic conditions) provided by the user. Also, information on fuel consumption and specifications is required to maintain a fuel balance between user provided figures and calculations. A summary of the variables required and the intermediate calculated values is given in the flow chart of Figure 4.1.

4.4. Spatial / temporal resolution of application

In order to meet the CORINAIR requirements, and in particular the one that data should be suitable for advanced long-range dispersion models, this information in principle should be available for the smallest territorial unit (NUTS 3 level).

For countries for which the required input data are not available at this low level, it seems to be more appropriate to start at NUTS level 0 (national level) and to allocate emissions to other NUTS levels with the help of available surrogate data. National particularities can be taken into account by this top-down approach via the composition of the vehicle parc, the driving conditions and the temperature dependency of some emission factors, and the influence of road gradient on heavy vehicles' emissions.

For countries which have the required input available at smaller NUTS level (including for example traffic counting) it is proposed to make use of this information and to apply a bottom-up approach. As already mentioned, it has been shown (Zachariadis and Samaras 1996, Moussiopoulos et al., 1996) that the proposed methodology can be used with a sufficient degree of certainty at a higher resolution too, i.e. for the compilation of urban emission inventories with a spatial resolution of 1x1 km^2 and a temporal resolution of 1 hour.

However, specific assumptions have been made for the application of the methodology because COPERT III has mainly been developed for the compilation of national annual emission inventories. In that respect, evaporation emissions are calculated for a year-period while maximum temporal resolution for cold start emissions is one month. Therefore, excluding evaporation emissions, the application of the methodology can be considered adequate for a maximum resolution of one month. Moreover, the distinction into three different driving conditions provides the maximum spatial resolution limit. Therefore the application of the methodology can be applied at maximum spatial resolution on a street network (e.g. highways) or on a whole urban area (e.g. small city). As a general guideline, it can be proposed that the smaller area of application should be the one for which it can be considered that the fuel sold in this region (statistical consumption), equals the actual consumption of the vehicles operating in this region.

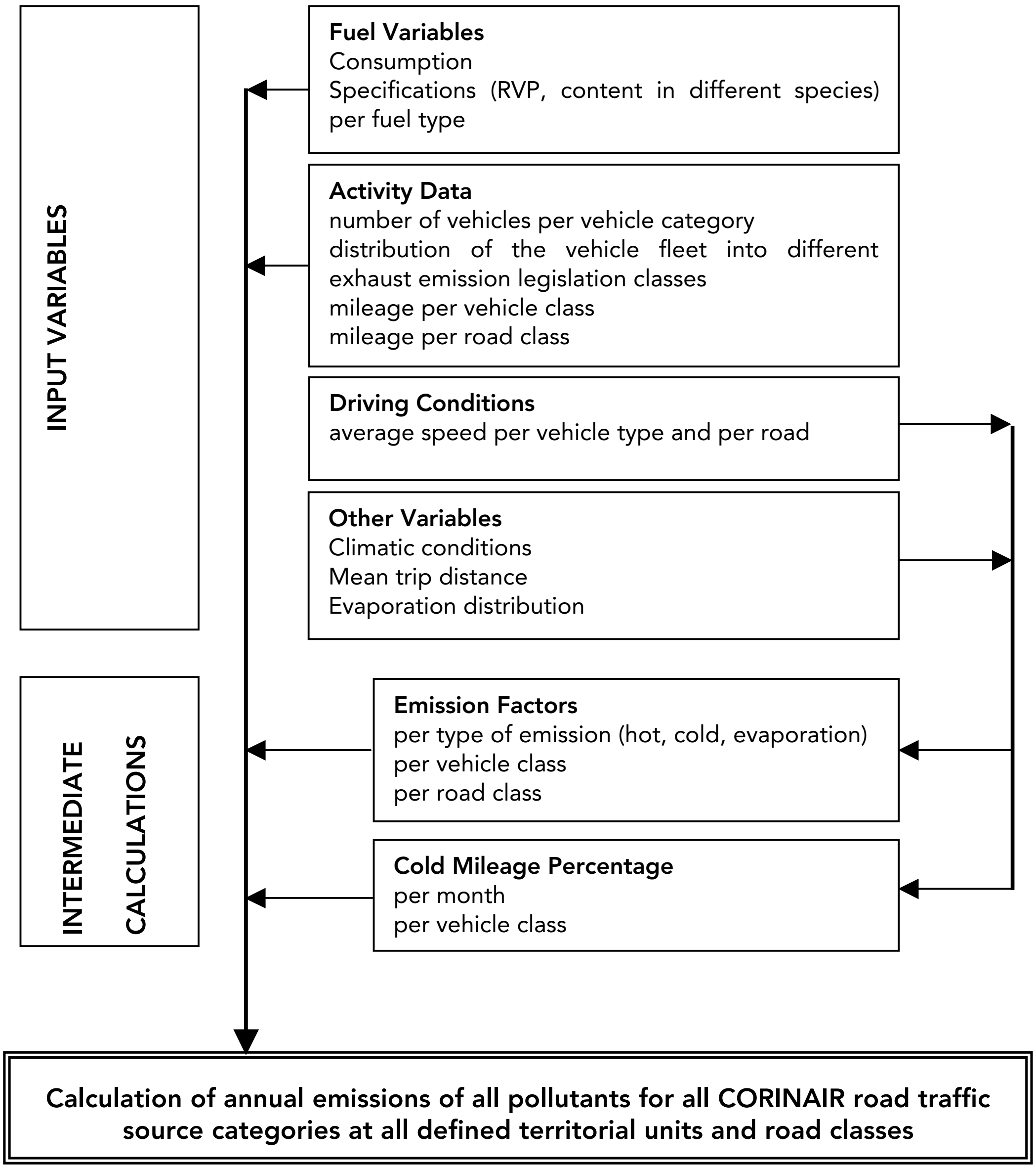

Figure 4.1: Flow chart of the application of the baseline methodology

4.5. Hot emissions

By 'Hot emissions' we mean by convention the emissions occurring under thermally stabilised engine and exhaust aftertreatment conditions. These emissions depend on a variety of factors including the distance that each vehicle travels, its speed (or road type), its age, engine size and weight. As explained later, many countries do not have solid estimates of these data. Therefore a method to estimate the emissions from available solid data has been proposed. However, it is important that each country uses the best data they have available. This is an issue to be resolved by each individual country.

The basic formula for estimating hot emissions, using experimentally obtained emission factors is:

Emissions per Period of Time [g] = Emission Factor [g/km] × Number of Vehicles [veh.]× Mileage per Vehicle per Period of Time [km/veh.]

Different emission factors, number of vehicles and mileage per vehicle need to be introduced for each vehicle category and class. COPERT III assumes that hot emission factors, i.e. emission factors corresponding to hot engine operation, depend only on average speed. The dependency of hot emission factors with speed is given by the functions quoted in Tables at the end of this document for each vehicle category and class. The period of time depends on the application (month, year, etc.)

Therefore, the formula to be applied for the calculation of hot emissions of pollutants in Groups 1 and 3 and in the case of an annual emission estimation, yields (Note: the same formula is also applied for the calculation of the total fuel consumed by vehicles of the specific class. In the case of fuel consumption, an additional distinction needs to be made for different fuel types):

$$E_{HOT;\,i,\,j,\,k} = N_j \times M_{j,k} \times e_{HOT;\,i,\,j,\,k} \qquad (3)$$

Where,

$E_{HOT;\,i,\,j,\,k}$: emissions of the pollutant i in [g], produced in the reference year by vehicles of class j driven on roads of type k with thermally stabilised engine and exhaust aftertreatment system

N_j: number of vehicles [veh.] of class j in circulation at the reference year

$M_{j,k}$: mileage per vehicle [km/veh.] driven on roads of type k by vehicles of class j

$e_{HOT;\,i,\,j,\,k}$: average fleet representative baseline emission factor in [g/km] for the pollutant i, relevant for the vehicle class j, operated on roads of type k, with thermally stabilised engine and exhaust aftertreatment system

and,

i (pollutants): 1-33 for the pollutants of Group 1 and Group 3 (Chapter 2)

j (vehicle class): 1-99 for the vehicle classes defined in the vehicle split (Table 2.2)

k (road class): 1-3 for ‘urban’, ‘rural’, and ‘highway’ driving.

4.5.1. Accounting for vehicle speed

Vehicle speed, which is introduced into the calculation via the three driving modes, has a major influence on the emissions of the vehicles. Different approaches have been developed to take into account the driving patterns. With the emission factors presented in this chapter, the authors propose two alternative methods:

- to select one single average speed, representative of each of the road types ‘urban’, ‘rural’ and ‘highway’ (e.g. 20 km/h, 60 km/h and 100 km/h, respectively) and to apply the emission factors taken from the graphs or calculated with the help of the equations, or
- to define mean speed distribution curves $f_{k,\,j}(V)$ and to integrate over the emission curves, i.e.

$$e_{HOT;\,i,\,j,\,k} = \int [e(V) \times f_{k,\,j}(V)]\, dV \qquad (4)$$

where,

V:	speed of vehicles on road classes 'rural', 'urban', 'highway',
e(V):	mathematical expression of the speed-dependency of $e_{HOT;\,i,\,j,\,k}$
$f_{k,\,j}(V)$:	equation (e.g. formula of 'best fit' curve) of the frequency distribution of the mean speeds which corresponds to the driving patterns of vehicles on road classes 'rural', 'urban' and 'highway'. $f_{k,\,j}(V)$ depends on road type k and vehicle class j.

It is evident that the first approach mentioned above is much easier and most likely the one to be chosen by most of the countries. For this reason the software application of the methodology provides only the first possibility for the calculation of hot emission factors. Table 4.3 shows as an example the speed selection of Member States applied in the COPERT 1990 exercise (Andrias et al., 1994).

4.5.2. Range of application of hot emission factors

Emission factors proposed by the methodology have been derived in the framework of different scientific programmes. Emission factors of of former technology passenger cars and light duty vehicles have been developed in the frame of older COPERT/ CORINAIR activities (Eggleston et al., 1989) while emissions from recent vehicles are calculated on the basis of the work conducted in the frame of MEET (Samaras and Ntziachristos, 1998). Emission factors for heavy-duty trucks, coaches and busses originate from the German/Swiss Handbook of emission factors (Keller et al., 1995). Also, emission factors for mopeds and motorcycles are derived from the same work with further processing by TNO (Rijkeboer R.C., 1997).

It follows that because of the large range of data utilised and processing involved, different limitations/restrictions are associated with the emission factors of different vehicle classes. However, general directions which should be followed when applying the methodology include:

- Application of the emission factors should only be made within the speed ranges given in the respective tables providing the emission factors. Those ranges have been defined according to the availability of the input data. Extrapolation of the proposed formulas to lower/higher speeds is therefore not advised, because this is not justified on the basis of the available experimental data.
- The proposed formulas should only be used with average travelling speed and by no means can be considered an accurate approach when only instant speed values are available. Emission factors can be considered representative of emission performance with constant speed only at high velocities (>100 km/h) when, in general, speed fluctuation is relatively low.
- The emission factors should not be applied in cases in which the driving pattern differs too much from what is common, e.g. in traffic calming areas.
- The three road types (highway, urban, rural) are obviously synonyms for certain driving patterns which are to some extent typical, but not the same in all countries and cities, e.g. there are indications that highway driving in Germany takes place at a higher average speed than in Belgium, or urban

driving in Athens takes place at a lower average speed than in Berlin, and so on. Moreover, it is possible that driving patterns depend on additional parameters, such as age of the vehicle or cylinder capacity. Such dependencies should only be taken into account if sound statistical data are available.

4.6. Cold start emissions

Cold starts, compared with the ‘hot emissions’, result in additional emissions. They take place under all three driving conditions, however, they seem to be most likely for urban driving. In principle they occur for all vehicle categories. However, emission factors are only available or can be reasonably estimated for gasoline, diesel and LPG passenger cars and – assuming that these vehicles behave like passenger cars – light duty vehicles, so that just these categories are covered by the methodology. Moreover, they are considered not to be a function of vehicle age.

These emissions are calculated as an extra emission over the emissions that would be expected if all vehicles were only operated with hot engines and warmed-up catalysts. A relevant factor, corresponding to the ratio of cold over hot emissions, is used and applied to the fraction of kilometres driven with cold engines. These factors may vary from country to country. Different driving behaviour (varying trip lengths), as well as climate with varying time (and hence distance) required to warm up the engine and/or the catalyst affect the fraction of distance driven with cold engines. These factors can be taken into account, but again information may not be available to do this thoroughly in all countries, so that estimates have to close identified gaps.

The cold emissions are introduced into the calculation as additional emissions per km by using the following formula:

$$\mathbf{E_{COLD;\,i,\,j} = \beta_{i,\,j} \times N_j \times M_j \times e_{HOT;\,i,\,j} \times (e^{COLD} / e^{HOT}|_{i,j} - 1)} \qquad \mathbf{(5)}$$

Where,

$\mathbf{E_{COLD;\,i,\,j}}$:	cold start emissions of the pollutant i (for the reference year), caused by vehicle class j,
$\beta_{i,\,j}$:	fraction of mileage driven with cold engines or catalyst operated below the light-off temperature,
$\mathbf{N_j}$:	number of vehicles [veh.] of class j in circulation in vehicle class j,
$\mathbf{M_j}$:	total mileage per vehicle [km/veh.] in vehicle class j,
$\mathbf{e^{COLD} / e^{HOT}|_{i,j}}$:	cold over hot ratio of pollutant i emissions, relevant to vehicles of class j.

The β-parameter depends on ambient temperature $\mathbf{t_a}$ (for practical reasons the average monthly temperature is proposed to be used) and pattern of vehicle use, in particular the average trip length $\mathbf{l_{trip}}$. However, since information on $\mathbf{l_{trip}}$ is not available in many countries for all vehicle classes, simplifications have been introduced for some vehicle categories. According to available statistical data (André et al., 1998) a European value of 12,4 km has been established for the $\mathbf{l_{trip}}$ value. Moreover, according to a relevant analysis, the value of $\mathbf{l_{trip}}$ for annual vehicle circulation should be found in the range of 8 to 15 km. Therefore it is proposed to use the value of 12,4 km unless firm national estimates are available. Table 4.4 presents the $\mathbf{l_{trip}}$ values used in the COPERT 1990 inventories by different member states.

The introduction of more stringent emission standards for catalyst gasoline vehicles has imposed shorter periods for the catalyst to reach the light-off temperature. This is reflected to less mileage driven under warming-up conditions. Therefore, the β-parameter is also a function of the level of legislation conformity for gasoline catalyst vehicles. Table 5.27 presents the fraction of the original β-parameter to be used for current and future catalyst vehicles for the main pollutants.

The over-emission ratio e^{COLD}/e^{HOT} also depends on the ambient temperature and pollutant considered.

Although the model introduced in COPERT 1990 is still used for the calculation of emissions during the cold start phase, new over-emission ratios have been introduced for catalyst equipped gasoline vehicles. The new ratios are based on a more detailed and accurate method which has been recently developed in the framework of MEET (Hickman A.J. (ed.), 1999), which accounts for data and methods produced in a number of national programmes. However, the application of the new approach still needs to be further refined and tested. Therefore, an intermediate step has been decided which accommodates the findings of the revised methodology on the existing COPERT 1990 approach.
As has already been discussed in §4.2, cold start over-emission is attributed to urban driving only because the valid assumption is made that the majority of trips start to urban areas. However, a portion of cold start over-emissions may also be attributed to rural conditions, in cases where the mileage fraction driven with non-thermally stabilised engine conditions (β-parameter) exceeds the mileage share attributed to urban conditions (S_{URBAN}). This case requires a transformation of equation 5, which then yields:

If $\beta_{i,j} > S_{URBAN}$,

$$E_{COLD;\, i,\, j,\, URBAN} = S_{URBAN;\, i,\, j} \times N_j \times M_j \times e_{HOT;\, i,\, j,\, URBAN} \times (e^{COLD} / e^{HOT}|_{i,j} - 1) \quad \text{(6a)}$$

$$E_{COLD;\, i,\, j,\, RURAL} = (\beta_{i,j} - S_{URBAN;\, i,\, j}) \times N_j \times M_j \times e_{HOT;\, i,\, j,\, URBAN} \times (e^{COLD} / e^{HOT}|_{i,j} - 1) \quad \text{(6b)}$$

In this case, it is considered that the total mileage driven under urban conditions corresponds to warming-up conditions, while the remaining over-emissions are attributed to urban conditions. The case demonstrated by equation 6 is rather extreme for a national inventory and can only happen in cases where a very small value has been provide for l_{trip}.

Note: VOC values proposed for the β-parameter and the e^{COLD}/e^{HOT} over-emission ratio are applied to calculate over-emissions of both NMVOC and CH_4 during cold start.

4.7. Evaporative VOC emissions

There are three primary sources of evaporative emissions from vehicles, which are separately estimated:

i) diurnal (daily) emissions
ii) hot soak emissions
iii) running losses

Due to the lack of data, evaporation emissions can be estimated only for gasoline passenger cars, gasoline light duty vehicles and two wheelers, but not asoline heavy duty vehicles. Additionally, the methodology outlined below can only be fully applied in the case of gasoline passenger cars. Simplifications are made for the remaining two vehicle categories. Since evaporation emissions are very sensitive to temperature, the estimates are made on a monthly basis.

4.7.1. Diurnal emissions

The evaporative emissions associated with the daily (diurnal) variation in ambient temperature result from the vapour expansion inside the gasoline tank that occurs as the ambient temperature rises during the daylight hours. Without an evaporation control system, some of the increasing volume of fuel vapour is vented to the atmosphere. At night, when the temperature drops, vapour contracts and fresh air is drawn into the gasoline tank through the vent. This lowers the concentration of hydrocarbons in the vapour space above the liquid gasoline, which subsequently leads to additional evaporation.

4.7.2. Hot soak emissions

Hot soak evaporative emissions are the emissions caused when a hot engine is turned off. Heat from the engine and exhaust system increases the temperature of the fuel in the system that is no longer flowing. Carburettor float bowls are particularly significant source of hot soak emissions.

4.7.3. Running losses

Running losses are the result of vapour generated in gasoline tanks during vehicle operation. Running losses are most significant during periods of high ambient temperatures. The combined effect of high ambient temperature and exhaust system heat, and any heated fuel returned back to the tank from the engine can generate a significant amount of vapour in the gasoline tank.

All three types of evaporative emissions are significantly affected by the volatility of the gasoline being used, the absolute ambient temperature and temperature changes, and vehicle design characteristics. For hot soak emissions and running losses the driving pattern is also of importance.

Evaporative VOC emissions from gasoline-fuelled vehicles add to the total NMVOC emissions.

The methodology used in order to estimate evaporative VOC emissions has been proposed by CONCAWE (1990a) and complemented by US (US EPA 1990 and 1991) and European (Heine et al., 1987) data. The methodology is the same that has been incorporated in the previous versions of COPERT.

A literature review, which was conducted in the framework of MEET (Samaras et al., 1997b) and in which a number of different approaches were compared, concluded that:

'*There is no method that is based on a comprehensive experimental data set (which would be the most important advantage of a calculation procedure)*'

and therefore

'*It seems reasonable to propose to use the CORINAIR methodology for estimation of evaporative emissions in the framework of MEET*'.

This method is referred to as *Standard CORINAIR* approach, to be differentiated from an alternative approach, which is discussed in a following section.

4.7.4. Standard CORINAIR evaporation method

The main equation for estimating the evaporative emissions is:

$$\mathbf{E_{EVA,\ VOC;\ j} = 365 \times N_j \times (e^d + S^c + S^{fi}) + R} \qquad \textbf{(7a)}$$

Where,

$E_{EVA,\ VOC;\ j}$: VOC emissions due to evaporative losses caused by vehicle category j,
N_j: number of gasoline vehicles of category j,
e^d: mean emission factor for diurnal losses of gasoline powered vehicles equipped with metal tanks, depending on average monthly ambient temperature, temperature variation, and fuel volatility (RVP),
S^c: average hot and warm soak emission factor of gasoline powered vehicles equipped with carburettor,
S^{fi}: average hot and warm soak emission factor of gasoline powered vehicles equipped with fuel injection,
R: hot and warm running losses.

and,

$$\mathbf{S^c = (1-q) \times (p \times x \times e^{s,hot} + w \times x \times e^{s,warm})} \qquad \textbf{(8a)}$$

$$\mathbf{S^{fi} = q \times e^{fi} \times x} \qquad \textbf{(9a)}$$

$$\mathbf{R = M_j \times (p \times e^{r,hot} + w \times e^{r,warm})} \qquad \textbf{(10a)}$$

where,

q: fraction of gasoline powered vehicles equipped with fuel injection,
p: fraction of trips finished with hot engine (dependent on the average monthly ambient temperature),
w: fraction of trips finished with cold or warm engine[1] (shorter trips) or with catalyst below its light-off temperature,
x: mean number of trips of a vehicle per day, average over the year, i.e.

$$\mathbf{x = M_j / (365 \times l_{trip})} \qquad \textbf{(11)}$$

$e^{s,hot}$: mean emission factor for hot soak emissions (which is dependent on fuel volatility RVP),
$e^{s,warm}$: mean emission factor for cold and warm soak emissions (which is dependent on fuel volatility RVP and average monthly ambient temperature),
e^{fi}: mean emission factor for hot and warm soak emissions of gasoline powered vehicles equipped with fuel injection,
$e^{r,hot}$: average emission factor for hot running losses of gasoline powered vehicles (which is dependent on fuel volatility RVP and average monthly ambient temperature),

[1] Engines are defined as 'cold' or 'warm' if the water temperature is below 70^{o}C

$e^{r,warm}$: average emission factor for warm running losses of gasoline powered vehicles (which is dependent on fuel volatility RVP and average monthly ambient temperature),

M_j: total annual mileage of gasoline powered vehicles of category j.

As previously demonstrated, the evaporation losses depend on the technology used, the fuel properties and the average ambient temperatures. The basic emission factors, which are necessary to apply the methodology, are listed in Table 5.32 for uncontrolled and controlled vehicles (based mainly on CONCAWE 1987, 1990a, Heine 1987, US EPA 1990). However, it should be mentioned that the authors consider the data base as still far too small, so that the reliability of the estimates obtained when using the emission factors is not very satisfactory.

Apart from the emission factors, the proposed methodology requires a number of statistical data which are more likely not available in many countries, e.g. the parameters **p**, **w** and **x**.

The fraction of trips finished with cold and warm engine, **w**, is connected with the β-parameter used in the calculation of cold start emissions: both depend, inter alia, on ambient temperature. In the absence of better data, the assumed relation between **w** and β is:

$$w \sim \beta \qquad (12)$$

Parameter β depends on the average trip length l_{trip}. This indicates that, for the calculation of the cold start emissions and soak emissions, the average trip length is of great importance.

4.7.5. Alternative approach for calculating evaporation losses

Application of the standard CORINAIR methodology (in particular in the framework of the Auto Oil programmes) showed that this method fails to account correctly the recently decided advances in terms of legislative evaporative losses testing and improved fuel volatility, resulting in somewhat overstated reductions compared to the first generation of controlled cars.

Therefore, in this section an alternative methodology is presented for calculating evaporation emissions: This method was developed based on a revision of the research work undertaken by CONCAWE during the late 80's/early 90's (CONCAWE, 1987, 1990a, 1990b, 1992). This method attempts to account for the relationship between the 'SHED performance' and 'in-service' performance. In other words it addresses the question 'how will a vehicle that passes the SHED test perform on the road'. As such it is possible to quantify the benefit of the recent improved SHED test procedure[2] in conjunction with the mandating of 60 kPa summer grade gasoline throughout the European Union from 2000 onwards. In all cases, performance is expressed by a simple efficiency term, which relates 'controlled' losses to 'uncontrolled'.

[2] Directive 98/69/EC of the European Parliament and of the Council, 13 October 1998.

a. Uncontrolled vehicle losses

The following relationships for Hot Soak Losses (**S**), Running Losses (**R**) and Diurnal Loss (**e^d**) have been derived from the Concawe reports referenced before. *In each case the formulation has been adjusted to for RVP expressed in mbar rather than kPa (1 kPa=10 mbar)* while temperature is given in °C. Total estimates of evaporation losses are based on equation (7b), where relevant emission factors are expressed in g/veh./day:

$$E_{EVA,\,VOC;\,j} = 365 \times N_j \times (e^d + S + R) \qquad (7b)$$

In this case **S** accounts for total soak losses and it is not further distinguished in hot or warm, neither it depends on the fuel evaporation system of the vehicle (basically it is assumed that all uncontrolled vehicles are carburettor equipped).

$$S = 3{,}4 \times EXP\,[32{,}18 + LN\,(RVP / (T_{max} + 8{,}13)) + (0{,}26 - 10201 \times RVP) / (T_{max} + 273)] \qquad (8b)$$

$$R = 35 / 45 \times EXP\,[63{,}78 + LN\,(RVP / (T_{max} + 6{,}0)) + (0{,}9 – 20119 \times RVP / (T_{max} + 273)] \qquad (9b)$$

$$e^d = -25 + 0{,}51 \times (T_{max} - T_{min}) + 0{,}62 \times T_{max} + 0{,}022 \times RVP \qquad (10b)$$

b. Controlled losses:

As indicated above, the approach taken to determine controlled losses is based on determining the emission reduction efficiency of the canister system over uncontrolled losses. The first step involved determining the minimum requirements for the evaporative control system to pass the SHED test procedure (size/purge). The second step, based on monthly marked RVP and Temperature data in each European country, was to determine the 'in-service' performance expressed as a reduction efficiency over uncontrolled losses. The resulting matrix of efficiency by country by month is given in Tables 4.6 and 4.7 Table 4.6 reflects the efficiencies prior to the introduction of the revised SHED test procedure and requirement for 600 mbar RVP gasoline, both from 2000 onwards. Table 4.7 reflects the post-2000 situation. For countries not included in those Tables, it is proposed that canister efficiency values corresponding to a country of similar climatic conditions should be used.

Note: Prior to 2000, the efficiency should be based on Table 4.6, post 2000 the efficiencies given in Table 4.7 should be used, even for 'controlled' vehicles registered before January 1st 2000.

4.7.6. Note on the two methodologies

From a technical point of view, the following must be stressed:

There are significant differences between the two methods, as regards the emissions of uncontrolled vehicles. The difference comes mainly from the hot soak losses, which are by far greater in the standard CORINAIR approach than in the alternative method. This is due to the fact that overwhelming hot soak losses are reported by American and older European data (US EPA 1990, 1991, Heine et al., 1987), while CONCAWE reports hot soak losses of the same order of magnitude with diurnal losses.

The differences are insignificant as regards the evaporation losses of the first generation of controlled vehicles (Euro I and Euro II).

It is considered that the alternative approach better accounts for the evolution of evaporation control technology (i.e. Euro III and Euro IV vehicles). As already mentioned the standard CORINAIR approach results in overstated reductions, as it assumes high efficiencies of the canisters as early as for Euro I vehicles.

Therefore, when it comes to total evaporative emissions, individual differences are expected to be marginal in cases of fleets with controlled vehicles. In the opposite direction, evaporation losses of fleets with high shares of uncontrolled vehicles may be significantly different between the two methods.

Both methodologies have been incorporated in the software of COPERT III. It is in the hand of the user to decide upon the method to apply and a clear statement is needed when reporting the results.

Nevertheless, it is suggested that the standard CORINAIR approach is used in time series inventorying reporting where the relative – rather than the absolute – level of emissions is of more importance. However, when predicting the future the alternative approach is probably more appropriate especially as regards the simulation of overall effect of improved carbon canisters and purging strategies, as well as improved volatility fuels.

It is self evident that more work is necessary in this area.

4.8. Unleaded fuel allocation

Ideally, unleaded fuel consumption calculated with the proposed consumption factors should be equal to the statistical consumption provided by the user. However, it has been recorded that drivers of conventional (non-catalyst) vehicles may sporadically refuel their vehicles with unleaded gasoline to benefit from the lower prices of this fuel type (however, this is not recommended by manufactures due to the failure of unleaded fuel to provide the necessary lubrication of the engine valve stems). Therefore, statistical values provided for unleaded fuel consumption cannot be solely used to check the quality of calculations via an unleaded fuel balance because of the failure to identify the exact use of this fuel type. However, an alternative approach is adopted to allocate unleaded fuel consumption to vehicle classes introduced in COPERT III.

It is assumed that passenger cars originally considered to use leaded gasoline, have also the potential to operate on unleaded fuel, in cases where the statistical value provided for unleaded fuel exceeds the respective calculated one. To account for this, one or more vehicle classes are shifted to the use of unleaded fuel, until the calculated consumption of unleaded fuel equals or just exceeds the statistical one. This change starts from the most recent leaded gasoline classes ('Improved Conventional' vehicles) and can reach up to 'PRE ECE' ones in cases where a large positive deviation exists between the statistical and the calculated value. Preferably, consumption of vehicles of large engine capacity is corrected first. Table 4.5 provides the exact sorting of vehicle classes applied to allocate unleaded fuel.

However, in actual inventories corrections should not exceed a few vehicle classes. In cases where a large number of classes need to be shifted from leaded to unleaded fuel use, input data should be checked and probably corrected.

Moreover, the ban of unleaded fuel expected to take place by 2000 in most Member States, may render this discussion obsolete.

4.9. Fuel balance

As a rule, the total calculated fuel consumption per fuel type should be equal to the consumption statistics provided by the user. If however the calculated value does not match the true one, the 'soft' input variables should be modified. By 'soft' in this case it is meant those variables associated with large uncertainty intervals. Since the availability of statistical data differs from one country to another, it is up to national experts to make the appropriate modifications. However, the authors have the impression that the distribution of mileage in driving conditions (urban, rural, highway) and the respective average travelling speeds are those variables for which most attention should be given in most of the cases.

4.10. Fuel dependent emissions

In principle, total emission estimates for pollutants depending on fuel consumption should be derived on the basis of the statistical (true) fuel consumption provided by the user. However, the necessity to allocate emissions to different vehicle categories (and classes) cannot be covered solely by means of the statistical consumption which is not separately provided for each vehicle class. In order to achieve both aims, first fuel dependent pollutants are calculated on the basis of the calculated fuel consumption (per vehicle class) and then a correction is applied based on the true consumption. In mathematical terms, this correction can be expressed:

$$\mathbf{E}^{\mathbf{CORR}}_{\mathbf{i,jm}} = \mathbf{E}^{\mathbf{CALC}}_{\mathbf{i,jm}} \times \frac{\mathbf{FC}^{\mathbf{STAT}}_{\mathbf{m}}}{\sum_{\mathbf{jm}} \mathbf{FC}^{\mathbf{CALC}}_{\mathbf{jm}}} \qquad \mathbf{(13)}$$

where,

$\mathbf{j_m}$: class j (1-98) from Table 3.2 operating on fuel type m,

$\mathbf{E}^{\mathbf{CORR}}_{\mathbf{i,jm}}$: the corrected emission of fuel dependent pollutant i (CO_2, SO_2, Pb, HM) for vehicle class j_m,

$\mathbf{E}^{\mathbf{CALC}}_{\mathbf{i,jm}}$: the emission of fuel dependent pollutant i estimated on the basis of the calculated fuel consumption of vehicle class j_m,

$\mathbf{FC}^{\mathbf{STAT}}_{\mathbf{m}}$: the statistical (true) total consumption of fuel type m (leaded gas unleaded gasoline, diesel, LPG)

$\sum_{\mathbf{jm}} \mathbf{FC}^{\mathbf{CALC}}_{\mathbf{jm}}$: the total calculated fuel consumption of all vehicle classes operating on fuel type m.

In that respect, total emission estimates for any emission dependent pollutant equals that derived by the statistical fuel consumption while there is still information provided for the allocation of emissions to different vehicle classes. The calculation of value $\mathbf{E}^{\mathbf{CALC}}_{\mathbf{i,jm}}$ is demonstrated in the following paragraphs.

4.10.1. *Carbon dioxide emissions*

Ultimate CO_2 emissions are estimated on the basis of fuel consumption only, assuming that the carbon content of the fuel is fully oxidised into CO_2. The following formula is applied:

$$\mathbf{E_{CO_2,j}^{CALC} = 44{,}011 \times \frac{FC_{jm}^{CALC}}{12{,}011 + 1{,}008 r_{H:C,m}}} \qquad \textbf{(14)}$$

where,

$\mathbf{r_{H:C,m}}$ the ratio of hydrogen to carbon atoms in the fuel (~1,8 for gasoline and ~2,0 for diesel).

If **end-of-pipe CO_2** emissions are to be calculated, then other emissions of C atoms in the form of CO, VOC and particulate emissions have to be taken into account. Then the following formula is applied:

$$\mathbf{E_{CO_2,j}^{CALC} = 44{,}011 \times \frac{FC_{jm}^{CALC}}{12{,}011 + 1{,}008 r_{H:C,m}} - \frac{E_{jm}^{CO}}{28{,}011} - \frac{E_{jm}^{VOC}}{13{,}85} - \frac{E_{jm}^{PM}}{12{,}011}} \qquad \textbf{(15)}$$

4.10.2. *Sulphur dioxide emissions*

The emissions of SO_2 are estimated by assuming that all sulphur in the fuel is transformed completely into SO_2 using the formula:

$$\mathbf{E_{SO_2,j}^{CALC} = 2 \times k_{S,m} \times FC_{jm}^{CALC}} \qquad \textbf{(16)}$$

where,

$\mathbf{k_{S,m}}$: weight related sulphur content in fuel of type m [kg/kg fuel].

4.10.3. *Lead and other heavy metals emissions*

Emissions of lead are estimated by assuming that 75 % of lead contained in the fuel is emitted into air (Hassel et al., 1987). The formula used is:

$$\mathbf{E_{Pb,j}^{CALC} = 0{,}75 \times k_{Pb,m} \times FC_{jm}^{CALC}} \qquad \textbf{(17)}$$

where,

$\mathbf{k_{Pb,m}}$: weight related lead content of gasoline (type m) in [kg/kg].

With regard to the emission of other heavy metal species, emission factors provided correspond both to fuel content and engine wear. Therefore it is considered that the total quantity is emitted to the atmosphere (no losses in the engine). Therefore, emissions of heavy metals included in Group 2 are calculated by means of:

$$\mathbf{E_{i,j}^{CALC} = k_{i,m} \times FC_{jm}^{CALC}} \qquad \textbf{(18)}$$

where,

$\mathbf{k}_{i,m}$: weight related content of i- heavy metal in fuel type m [kg/kg fuel].

Table 5.40 presents the fuel content in mg/(kg fuel) for Cadmium, Copper, Chromium, Nickel, Selenium and Zinc, as provided by the Expert Panel on Heavy Metals and POPs of the UNECE Task Force on Emission Inventories. However, these emission factors have to be considered as preliminary estimates only. More measurements are needed in order to confirm these values.

4.11. Emissions of non-regulated pollutants

4.11.1. Nitrous oxide emissions

Emission factors for N_2O are roughly estimated on the basis of literature review for all vehicle categories (Pringent et al., 1989; Perby, 1990; de Reydellet, 1990; Potter, 1990; OECD, 1991; Zajontz et al., 1991 and others). Again these data are still quite unreliable and need further confirmation by measurements. There is no separate methodology for estimating cold start over-emissions but they are assumed to be already incorporated in the bulk emission factors. Therefore total emissions estimates for Nitrous Oxide are made by application of equation 3, substituting $\mathbf{e}_{HOT;\, i,j,k}$ with the total emission factors provided in Table 5.34 for each vehicle category.

4.11.2. Ammonia emissions

For estimating ammonia emissions average emission factors are given for conventional and closed loop gasoline passenger cars and light duty vehicles and diesel passenger cars and light duty vehicles, related to the total annual kilometres driven. Again, no separate calculation is made for cold start over-emissions. Application of equation 3 provides total ammonia estimates by using emission factors provided in Table 5.35.

These emission factors are based on literature review only and should be considered as broad estimates (de Reydellet, 1990; Volkswagen, 1989).

4.11.3. PAHs and POPs

Emission factors (in [μg/km]) for polycyclic aromatic hydrocarbons (PAHs) and persistent organic pollutants (POPs) are given in Table 5.38 for different species and vehicle categories. A rough distinction is made to conventional (pre Euro I) and closed loop catalyst equipped vehicles (Euro I and on). For diesel passenger cars and light duty vehicles, different emission factors are quoted for direct injection and indirect injection vehicles. Since statistical information on the distribution of fleet vehicles according to their combustion concept is difficult to collect, it is proposed to use the average (DI, IDI) emission factor to estimate emissions from diesel non heavy-duty vehicles.

Table 5.38 provides emission factors for the six protocol pollutants (indeno(1,2,3-cd)pyrene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(ghi)perylene, fluoranthene, benzo(a)pyrene) and several others. Those emission factors should be considered as bulk values and no distinction is made to hot and cold start emissions. They have been developed on the basis of literature review including the following sources: BUWAL, 1994; TNO, 1993; Volkswagen, 1989. Application of equation 3 with those emission factors provides total emissions of PAHs and POPs per vehicle class.

Although this introduces just another simplification, PAHs and POPs emissions from 4 stroke motorcycles are estimated with the same emission factors used for conventional gasoline passenger cars. This approach is due to modification as soon any results on emissions of such species from motorcycles become available.

4.11.4. Dioxins and furans

Emission factors of Dioxins and Furans are given in Table 5.39 separately to other POPs because an aggregate toxicity equivalent emission factor is provided in this case. This emission factor takes into account the toxicity of different Dioxin and Furan species according to the NATO - Committee on the Challenges of the Modern Society (NATO-CCMS). Actual emission rates of different Dioxin and Furan species have been collected from the available literature sources (Umweltbundesamt, 1996). The final value is a bulk emission factor expressed in [pg/km]. Due to the limited available information, emission factors provided need to be reconsidered when updated data become available. In order to keep a consistent approach for all vehicle sources, Dioxin and Furan emissions from 4 stroke motorcycles are calculated with the same toxicity equivalent emission factors as of conventional gasoline vehicles.

4.12. NMVOC Species profile

The content of non methane VOCs in different species is given in Table 5.36a and Table 5.36b. Proposed fractions have been obtained by results published in the literature (BUWAL, 1994; TNO, 1993; Volkswagen, 1989; Umweltbundesamt, 1996). Fractions quoted in those Tables are applied to the total NMVOC emissions from vehicle classes classified as conventional (pre Euro I) or closed loop catalyst equipped (Euro I and on) gasoline passenger cars and light duty vehicles, diesel passenger cars and light duty vehicles, diesel heavy duty vehicles and LPG passenger cars. A common speciation is proposed for diesel passenger cars and light duty vehicles, regardless of the combustion concept (DI or IDI).

NMVOC speciation from four stroke motorcycles is estimated with fractions derived from conventional gasoline vehicles as in the case of PAHs and POPs. This approach needs to be reconsidered when more complete data become available.

5. Application of the baseline methodology to the different vehicle categories and pollutants

According to the availability of the input data and the relevant significance of the three types of emissions (hot, cold start and evaporation) for each type of vehicle and fuel, modified approaches have been adopted for different vehicle categories and classes to estimate emissions. Table 5.1 provides a summary of the proposed methods (classified according to type of emissions) and Table 5.2 displays the specific method adopted per vehicle category and pollutant. The following present a more detailed description on the application of each method for - at least the pollutants of Group 1 - and fuel consumption. The simplified approaches applied for the calculation of emissions from pollutants of other groups have already been described in chapter 4.

5.1. Gasoline passenger cars <2,5 tonnes

5.1.1. Pre Euro I – 'Conventional'

a. Hot emissions
Hot emission factors for conventional, improved conventional and open loop vehicles are given in Tables 5.3, 5.4, and 5.5 for different pollutants and Table 5.7 provides fuel consumption factors for the same vehicles. Those emission factors have been developed in the framework of older COPERT exercises (Eggleston et al., 1989). Separate equations are valid for different speed ranges and engine capacity classes.

b. Cold start emissions

Table 5.29 provides e^{COLD}/e^{HOT} over-emission ratios for pollutants of Group 1. The β-parameter is calculated by means of equation provided in Table 5.26. Introduction of those values in equation 5, together with the hot emission factors quoted previously provides estimates of cold start emissions. Again, those ratios have been produced during older COPERT versions.

c. Evaporation losses
Vehicles of pre-Euro I legislation classes are considered uncontrolled by default. Furthermore, only carburettor-equipped vehicles are considered. Therefore evaporation calculations are based on the uncontrolled emission factors corresponding to carburettor vehicles (Table 5.32). The β-parameter is calculated according to the formula of Table 5.26. If the alternative approach is adopted (§4.7.5), then the uncontrolled corresponding equations need to be applied.

5.1.2. Euro I

a. Hot emissions
Hot emission factors of this vehicle class have been developed in the framework of MEET and are quoted in Tables 5.3 to 5.5 (fuel consumption factors in Table 5.7). Equations provided hold for the range 5-130 km/h with no further distinction in speed classes. However, there is a distinction to different engine capacity classes. The low correlation coefficients provided are an indication of the highly scattered individual values about the estimated value. A detailed analysis of those effects are

thoroughly discussed in various publications (Samaras and Ntziachristos, 1998; Ntziachristos and Samaras, 1999).

b. Cold start emissions

Emissions of catalyst equipped vehicles during the warming up phase are significantly higher than during stabilised thermal conditions due to the negligible efficiency of the catalytic converter at temperatures below the light-off. Therefore, the effect of cold start has to be modelled in detail in the case of Euro I vehicles. Table 5.28 provides $\mathbf{e^{COLD}/e^{HOT}}$ over-emission ratios for three main pollutants (and fuel consumption). The values proposed are a result of fitting the existing COPERT methodology to the results recently published by MEET (Hickman et al., 1999), and are a function of ambient temperature and average travelling speed. Two speed regions have been introduced (5-25 km/h and 25-45 km/h). As in the case of hot emission factors, the value introduced for speed should correspond to the mean speed during travelling and not to the instantaneous speed. The speed range proposed is sufficient to cover most applications because cold start over-emissions are in principle allocated to urban driving only.

In the cases of CO and VOC over-emission occurs not only because of the low catalyst conversion efficiency but also because of the fuel enrichment during cold start conditions which allows for better drivability of a cold engine. The enrichment depends on the engine temperature during cold start. Therefore, over-emission of those pollutants during cold starts is not only higher than NO_x (which is generally not sensitive to fuel enrichment) but it also has a stronger dependence on temperature. This is why two different temperature ranges have to be distinguished for those pollutants.

At relatively high temperatures the proposed functions receive values less than unit. In this case, results should be replaced by unit. Generally, cold start effect becomes negligible in the region of 25°C in the case of CO and 30°C in the case of VOC. This is not only because over-emission under such ambient conditions is limited but also because actual engine start-up temperature can still be high after several hours of parking.

The mileage fraction driven during the warming up phase is calculated by means of the formula provided in Table 5.26. After calculating the β-parameter and the $\mathbf{e^{COLD}/e^{HOT}}$ over-emission ratios, the application of equation 5 or 6 is straightforward.

c. Evaporation losses

Almost all vehicles in this class are equipped with carbon canister, which eliminates fuel evaporation losses from the fuel tank, and fuel injection which reduces evaporation losses from the engine side. Therefore, overall evaporation losses are significantly reduced compared to conventional vehicles. Emission factors with the standard CORINAIR method are calculated by the formulas quoted in Table 5.32, corresponding to controlled vehicles equipped with fuel injection. However, the exact fraction of controlled and/or fuel injected vehicles should be provided in case that such data are available. Again, the β-parameter used to substitute $\mathbf{w}$ in equation 12 is calculated according to the formula of Table 5.26. In case the alternative approach is adopted, calculations should take into account the canister efficiency according to Table 4.6 if the calculation corresponds to year 1999 and before, or according to Table 4.7 for post-2000 calculations.

5.1.3. Post Euro I

a. Hot emissions

Hot emissions estimates for post-Euro I vehicles are calculated on the basis of reductions brought in the emission factors of Euro I vehicles due to the lack of experimental data. The reduction factors development has been conducted in the framework of the Auto Oil II exercise. It is based on the assumption that for any pollutant, the ratio of emission factor of any post-Euro I class over a reference class would be equal to the ratio of the respective emission standards. By taking Euro I vehicles as the reference, this assumption can be mathematically expressed as:

$$\frac{e_{TOT\,i}^{\;j}}{e_{TOT\,i}^{\;EURO\,I}} = \frac{ES_i^j}{ES_i^{EURO\,I,\,COP}} \qquad (19)$$

where,

$e_{TOT\,i}^{\;j}$: total emission factor of pollutant i for vehicle class j (j = Euro II, Euro III, Euro IV)

$e_{TOT\,i}^{\;EURO\,I}$: total emission factor of pollutant i of Euro I vehicles

ES_i^j: the emission standard of pollutant i for vehicle class j (j = Euro II, III, IV)

$ES_i^{EURO\,I,\,COP}$: the conformity of production emission standard for pollutant I of Euro I vehicles

One has to note that reductions cannot be solely brought in hot emissions because emission standards also include a cold start fraction. Therefore a part of the reduction is attributed to cold emissions. However, based on this assumption, representative reduction factors of hot emissions are given in Table 5.6 for all pollutants in Group 1. Therefore, in the case of post-Euro I vehicles, the calculation of hot emissions is made by means of equation 3, where $e_{HOT;\,i,\,j,\,k}$ should be replaced with:

$$e_{HOT;\,i,\,j,\,k} = (100-RF_{i,j}) / 100 \times e_{HOT;\,i,\,EURO\,I,\,k} \qquad (20)$$

where,

$RF_{i,j}$: the reduction factor as given by Table 5.6 for class j and pollutant i,

$e_{HOT;\,i,\,EURO\,I,\,k}$: the hot emission factor of Euro I vehicles (Tables 5.3 to 5.5) calculated for the average speed corresponding to vehicles of class j driven on roads of type k.

A separate statement needs to be made for the case of methane reduction factors. Current evidence suggests that the percentage of methane in the total VOC fraction increases in late catalyst vehicles because of its slower oxidation in the catalytic converter, compared to larger molecule hydrocarbons. However, the quantification of the increase is not possible with the available experimental data. The application of the methodology therefore assumes that the percentage of methane does not depend on the vehicle emission reduction technology. As a result the reduction factor assumed for VOC emissions (Table 5.6) to estimate emissions of post-Euro I vehicles needs to be equally applied to the NMVOC and CH_4 emission factors of Euro I vehicles.

b. Cold start emissions

Emission reduction compared to Euro I during the warming up phase of recent and future vehicle technologies mainly comes from the reduced time which is required from new catalytic systems to reach the light-off temperature. This time reduction is further reflected to a decrease in the distance travelled with a partial warmed engine and/or exhaust aftertreatment devices. Therefore, reduced cold start emissions are simulated with a respective decrease of the β-parameter, which stands for the mileage fraction driven with a cold or partially warmed engine. Table 5.27 provides reduction factors ($\mathbf{bc_{i,j}}$) to be applied on the β-parameter according to pollutant and vehicle class. The different reduction factors proposed for each pollutant are due to the particularities of the application of equation 19 rather than the different time required to reach light off conditions (this should very little differ for CO, NO_x and VOC).

On the other hand, the actual over-emission rate should not substantially differ between vehicle classes[3]. This means that the $\mathbf{e^{COLD}/e^{HOT}}$ value calculated for Euro I vehicles can be also applied in the case of later vehicle classes without further reductions. In the same respect, even the hot emission factor involved in the equation of cold start over-emission of post-Euro I vehicles should keep the Euro I calculated value. This is valid because, as mentioned before, there is no evidence for significant reduction of the rate of over-emission for later than Euro I vehicle classes.

Therefore, equation 5 in the case of post-Euro I vehicle classes yields:

$$\mathbf{E_{COLD;i,j} = bc_{i,j} \times \beta_{i,EURO\,I} \times N_j \times M_j \times e_{hot,\,i,\,EURO\,I} \times (e^{cold} / e^{hot} - 1)|_{i,EURO\,I}} \qquad \mathbf{(21)}$$

Respective modifications should also be brought in equation 6 in cases where: $\mathbf{bc_{i,j} \times \beta_{i,EURO\,I} > S_U}$. It is obvious that the corrected value should be used for the mileage fraction during the warming up phase.

c. Evaporation losses

All vehicles falling in those classes are equipped with carbon canister and fuel injection. Therefore corresponding evaporation emission factors are those of controlled, fuel injected vehicles (Table 5.32). It has been observed that the proposed, controlled vehicle equations lead to very low levels of evaporation losses, levels which are the target of the current legislation. Therefore, for application of the standard CORINAIR approach, it is not advised to further decrease the **w**-parameter (equation 12), according to the corrected β-parameter (thus applying the $\mathbf{bc_j}$ values) because this would lead to very low evaporation levels from future vehicle technologies. Such low levels cannot be justified by the evaporation control technology implemented on the vehicles. Therefore, equation 12 should be calculated with the original β-parameter as given by the equation of Table 5.26. In case of application of the alternative approach, values

[3] However this statement probably fails to predict the additional emission reduction which might be brought by the introduced cold start testing for Euro III and later vehicles, conducted at -7°C. Most probably, the mixture enrichment strategy has to be changed if future vehicles have to comply with this test. This in it s turn will lead to a reduction of the $\mathbf{e^{COLD}/e^{HOT}}$ ratio. However the magnitude of the effect of such modification at higher temperatures is arguable. Because of this reason and in the absence of a more detailed analysis for the time being, it was decided to abandon any correction of $\mathbf{e^{COLD}/e^{HOT}}$ ratio.

from Table 4.6 need to be selected for Euro II equivalent canister efficiency and values from Table 4.7 for later emission technologies.

5.2. Diesel passenger cars < 2,5 tonnes

5.2.1. Pre Euro I and Euro I

a. Hot emissions

Based on a relatively large number of measured data on emissions of diesel passenger cars <2,5 tonnes (CCMC, 1989; Hassel et al., 1987; Pattas et al., 1985; Rijkeboer et al., 1989, 1990) enabled to differentiate between cylinder capacities and to come up with speed dependent emission factors for conventional (pre Euro I) vehicles. Emission factors to be introduced in equation 3 for the calculation of hot emissions from conventional diesel passenger cars are given in Table 5.8.

From a methodological point of view, calculation of hot emissions from Euro I vehicles does not differ from conventional ones. Table 5.9 provides emission factors for pollutants of Group 1. In the case of Euro I vehicles, engine capacity does not seem relevant to characterise emissions and thus no distinction is made to different engine capacity classes.

b. Cold start emissions

Cold start over-emissions from diesel vehicles are not very significant compared to gasoline vehicles. Therefore, no distinction is made between conventional and Euro I vehicles. $\mathbf{e^{COLD}/e^{HOT}}$ ratios for calculating cold start over-emissions for those vehicles are quoted in Table 5.30.

5.2.2. Post Euro I

a. Hot emissions

Emissions of post-Euro I vehicle classes are calculated by introducing proper reduction factors to the emission factors of the Euro I class. In principle, the approach introduced by equation 19 holds also in the case of diesel vehicles. However, the initial low values of the emission factors compared to the emission standards of Euro I vehicles brings no additional reductions of Euro II vehicles compared to Euro I. Especially in the case of CO, it is proposed that emission factors of Euro I vehicles should not reduced even up to Euro IV vehicles. Therefore, hot emission factors of post-Euro I diesel passenger cars are calculated by application of equation 20 by introducing the relevant reduction factors given in Table 5.10.

b. Cold start emissions

Reduction factors proposed for hot emissions are also applicable for cold start over-emissions from diesel passenger cars. The β-parameter is calculated by the formula given in Table 5.26 for all classes. $\mathbf{e^{COLD}/e^{HOT}}$ ratios are quoted in Table 5.30 and are the same as in the case of conventional and Euro I diesel vehicles. Therefore, application of equation 5 in this case yields:

$$\mathbf{E_{COLD;i,j} = \beta_{i,j} \times N_j \times M_j \times (100\text{-}RF_{i,j}) / 100 \times e_{HOT;\,i,\,EURO\,I} \times (e^{COLD} / e^{HOT}|_{i,EURO\,I} - 1)} \qquad \mathbf{(22)}$$

Again, a similar transformation needs to be made in the case of equation 6.

5.3. LPG passenger cars <2,5 tonnes

The methodology introduced in the case of gasoline passenger cars is valid also in the case of LPG vehicles. However, it has to be stressed that the amount of data in the case of LPG vehicles was very limited and therefore a large number of assumptions and extrapolations has to be made on the basis of existing information to provide a consistent set of emission factors to calculate hot and cold start emissions.

a. Hot emissions
Equation 3 is applied to calculate hot emissions for conventional and Euro I LPG vehicles. Table 5.11 provides hot emission factors for conventional passenger cars and Table 5.12 for those complying with 91/441/EEC (Euro I). The former emission factors have been developed in the framework of earlier COPERT exercises and the latter ones in the framework of MEET (Samaras and Ntziachristos, 1997). In respect to current and future vehicle classes (post-Euro I) of LPG vehicles and in the absence of more updated data, it is proposed to introduce reductions proposed for gasoline vehicles (Table 5.6) in equation 19.

b. Cold start emissions
Very few data on cold start over-emission from LPG vehicles are available (AQA, 1990; Hauger et al.; 1991). For consistency however and since LPG emission limitation technology is similar to that of gasoline vehicles, the methodology applied to calculate emissions from gasoline vehicles is also applied here. Table 5.31 provides over-emission ratios which are valid for all emission classes of LPG vehicles. Equations 5, 6 are applied up to Euro I vehicles while equation 21 is applied to post-Euro I ones. Reduction factors for the β-parameter equal those of gasoline vehicles (Table 5.26).

5.4. Two-stroke passenger cars <2,5 tonnes

Few measured data are available (Appel et al., 1989; Jileh, 1991; Pattas et al., 1983) which have been used to derive emission factors for urban, rural and highway driving for two-stroke gasoline powered cars in the framework of older COPERT exercises.

Total emission factors (hot + cold) are given in Table 5.13. They are relevant mainly for some Eastern European countries (and to some extent for Germany). However, it should be noted that due to the limited knowledge of the authors about the actual driving behaviour in Eastern European countries (e.g. average speed on urban and rural roads and on highways) and the limited number of test data, the emission factors are less reliable than, for example, those given for other gasoline passenger cars.

5.5. Gasoline light duty vehicles

a. Hot emissions
In the EU the emissions of these vehicles were covered by the different ECE steps. All those vehicle classes have been introduced in a common ‘Conventional’ class and emission factors for pollutants of Group 1 are given in Table 5.14. Emission factors of Euro I vehicles can also be found in the same Table. Hot emission factors of post-Euro I vehicles are calculated by application of equation 20 by introducing the reduction factors given in Table 5.15. Those reduction factors have been based on the rationale introduced by equation 19.

b. Cold start emissions

The same over-emission ratios applied in the case of gasoline passenger cars (case >2.0 l) are also applied in the case of light duty vehicles in the absence of more detailed data. Although this was a very rough estimate for past vehicle classes, due to the very different emission standards of light duty vehicles and passenger cars, it tends to be a reality since the technology introduced nowadays in light duty vehicles does not significantly differ from respective passenger cars. Therefore the over-emission ratios proposed in Tables 5.29 (pre-Euro I) and Table 5.28 (Euro I and on) are applied in the case of light duty vehicles. Furthermore, equations 5, 6 are valid for pre-Euro I vehicles and equation 21 for Euro I and later ones in conjunction with the β-parameter reduction factors given in Table 5.27.

c. Evaporation losses

Again, the same approach adopted in the case of passenger cars is applied here. Conventional vehicles are treated as uncontrolled, carburettor equipped passenger cars while Euro I and later technologies are treated as controlled, fuel injected vehicles. Table 5.32 provides the respective emission factors for each case. As in the case of cold start emissions, this is merely a simplification, because it implies the assumption that light duty vehicles are used in the same way as passenger cars. The same applies for the alternative evaporation approach.

5.6. Diesel light duty vehicles

Diesel light duty vehicles are treated as passenger cars. Hot emission factor speed dependencies have been developed in the framework of older COPERT exercises (Conventional vehicles) and in the MEET project (Euro I and later vehicles) and are quoted in Table 5.16 for pollutants of Group 1. Cold start over-emissions up to Euro I are calculated with the help of equation 5, where $\mathbf{e^{COLD}/e^{HOT}}$ are selected from Table 5.30. Emission factors of post-Euro I vehicle classes are calculated by the functions corresponding Euro I vehicles by introducing the reduction factors given in Table 5.17 both for hot and cold start emissions (equations 3, 19 and 21 respectively).

5.7. Gasoline heavy duty vehicles

Only hot emissions are calculated for gasoline heavy duty vehicles. Emission factors derived from an extrapolation of results from smaller vehicles are presented in Table 5.18 and are distinguished only to the three driving modes (urban, rural, highway). Total emission estimates are therefore calculated by application only of equation 3.

5.8. Diesel heavy duty vehicles and busses

Speed dependencies of emission factors for diesel heavy duty vehicles have been built on the results provided by the German/Swiss Handbook (Keller et al., 1995) and are quoted in Table 5.19. Similarly, Table 5.21 provides hot emission factors for urban busses and coaches. The emission factors proposed correspond only to Conventional (pre 91/542/EEC Directive) vehicles. Estimation of emissions from improved vehicles is made by introducing the reduction factors given in Table 5.20 for different weight classes of heavy-duty vehicles, busses and coaches. Those factors are in principle based on application of equation 19 with the emission standards imposed by Stage 1 and 2 of 91/542/EEC or the different Proposals.

Because of the different emission performance for different driving conditions, reduction factors are distinguished to urban, rural and highway.

5.9. Two-stroke mopeds <50 cm³

Mopeds are mostly driven under ‘urban’ driving conditions and therefore only an urban emission factor value is proposed in Table 5.23. Reduction factors for improved moped technologies are given in Table 5.24. Emissions factors should be considered as bulk values which include the cold start fraction, therefore no distinction is made to hot and cold start emissions

5.10. Motorcycles >50 cm³

As far as motorcycles are concerned, a recent inventory made by Swiss and German institutes and published by the Swiss BUWAL (Keller et al., 1995) provides more information. In total 24 motorcycles (including motor scooters) were measured, of which 15 four-stroke and 9 two-stroke, and of which 8 (6 four-stroke and 2 two-stroke) had to comply with the stricter Swiss legislation. The vehicles were measured over the European UDC, the European EUDC, the American US-FTP (divided into the first and second part), the American Highway Cycle and the German Motorway Cycle. This allowed a speed dependency to be established.

Tables 5.22 displays the bulk (hot + cold) emission factors proposed for 2-sroke motorcycles and Table 5.25 for respective 4-stroke ones.

6. Emission corrections

The effect of different variables on the emission of vehicles is modelled in COPERT III. Corrections are applied to the emission factors, as they have been calculated by the baseline equations given in the previous chapters, to accommodate variation of emissions according to the various effects. Specifically, the effect on emissions of the following parameters are tackled:

a. Vehicle age (mileage). Baseline emission factors proposed in chapter 5 correspond to a fleet of average mileage (30-60 Mm) and an inherent degradation factor is implemented. Further emission degradation due to increased mileage is modelled by additional degradation factors. However, for the sake of consistency between the Member States, it is proposed not to introduce such corrections when compiling a baseline inventory up to the year 2000 because of the relatively young fleet age. However, when inventories and forecasts for future years need to be made, it is advised to correct emission factors according to mileage to introduce the effect of vehicle age in the calculations.

b. Enhanced Inspection and Maintenance scheme. Current European standards on in-service emission testing have been introduced with Directive 92/55/EEC which seeks for emission compliance at two idle conditions (low and high idling). This testing, with only minor modifications is today applied by all Member States. In case that an enhanced Inspection and Maintenance scheme was introduced (e.g. transient testing) then lower average emission levels would be reached from aged fleets. This effect has been simulated with correction of the degradation factors proposed. However, such correction has to be seen only as a relevant future scenario and should not be applied for a baseline national inventory.

c. Improved fuels. Improved fuel qualities become mandatory in the European Union after year 2000. The effect on the emissions of current and older vehicles is simulated again by means of relevant correction factors. Those corrections should only be applied in inventories compiled for years after the introduction of the improved fuels.

d. Road gradient on heavy duty vehicles emissions. Corrections are applied to heavy duty vehicle emissions in cases of driving on non-flat roads. The corrections should only be applied in national inventories by those Member States where statistical data allow for a distinction of heavy duty vehicle mileage on roads of positive or negative gradient.

e. Heavy duty vehicle load. By default, a factor of 50 % is considered for the load of heavy duty vehicles. In cases where significant deviations exist for the mean load factor of the heavy duty vehicle fleet, respective corrections can be brought by means of emission correction load factors.

The following provide a detailed description of the application of the various corrections.

6.1. Emission degradation due to vehicle age and effect of I&M schemes

6.1.1. Euro I gasoline passenger cars and light duty vehicles

The degradation of the emission reduction system efficiency with mileage for gasoline Euro I vehicles has been modelled in MEET. The degradation lines have been developed on the basis of emission measurements over the Urban and the Extra Urban part of the European Driving Cycle respectively. Table 6.1 provides the mileage functions used for the estimation of the effect of mileage on emissions from Euro I gasoline passenger cars of three different capacity classes over the two driving cycles (UDC, EUDC). The mileage correction, for a given average fleet mileage and specific cycle is given by means of:

$$MC_{C,i} = A^{M} \times M^{MEAN} + B^{M} \qquad (23)$$

where,

M^{MEAN}: the mean fleet mileage of vehicles for which correction is applied

$MC_{C,i}$: the mileage correction for a given mileage (M_{av}), pollutant i and a specific cycle (C: UDC, EUDC)

A^{M}, B^{M}: coefficients to be selected from Tables 6.1 and 6.2

The coefficient A^{M} corresponds to the degradation of the emission performance per kilometre. The correction factor at 0 km (B^{M} coefficient) reflects the emission level of a fleet of brand new vehicles. It is lower than 1 because emission functions proposed in COPERT III have been derived on the basis of an in-use vehicle sample of a specific average mileage (~30-50 Mm). Therefore, brand new vehicles are expected to emit less than the sample vehicles.

It was found that sample emissions tend to stabilise at the higher mileage region (above ~120.000 km). Therefore, it is assumed that emissions do not further degrade above this limit and a constant degradation value is applied on the base emission factor to calculate the emission level of older vehicles (this value is shown in the last Table 6.1 column).

The effect of speed on emission degradation is taken into account by combining the observed degradation lines over the two cycles. The actual emission degradation proposed for a speed different than that of the cycles is shown in Table 6.3. It is assumed that for speeds outside the region defined by the average speed over UDC (19 km/h) and EUDC (63 km/h), the degradation is independent of speed. Linear interpolation between the two values provides the emission degradation in the intermediate speed region.

Finally, the mileage corrected emission factor is calculated by means of the equation:

$$MCe_{HOT;\, i,\, EURO\ I,\, k} = MCorr_{i,\, EURO\ I}(\text{speed, mileage}) \times e_{HOT;\, i,\, EURO\ I,\, k} \qquad (24)$$

where,

$MCe_{HOT;\, i,\, EURO\ I,\, k}$: hot emission factor corrected for degraded vehicle performance due to mileage

$\mathbf{MCorr_{i,\,EURO\,I}}$: the mileage correction as proposed in Table 6.3 for a specific speed and mileage

$\mathbf{e_{HOT;\,i,\,EURO\,I,\,k}}$: the speed dependent emission factor (Tables 5.3 to 5.5)

The degradation proposed has been obtained from the emission performance of vehicles complying with Directive 92/55/EEC in what concerns their emission control system performance[4]. The improvement of an enhanced Inspection and Maintenance scheme which would include, e.g. testing of vehicles on a dynamometer, would most probably have an effect on the emission level of aged vehicles. The I&M project (LAT/AUTh et al., 1998) resulted in reductions of the emissions of catalyst passenger cars which would appear if an enhanced I&M scheme were in place. Those reductions are quoted in Table 6.4.

According to those reductions, new degradation lines are applied in case of an enhanced I&M scheme (Table 6.2). Emissions again are assumed to stabilise at the same level as of the 92/55/EEC corresponding ones. Although a reduction on the stabilisation level is also probable with an enhanced I&M scheme, the new stabilisation level cannot be established with the available measurement data. Therefore, the stabilisation mileage is also quoted in Table 6.2.

The stabilisation of degradation is achieved in most cases within the interval of 200 Mm, which is a reasonable figure. However and EUDC CO and large vehicles (capacity >2.0 l), the stabilisation is achieved at very high mileage. This has no physical meaning but it is rather an artefact of the applied correction methodology. On the other hand, this introduces no actual error to the calculations because the fleet fraction at this high mileage region is very limited. It is therefore proposed, for the sake of consistency, to keep the proposed I&M correction. Again, the emission degradation is modelled by application of equations 23 and 24 with coefficients A, B selected from Table 6.22.

It has to be stressed that these degradation lines are applicable on the hot emission factors and therefore cold-start overemission remains unaffected by degradation. This assumption is based on the fact that degradation is mainly induced from catalyst ageing which in any case does not affect substantially the cold start overemission. Therefore, equation 3 in case that mileage degradation correction has been applied for Euro I vehicles, yields:

$$\mathbf{E_{HOT;\,i,\,EURO\,I,\,k} = N_j \times M_{j,k} \times MCorr_{i,\,EURO\,I} \times e_{HOT;\,i,\,EURO\,I,\,k}} \qquad \mathbf{(25)}$$

While equations 5 and 6, for the calculation of cold start over-emission remains unmodified.

6.1.2. Euro II gasoline passenger cars and light duty vehicles

No further requirements have been set by the legislation on the emission performance degradation of Euro II vehicles, compared to Euro I ones. It is thus assumed that the same mileage degradation applied to Euro I vehicles should also hold for Euro II vehicles. Therefore the emission degradation for Euro II vehicles is given by the functions of Table 6.1 in the case of the I&M scheme defined by 92/55/EEC or by the functions of Table 6.2 in case an enhanced I&M project is

4 Most of the vehicles of the data base originate from countries who have adopted 92/55/EEC or some kind of equivalent legislation. In addition, the I&M project showed that the application of the provisions of the above Directive on roadworthiness will have marginal effects on the emissions of in-use cars.

introduced. However, equation 25 should be applied with the hot emission factor corresponding to Euro II vehicles.

6.1.3. *Euro III and IV gasoline passenger cars and light duty vehicles*

The control of emissions on in-use Euro III and newer vehicles will be achieved by extended catalyst durability and the introduction of OBD systems. It is reasonable therefore to assume that the emission degradation with mileage of such vehicles will be reduced compared to Euro I vehicles. Moreover, it is believed that not only hot emissions but cold start extra emissions may also be affected by the degradation of the catalyst and the engine control measures, especially in the case of the advanced catalyst controls of Euro IV.

However, due to absence of experimental data, one may assume that the degradation of Euro III & IV vehicles, irrespective of the valid I&M scheme, will be approached by the degradation observed for Euro I vehicles in the case of an enhanced I&M scheme. In other words, we assume that on board engine 'inspection' achieved by an OBD system will have the same results with an enhanced I&M scheme. For that reason, it is proposed to apply the degradation functions given in Table 6.2 applicable to hot emissions only and to calculate degradation according to equations 23 and 25.

6.1.4. *Conventional gasoline passenger cars and light duty vehicles*

No initial degradation due to mileage is given for conventional vehicles because of limited available data However, enhanced inspection and maintenance may also have an effect on the emission behaviour of conventional, non-catalyst vehicles. Therefore, it is proposed to apply the reduction factors of Table 6.5 on conventional vehicles, irrespective of their total mileage, in case an improved 92/55/EEC I&M scheme is introduced (e.g. a tightening of the CO standard and introduction of an additional HC standard, as suggested by the I&M project).

6.1.5. *Diesel passenger cars and light duty vehicles*

The findings of the I&M project indicate that - as expected - the diesel cars were found to be high polluters only in the case of particulate emissions. CO, HC and NO_X emissions were always found to be well below the emission standards. Therefore, in case an enhanced I&M scheme is introduced (e.g. continuous opacity measurement over a transient dynamometer test), then the possible effect on PM emissions should be in the order of a 10 % reduction with respect to the baseline emissions (i.e. vehicles complying with emission standards up to Euro II) irrespective of the mileage of the vehicles. This level of reduction potential is in line with the basic assumptions of Auto Oil I programme. No reduction is proposed for post-Euro II vehicles.

6.1.6. *Diesel heavy duty vehicles*

In view of the absence of any experimental data, the same approach as in the case of Diesel passenger cars is adopted, i.e. 10 % overall PM emission reduction up to Euro II in case that an enhanced I&M scheme is in place.

6.1.7. *Two wheelers*

The absence of experimental data in simulating the effect of mileage and inspection and maintenance on the emissions of two-wheelers, together with the different technology applied in such vehicles, compared to passenger cars, prohibits the application of any correction.

6.2. Fuel effects

Fuels of improved specifications will become mandatory in Europe in two steps, January 2000 (Fuel 2000[5]) and January 2005 (Fuel 2005) respectively. The specifications of those fuels are displayed in Table 6.10 (Gasoline) and Table 6.11 (Diesel). Because of their improved properties, the fuels result in lower emissions from vehicles. Therefore, the stringent emission standards of Euro III technology (introduced ~2000) are achieved with fuel quality 'Fuel 2000' and the more stringent emission standards of Euro IV and V with fuel quality 'Fuel 2005'. Table 6.6 shows the base emission fuel considered for each vehicle class.

However use of such fuels results in reduced emissions also from pre-Euro III vehicle technologies, for which the 1996 market average fuel is considered as basis (Table 6.6). Those reductions are equally applied to hot and cold start emissions. To correct the emission factors proposed in Tables of Chapter 5, equations derived in the framework of the EPEFE programme (ACEA and EUROPIA, 1996) are applied. Tables 6.7, 6.8 and 6.9 display the equations for different vehicle categories and classes.

The hot emission factors are corrected according to the equation:

$$\mathbf{FCe_{HOT;\,I,\,j,\,k} = FCorr_{i,\,j,\,Fuel} \,/\, FCorr_{i,\,j,\,Base} \times e_{HOT;\,i,\,j,\,k}} \qquad \mathbf{(26)}$$

where,

$\mathbf{FCe_{HOT;\,i,\,j,\,k}}$: the hot emission factor corrected for the use of improved fuel for pollutant I of vehicle class j driven on road types k

$\mathbf{FCorr_{i,\,j,\,Fuel}}$: the fuel correction for pollutant i, vehicle category j, calculated with equations given in Tables 6.7, 6.8, 6.9 for the available improved fuel qualities (Table 6.6)

$\mathbf{FCorr_{i,\,j,\,Base}}$: the fuel correction for pollutant i, vehicle category j, calculated with equations given in Tables 6.7, 6.8, 6.9 for the base fuel quality of vehicle class j (Table 6.6)

It is mentioned that equation 26 should not be used to provide the deterioration of emissions in case that an older fuel is used in a newer technology (e.g. use of Fuel 2000 in Euro IV vehicles by inversion of **FC** coefficients). The emission factor calculated via equation 26 should be introduced in equations 3 and 5 or 6 respectively to estimate hot and cold start emissions.

6.3. Road slope effect

The gradient of a road has the effect of increasing or decreasing the resistance of a vehicle to traction, as the power employed during the driving operation is the decisive parameter for the emissions of a vehicle. Even in the case of large-scale considerations, however, it cannot be assumed that - for example - the extra emission when travelling uphill is compensated by correspondingly reduced emission when travelling downhill.

In principle the emissions and fuel consumption of both light and heavy duty vehicles are affected by road gradient. Nevertheless, the overall gradient effect on the behaviour of light duty vehicles (passenger cars and light duty trucks) was found to be very small (e.g. Keller et al., 1995), lying in the range of uncertainty of the

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5 By convention

basic emission factors. However, because of their higher masses, the gradient influence is much more significant in the case of heavy duty vehicles. Therefore it was decided to incorporate in COPERT II only the gradient effect on the emissions of heavy duty vehicles. The method adopted is the one developed in MEET (LAT/AUTh et al., 1997), which is largely based on the results of a Swiss/German test programme (Hassel et al., 1993; Keller et al. 1995). The same method with no modifications is also transferred in COPERT III.

Special gradient factors have been introduced for each heavy duty vehicle weight class. Those emission correction factors are considered to be a function of :

- The vehicle mass
- The road gradient
- The pollutant or consumption
- The mean speed of the vehicle

Heavy duty vehicles of different mass behave differently during uphill or downhill driving due to the different load of the engine. For each heavy duty vehicle class special equations to calculate the gradient factors have been provided.

Is obvious that the effect of the slope on emissions and consumption will be highly dependant on the road gradient. In order to represent the actual conditions, four road gradient classes have been introduced. These classes are presented in Table 6.18. Positive road gradient corresponds to uphill driving and vice versa. Gradient factors apply to all major pollutants (CO, VOC, NO_x, PM) as well as fuel consumption.

For each vehicle weight category, gradient and pollutant, the gradient factor can be calculated as a polynomial function of the vehicle's mean speed:

$$GCorr_{i,j,k} = A_{6i,j,k}V^6 + A_{5i,j,k}V^5 + A_{4i,j,k}V^4 + A_{3i,j,k}V^3 + A_{2i,j,k}V^2 + A_{1i,j,k}V + A_{0i,j,k} \quad (27)$$

where,

$GCorr_{i,j,k}$: the emission correction factor for the effect of road gradient

V: the mean speed

$A_{0;\,i,j,k} \ldots A_{6;\,i,j,k}$: constants for each pollutant, weight and gradient class (Tables 6.12 to 6.17)

It is proposed to correct the emission factor calculated for vehicle's use on a flat road according to the following equation, in order to incorporate the influence of the road gradient:

$$GCe_{HOT;i,j,k} = GCorr_{i,j,k} \times e_{hot,i,j,k} \quad (28)$$

where,

$GCe_{HOT;i,j,k}$: corrected emission factor of the pollutant i in [g/km] of the vehicle of category j driven on roads of type k with hot engines

$GCorr_{i,j,k}$: gradient correction factor of the pollutant i in [g/km] of the vehicle of category j driven on roads of type k.

The corrected hot emission factor calculated with the help of equation 28 is then introduced in equation 3 to calculated total (hot) emissions from heavy duty vehicles.

6.4. Vehicle load effect

The emission and consumption factors used for heavy duty vehicles are representative only for a partially loaded vehicle, that is load factor of 50 % is taken into account. For the same road pattern, the engine needs to operate under different loads for increased or decreased total vehicle weight. It is obvious that the lower the vehicle weight, the less load is demanded from the engine and vice versa. As a result, the consumption as well as the emission rate of the engine change in accordance to the vehicle weight.

The same applies to all vehicles carrying different load. The methodology applied though is valid only for heavy duty vehicles, since in this vehicle category a high load fluctuation is expected, depending on the different vehicle use. For smaller vehicles, a load factor of 50 % seems to be in accordance with the actual fleet average and thus, load effect is neglected.

To compensate for the different load, the emission factor of heavy duty vehicles (Tables 6.19, 6.20 and 6.21) which is calculated for a load of 50 %, is corrected with use of the following formula:

$$\mathbf{LCe_{HOT;\,i,j,k} = e_{HOT;\,i,j,k} \cdot \times [1 + 2 \times LCorr_i \times (LP - 50) / 100]} \qquad \mathbf{(29)}$$

where,

$LCe_{HOT;\,i,j,k}$: load corrected emission factor of the pollutant i in [g/km] of the vehicle of category j

LP: the actual load factor (expressed as a percentage of the maximum load. That is, **LP** = 0 denotes an unloaded vehicle and **LP** = 100 represents a totally laden one)

$LCorr_i$: load correction factor of the pollutant i (Table 6.19).

As in the case of road gradient, the corrected hot emission factor calculated with the help of equation 29 is introduced in equation 3 to calculated total (hot) emissions from heavy duty vehicles.

7. Examples of methodology application

A number of corrections and reduction factors have been proposed for different vehicle classes and types of emissions (hot, cold start evaporation). The following present two examples on the application of the methodology to demonstrate the synergistic effect of the various correction factors.

7.1. Emissions from Euro II gasoline passenger cars

The case is treated where urban hot and cold start total emission CO estimates need to be made for Euro II gasoline passenger cars <1.4 l. We also assume that a number of corrections need to be made, including degradation of emissions in case of an enhanced I&M scheme and use of Fuel 2000.

Input Variables:

- Number of vehicles - **N**
- Mileage driven for the specific time period - **M**
- Mean urban travelling speed - **V**
- Mean trip distance - $\mathbf{l_{trip}}$
- Average temperature for given time period - $\mathbf{t_a}$
- Mean fleet mileage - $\mathbf{M_{av}}$
- Fuel 2000 specifications (optional)

Calculation scheme:

- **V** is introduced into the equation of Table 5.3 corresponding to Euro I vehicles and $\mathbf{e_{HOT;EUROI}}$ is calculated
- The **RF** value is selected from Table 5.6 (**RF** = 32)
- $\mathbf{FCorr_{BASE}}$ is calculated by means of the first equation given in Table 6.7 by introducing the fuel specifications given Table 6.10 under the title '1996 Base Fuel'
- $\mathbf{FCorr_{FUEL}}$ is calculated by means of the first equation given in Table 6.7 by introducing the fuel specifications given Table 6.10 under the title 'Fuel 2000' or by other values provided by the user
- $\mathbf{MC_{UDC}}$, $\mathbf{MC_{EUDC}}$ values are calculated by the equation given in Table 6.2 (enhanced I&M) by introducing the $\mathbf{M_{av}}$ value into the respective equations
- **MCorr** is calculated by the algorithm of Table 6.3 according to the urban speed **V**
- The β-parameter is given by the equation of Table 5.26, introducing variables $\mathbf{l_{trip}}$ and $\mathbf{t_a}$
- **bc** is selected from Table 5.27 (**bc** = 0,72)

- $\mathbf{e^{COLD}/e^{HOT}}$ ratio is calculated by equation in Table 5.28 according to urban speed **V** and mean temperature $\mathbf{t_a}$

Finally combination of equations 3, 20, 21, 23, 24 and 26 provides the total hot and cold start emissions:

$$\mathbf{E_{TOT,\ URBAN} = N \times M \times FCorr_{FUEL} / FCorr_{BASE} \times}$$
$$\mathbf{[(100\text{-}RF) / 100 \times e_{HOT;EURO\ I} \times MCorr + bc \times \beta \times e_{HOT;EURO\ I} \times (e^{COLD}/e^{HOT}\text{-}1)]}$$

7.2. Emissions from Euro III heavy duty vehicles

In this case it is assumed that total NO_x emissions from Euro III heavy duty vehicles 16-32 t need to be calculated. It is further assumed that vehicles operate with a load factor of 80 % on roads of 3 % positive gradient.

Input parameters and variables:

- Number of vehicles - **N**
- Mileage driven for the specific time period - **M**
- Mean travelling speed for urban, rural and highway driving- $\mathbf{V_U, V_R, V_H}$
- Mileage share to different driving modes $\mathbf{S_{URBAN}, S_{RURAL}, S_{HIGHWAY}}$
- Road gradient class
- Load factor **– LP**

Calculation scheme:

- The three speeds are introduced in the appropriate equation of Table 5.19 and three emission factors for each driving mode are calculated ($\mathbf{e_{TOT,U}}$, $\mathbf{e_{TOT,R}}$, $\mathbf{e_{TOT,H}}$)
- Three reduction factors are selected from Table 5.20 ($\mathbf{RF_{URBAN}}$ = 72, $\mathbf{RF_{RURAL}}$ = 68,5,
  $\mathbf{RF_{HIGHWAY}}$ = 68,5)
- Coefficients $\mathbf{A_0}$ to $\mathbf{A_6}$, corresponding to NO_x 0…4 % slope are selected from Table 6.14 and are introduced in equation 27. Three correction factors are then calculated ($\mathbf{GCorr_{URBAN}}$, $\mathbf{GCorr_{RURAL}}$, $\mathbf{GCorr_{HIGHWAY}}$). It is mentioned that in case that a speed is outside the V_{min} and V_{max} limits given in Table 6.14 then the correction factors are calculated with the respective speed limit.
- The **LCorr** value is selected from Table 6.19 (**LCorr** = 0,18)

Finally combination of equations 2, 3, 20, 28 and 29 provides the total emission estimates (U: Urban, R: Rural, H: Higway):

$$\mathbf{E_{TOT} = N \times M \times [1 + 2 \times LCorr \times (LP - 50) / 100] \times}$$
$$\mathbf{[e_{TOT,U} \times (100 - RF_U)/100 \times GCorr_U + e_{TOT,R} \times (100 - RF_R)/100 \times GCorr_R + e_{TOT,H} \times}$$
$$\mathbf{(100 - RF_H)/100 \times GCorr_H]}$$

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9. Tables

Table 2.1: Motor vehicle categories as defined in the Atmospheric Emission Inventory Guidebook (EMEP / CORINAIR 1999)

0701	**PASSENGER CARS**	
070101	Conventional Gasoline Passenger Cars	
	07 01 01 01	Highway Driving
	07 01 01 02	Rural Driving
	07 01 01 03	Urban Driving
070102	Catalyst Gasoline Passenger Cars	
	07 01 02 01	Highway Driving
	07 01 02 02	Rural Driving
	07 01 02 03	Urban Driving
070103	Diesel Passenger Cars	
	07 01 03 01	Highway Driving
	07 01 03 02	Rural Driving
	07 01 03 03	Urban Driving
070104	L P G Passenger Cars	
	07 01 04 01	Highway Driving
	07 01 04 02	Rural Driving
	07 01 04 03	Urban Driving
070105	Two Stroke Gasoline Vehicles	
	07 01 05 01	Highway Driving
	07 01 05 02	Rural Driving
	07 01 05 03	Urban Driving
0702	**LIGHT DUTY VEHICLES**	
070201	Gasoline Light Duty Vehicles	
	07 02 01 01	Highway Driving
	07 02 01 02	Rural Driving
	07 02 01 03	Urban Driving
070202	Diesel Light Duty Vehicles	
	07 02 02 01	Highway Driving
	07 02 02 02	Rural Driving
	07 02 02 03	Urban Driving
0703	**HEAVY DUTY VEHICLES**	
070301	Gasoline Heavy Duty Vehicles	
	07 03 01 01	Highway Driving
	07 03 01 02	Rural Driving
	07 03 01 03	Urban Driving
070302	Diesel Heavy Duty Vehicles	
	07 03 02 01	Highway Driving
	07 03 02 02	Rural Driving
	07 03 02 03	Urban Driving
0704	**MOPEDS & MOTORCYCLES < 50cm³**	
	07 04 01	Rural Driving
	07 04 02	Urban Driving
0705	**MOTORCYCLES > 50cm³**	
	07 05 01	Highway Driving
	07 05 02	Rural Driving
	07 05 03	Urban Driving
0706	**GASOLINE EVAPORATION FROM MOTOR VEHICLES**	

Table 2.2: Vehicle category split

Vehicle Type	Class	Legislation
Passenger Cars	Gasoline <1,4l	PRE ECE
		ECE 15/00-01
		ECE 15/02
		ECE 15/03
		ECE 15/04
		Improved Conv.
		Open Loop
		Euro I - 91/441/EEC
		Euro II - 94/12/EC
		Euro III - 98/69/EC Stage 2000
		Euro IV - 98/69/EC Stage 2005
	Gasoline 1,4 - 2,0l	PRE ECE
		ECE 15/00-01
		ECE 15/02
		ECE 15/03
		ECE 15/04
		Improved Conv.
		Open Loop
		Euro I - 91/441/EEC
		Euro II - 94/12/EC
		Euro III - 98/69/EC Stage 2000
		Euro IV - 98/69/EC Stage 2005
	Gasoline >2,0l	PRE ECE
		ECE 15/00-01
		ECE 15/02
		ECE 15/03
		ECE 15/04
		Euro I - 91/441/EEC
		Euro II - 94/12/EC
		Euro III - 98/69/EC Stage 2000
		Euro IV - 98/69/EC Stage 2005
	Diesel <2,0l	Conventional
		Euro I - 91/441/EEC
		Euro II - 94/12/EC
		Euro III - 98/69/EC Stage 2000
		Euro IV - 98/69/EC Stage 2005
	Diesel >2,0l	Conventional
		Euro I - 91/441/EEC
		Euro II - 94/12/EC
		Euro III - 98/69/EC Stage 2000
		Euro IV - 98/69/EC Stage 2005
	LPG	Conventional
		Euro I - 91/441/EEC
		Euro II - 94/12/EC
		Euro III - 98/69/EC Stage 2000
		Euro IV - 98/69/EC Stage 2005
	2 Stroke	Conventional
Light Duty Vehicles	Gasoline <3,5t	Conventional
		Euro I - 93/59/EEC
		Euro II - 96/69/EC
		Euro III - 98/69/EC Stage 2000
		Euro IV - 98/69/EC Stage 2005

Vehicle Type	Class	Legislation
Light Duty Vehicles	Diesel <3,5t	Conventional
		Euro I - 93/59/EEC
		Euro II - 96/69/EC
		Euro III - 98/69/EC Stage 2000
		Euro IV - 98/69/EC Stage 2005
Heavy Duty Vehicles	Gasoline >3,5t	Conventional
	Diesel <7,5t	Conventional
		Euro I - 91/542/EEC Stage I
		Euro II - 91/542/EEC Stage II
		Euro III - 1999/96/EC
		Euro IV - COM(1998) 776
		Euro V - COM(1998) 776
	Diesel 7,5 - 16t	Conventional
		91/542/EEC Stage I
		91/542/EEC Stage II
		Euro III - 1999/96/EC
		Euro IV - COM(1998) 776
		Euro V - COM(1998) 776
	Diesel 16-32t	Conventional
		91/542/EEC Stage I
		91/542/EEC Stage II
		Euro III - 1999/96/EC
		Euro IV - COM(1998) 776
		Euro V - COM(1998) 776
	Diesel >32t	Conventional
		91/542/EEC Stage I
		91/542/EEC Stage II
		Euro III - 1999/96/EC
		Euro IV - COM(1998) 776
		Euro V - COM(1998) 776
Buses	Urban Buses	Conventional
		91/542/EEC Stage I
		91/542/EEC Stage II
		Euro III - 1999/96/EC
		Euro IV - COM(1998) 776
		Euro V - COM(1998) 776
	Coaches	Conventional
		91/542/EEC Stage I
		91/542/EEC Stage II
		Euro III - 1999/96/EC
		Euro IV - COM(1998) 776
		Euro V - COM(1998) 776
Mopeds	<50cm^3	Conventional
		97/24/EC Stage I
		97/24/EC Stage II
Motorcycles	2 Stroke >50cm^3	Conventional
		97/24/EC
	4 stroke 50 - 250cm^3	Conventional
		97/24/EC
	4 stroke 250 - 750cm^3	Conventional
		97/24/EC
	4 stroke >750cm^3	Conventional
		97/24/EC

Table 2.3: Classification of vehicles according to UN-ECE

CATEGORY L:	Motor vehicles with less than four wheels
CATEGORY L1:	Two-wheeled vehicles with an engine cylinder capacity not exceeding 50 cc and a maximum design speed not exceeding 40 km/h.
CATEGORY L2:	Three-wheeled vehicles with an engine cylinder capacity not exceeding 50 cc and a maximum design speed not exceeding 40 km/h.
CATEGORY L3:	Two-wheeled vehicles with an engine cylinder capacity exceeding 50 cc or a design speed exceeding 40 km/h.
CATEGORY L4:	Vehicles with three wheels asymmetrically arranged in relation to the longitudinal median axis, with an engine cylinder capacity exceeding 50 cc or a design speed exceeding 40 km/h (motor cycles with sidecar).
CATEGORY L5:	Vehicles with three wheels symmetrically arranged in relation to the longitudinal median axis, with a maximum weight not exceeding 1,000 kg and either an engine cylinder capacity exceeding 50 cc or a design speed exceeding 40 km/h (motor cycles with sidecar).
CATEGORY M:	Power driven vehicles having at least four wheels or having three wheels when the maximum weight exceeds 1 metric ton, and used for the carriage of passengers
CATEGORY M1:	Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat.
CATEGORY M2:	Vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat, and having a maximum weight not exceeding 5 metric tonnes.
CATEGORY M3:	Vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat, and having a maximum weight exceeding 5 metric tonnes.
CATEGORY N:	Power-driven vehicles having at least four wheels or having three wheels when the maximum weight exceeds 1 metric ton, and used for the carriage of goods
CATEGORY N1:	Vehicles used for the carriage of goods and having a maximum weight not exceeding 3.5 metric tonnes.
CATEGORY N2:	Vehicles used for the carriage of goods and having a maximum weight exceeding 3.5 but not exceeding 12 metric tonnes.
CATEGORY N3:	Vehicles used for the carriage of goods and having a maximum weight exceeding 12 metric tonnes.
CATEGORY L:	Motor vehicles with less than four wheels not exceeding 50 cc and a maximum design speed not exceeding 40 km/h.

Table 3.1: Pollutants included in Group 1 and methodology equivalencies

Pollutant	Equivalent
Carbon Monoxide (CO)	Given as CO
Nitrogen Oxides (NO_X: NO and NO_2)	Given as NO_2 equivalent
Volatile Organic Compounds (VOC)	Given as $CH_{1.85}$ equivalent
Methane (CH_4)	Given as CH_4
Non Methane VOC (NMVOC)	Given as the remainder of VOC minus CH_4
Particulate Matter (PM)	Given as mass collected on a filter under 52°C in dilution tunnel measurements - PM

Table 3.2 Pollutants included in Group 2 and methodology equivalencies

Pollutant	Equivalent
Carbon Dioxide (CO_2)	Given as CO_2
Sulphur Dioxide (SO_2)	Given as SO_2
Lead (Pb)	Given as Pb
Cadmium (Cd)	Given as Cd
Chromium (Cr)	Given as Cr
Copper (Cu)	Given as Cu
Nickel (Ni)	Given as Ni
Selenium (Se)	Given as Se
Zinc (Zn)	Given as Zn

Table 3.3: Pollutants included in Group 3 and methodology equivalencies

Pollutant	Equivalent
Ammonia (NH_3)	Given as NH_3
Nitrous Oxide (N_2O)	Given as N_2O
PolyAromatic Hydrocarbons (PAHs) and Persistent Organic Pollutants (POPs)	Detailed speciation including indeno(1,2,3-cd)pyrene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(ghi)perylene, fluoranthene, benzo(a)pyrene
Polychlorinated Dibenzo Dioxins (PCDDs) and Polychlorinated Dibenzo Furans (PCDFs)	Given as Dioxins and Furans respectively

Table 3.4: Pollutants included in Group 4 and methodology equivalencies

Pollutant	Equivalent
Alkanes (C_nH_{2n+2}):	Given in Alkanes speciation
Alkenes (C_nH_{2n}):	Given in Alkenes speciation
Alkynes (C_nH_{2n-2}):	Given in Alkynes speciation
Aldehydes ($C_nH_{2n}O$)	Given in Aldehydes speciation
Ketones ($C_nH_{2n}O$)	Given in Ketones speciation
Cycloalkanes (C_nH_{2n})	Given as Cycloalkanes
Aromatics (C_nH_{2n-2})	Given in Aromatics speciation

Table 4.1: Typical average speed ranges for the application of the methodology in different driving situations

Driving Situation	Typical Speed Range (km/h)
Urban	10 - 50
Rural	40 - 80
Highway	70 - 130

Table 4.2: Examples of estimated share of mileage (in %) driven by different passenger cars <2,5 t on different road classes as provided in COPERT 1990 (Andrias et al., 1994) or more recent data

Vehicle Capacity	Country	Road Class			Country	Road Class		
		Urban	Rural	Highway		Urban	Rural	Highway
< 1,4 l	AT	31,00	43,50	25,50	IRL	25,00	55,00	20,00
1,4 - 2,0 l		31,00	43,50	25,50		25,00	55,00	20,00
> 2,0 l		31,00	43,50	25,50		25,00	55,00	20,00
< 1,4 l	B	27,13	48,74	24,13	L	45,00	35,00	20,00
1,4 - 2,0 l		27,13	48,74	24,13		45,00	35,00	20,00
> 2,0 l		27,13	48,74	24,13		45,00	35,00	20,00
< 1,4 l	D	37,24	38,37	24,39	LT	35,00	55,00	10,00
1,4 - 2,0 l		37,24	38,37	24,39		35,00	55,00	10,00
> 2,0 l		37,24	38,37	24,39		35,00	55,00	10,00
< 1,4 l	DK	40,00	47,00	13,00	M	50,00	20,00	30,00
1,4 - 2,0 l		40,00	47,00	13,00		50,00	20,00	30,00
> 2,0 l		40,00	47,00	13,00		50,00	20,00	30,00
< 1,4 l	E	30,50	30,60	38,90	NL	32,70	38,00	29,30
1,4 - 2,0 l		30,50	30,60	38,90		32,70	38,00	29,30
> 2,0 l		30,50	30,60	38,90		32,70	38,00	29,30
< 1,4 l	F	40,00	50,00	10,00	P	24,00	68,80	7,20
1,4 - 2,0 l		40,00	50,00	10,00		24,00	68,80	7,20
> 2,0 l		40,00	50,00	10,00		24,00	68,80	7,20
< 1,4 l	FIN	30,00	60,00	10,00	PL	30,00	67,00	3,00
1,4 - 2,0 l		30,00	60,00	10,00		30,00	67,00	3,00
> 2,0 l		30,00	60,00	10,00		30,00	67,00	3,00
< 1,4 l	GR	44,00	42,00	14,00	SLO	45,00	53,00	2,00
1,4 - 2,0 l		44,00	42,00	14,00		38,00	59,00	3,00
> 2,0 l		44,00	42,00	14,00		38,00	59,00	3,00
< 1,4 l	H	32,10	61,30	6,60	UK	46,00	40,00	14,00
1,4 - 2,0 l		32,10	61,30	6,60		46,00	40,00	14,00
> 2,0 l		32,10	61,30	6,60		46,00	40,00	14,00
< 1,4 l	I	46,60	45,20	8,20				
1,4 - 2,0 l		23,70	50,70	23,00				
> 2,0 l		20,00	50,00	30,00				

Table 4.3: Examples of vehicle speed (in km/h) considered as representative to characterise the driving behaviour of gasoline vehicles <2,5t on different road classes as provided in COPERT 90 (Andrias et al., 1994)

Vehicle Category	Country	Road Class			Country	Road Class		
		Urban	Rural	Highway		Urban	Rural	Highway
< 1,4 l	AT	32	75	106	IRL	30	50	85
1,4 - 2,0 l	AT	32	75	115	IRL	30	50	85
> 2,0 l	AT	32	75	115	IRL	30	50	85
< 1,4 l	B	25	50	103	L	40	60	95
1,4 - 2,0 l	B	25	50	105	L	40	60	95
> 2,0 l	B	25	50	110	L	40	60	95
< 1,4 l	D	37	75	106	LT	35	70	90
1,4 - 2,0 l	D	37	75	116	LT	35	70	90
> 2,0 l	D	37	75	125	LT	35	70	90
< 1,4 l	DK	30	60	90	M	30	35	70
1,4 - 2,0 l	DK	30	60	90	M	30	35	80
> 2,0 l	DK	30	60	90	M	30	35	80
< 1,4 l	E	25	65	105	NL	25	60	100
1,4 - 2,0 l	E	25	65	105	NL	25	60	100
> 2,0 l	E	25	65	105	NL	25	60	100
< 1,4 l	F	30	70	95	P	30	70	-
1,4 - 2,0 l	F	30	70	105	P	30	70	-
> 2,0 l	F	30	70	115	P	30	70	-
< 1,4 l	FIN	30	80	100	PL	25	70	80
1,4 - 2,0 l	FIN	30	80	100	PL	25	70	80
> 2,0 l	FIN	30	80	100	PL	25	70	80
< 1,4 l	GR	19	60	90	SL	30	60	100
1,4 - 2,0 l	GR	19	60	90	SL	30	60	100
> 2,0 l	GR	19	60	90	SL	30	60	100
< 1,4 l	H	45	70	90	UK	40	77	115
1,4 - 2,0 l	H	45	75	100	UK	40	77	115
> 2,0 l	H	80	85	120	UK	40	77	115
< 1,4 l	I	20	65	105				
1,4 - 2,0 l	I	20	65	115				
> 2,0 l	I	20	65	125				

Table 4.4: Examples of average estimated trip length values- l_{trip} - as taken by COPERT 1990 updated run

Country	Trip Length [km]	Country	Trip Length [km]	Country	Trip Length [km]
AT	12	GR	12	NL	13,1
B	12	H	12	P	12
DK	9	IRL	14	PL	10
D	14	I	12	SLO	13
E	12	L	15	UK	10
F	12	LT	14		
FIN	17	M	18		

Table 4.5: Sorting order of vehicle classes originally operating on leaded gasoline and participating in the unleaded fuel allocation algorithm (classes appearing first in the table are the ones for which leaded to unleaded shift occurs first)

Sort Order	Legislation Class	Subsector
1	Improved Conventional	Gasoline 1,4 - 2,0 l
2	Improved Conventional	Gasoline <1,4 l
3	ECE 15/04	Gasoline >2,0 l
4	ECE 15/04	Gasoline 1,4 - 2,0 l
5	ECE 15/04	Gasoline <1,4 l
6	ECE 15/03	Gasoline >2,0 l
7	ECE 15/03	Gasoline 1,4 - 2,0 l
8	ECE 15/03	Gasoline <1,4 l
9	ECE 15/02	Gasoline >2,0 l
10	ECE 15/02	Gasoline 1,4 - 2,0 l
11	ECE 15/02	Gasoline <1,4 l
12	ECE 15/00-01	Gasoline >2,0 l
13	ECE 15/00-01	Gasoline 1,4 - 2,0 l
14	ECE 15/00-01	Gasoline <1,4 l
15	PRE ECE	Gasoline >2,0 l
16	PRE ECE	Gasoline 1,4 - 2,0 l
17	PRE ECE	Gasoline <1,4 l

Table 4.6: Canister efficiency of controlled vehicles over the uncontrolled evaporation losses. Values correspond to vehicles regulated with the original procedure and for use of fuel RVP <2000 mbar.

Country	Controlled vehicles efficiency per month											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Austria	92	92	92	92	92	92	92	92	92	92	92	92
Belgium	92	92	92	92	92	92	92	92	92	92	92	92
Denmark	92	92	92	92	92	92	92	92	92	92	92	92
Germany	92	92	92	92	92	92	92	92	92	92	92	92
Finland	92	92	92	92	92	92	92	92	92	92	92	92
France	92	92	92	92	92	*88*	*82*	*82*	92	92	92	92
Greece	92	92	92	92	92	*88*	*73*	*73*	*90*	92	92	92
Ireland	92	92	92	92	92	92	92	92	92	92	92	92
Italy	92	92	92	92	92	*82*	*64*	*64*	*78*	92	92	92
Luxembourg	92	92	92	92	92	92	92	92	92	92	92	92
Netherlands	92	92	92	92	92	92	92	92	92	92	92	92
Portugal	92	92	92	92	92	92	92	92	92	92	92	92
Spain	92	92	92	92	92	92	92	92	92	92	92	92
Sweden	92	92	92	92	92	92	92	92	92	92	92	92
UK	92	92	92	92	92	92	92	92	92	92	92	92

Table 4.7: Canister efficiency of controlled vehicles over the uncontrolled evaporation losses. Values correspond to vehicles regulated with the new SHED procedure and for use of fuel RVP 600 mbar.

Country	Controlled vehicles efficiency per month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Austria	92	92	92	92	92	92	92	92	92	92	92	92
Belgium	92	92	92	92	92	92	92	92	92	92	92	92
Denmark	92	92	92	92	92	92	92	92	92	92	92	92
Germany	92	92	92	92	92	92	92	92	92	92	92	92
Finland	92	92	92	92	92	92	92	92	92	92	92	92
France	92	92	92	92	92	92	92	92	92	92	92	92
Greece	92	92	92	92	92	92	*88*	*88*	92	92	92	92
Ireland	92	92	92	92	92	92	92	92	92	92	92	92
Italy	92	92	92	92	92	92	92	92	92	92	92	92
Luxembourg	92	92	92	92	92	92	92	92	92	92	92	92
Netherlands	92	92	92	92	92	92	92	92	92	92	92	92
Portugal	92	92	92	92	92	92	92	92	92	92	92	92
Spain	92	92	92	92	92	92	92	92	92	92	92	92
Sweden	92	92	92	92	92	92	92	92	92	92	92	92
UK	92	92	92	92	92	92	92	92	92	92	92	92

Table 5.1: Coding explanation used for the methodological approaches adopted for each vehicle category

Method	Hot Emissions	Cold Start Overemission	Evaporation Losses*
A	the total annual kilometres driven per vehicle the share of kilometres driven under the driving modes 'urban', 'rural', 'highway' A1: the average speed of the vehicles under the driving modes 'urban', 'rural', 'highway' A1: speed-dependent hot emission factors A2: driving mode dependent emission factors	the average trip length per vehicle trip the average monthly temperature temperature, trip length and catalyst technology dependent cold start correction factor	the fuel volatility (RVP) the average monthly temperature and temperature variation fuel volatility and temperature dependent emission factor
B	the total annual kilometres driven per vehicle the share of kilometres driven under the driving modes 'urban', 'rural', 'highway' B1: the average speed of the vehicles under the driving modes 'urban', 'rural', 'highway' B1: speed-dependent hot emission factors B2: driving mode dependent emission factors	*No Cold Start Overemission Calculations*	the fuel volatility (RVP) the average monthly temperature and temperature variation fuel volatility and temperature dependent emission factor
C	the total annual kilometres driven per vehicle the share of kilometres driven under the driving modes 'urban', 'rural', 'highway' driving mode dependent emission factors	*No Cold Start Overemission Calculations*	*No Evaporation Calculations*
D	the total annual fuel consumption of the vehicle category fuel consumption related emission factors	*No Cold Start Overemission Calculations*	*No Evaporation Calculations*

*Attributed only to NMVOC emissions from gasoline powered vehicles

Table 5.2: Summary of calculation methods applied for the different vehicle categories and pollutants

Vehicle Category	NO_x	CO	NM VOC	CH_4	PM	N_2O	NH_3	SO_2	CO_2	Pb	HM	FC
Gasoline Passenger Cars												
Pre-ECE	A1	A1	A1	A2	-	C	C	D	D	D	D	A1
ECE 15/00-01	A1	A1	A1	A2	-	C	C	D	D	D	D	A1
ECE 15/02	A1	A1	A1	A2	-	C	C	D	D	D	D	A1
ECE 15/03	A1	A1	A1	A2	-	C	C	D	D	D	D	A1
ECE 15/04	A1	A1	A1	A2	-	C	C	D	D	D	D	A1
Improved Conventional	A1	A1	A1	A2	-	C	C	D	D	D	D	A1
Open Loop	A1	A1	A1	A2	-	C	C	D	D	D	D	A1
Euro I to Euro IV	A1	A1	A1	A1	-	C	C	D	D	D	D	A1
Diesel Passenger Cars												
Conventional	A1	A1	A1	A1	A1	C	C	D	D	D	D	A1
Euro I to Euro IV	A1	A1	A1	A1	A1	C	C	D	D	D	D	A1
LPG Passenger Cars	A1	A1	A1	A2	-	C	-	-	D	-	-	A1
2 Stroke Passenger Cars	C	C	C	C	-	C	C	D	D	D	D	C
Light Duty Vehicles												
Gasoline <3,5t Conv.	A1	A1	A1	A2	-	C	C	D	D	D	D	A1
Gasoline <3,5t Euro I to Euro IV	A1	A1	A1	A1	-	C	C	D	D	D	D	A1
Diesel <3,5t Conventional	A1	A1	A1	A2	A1	C	C	D	D	D	D	A1
Diesel <3,5t Euro I to Euro IV	A1	A1	A1	A2	A1	C	C	D	D	D	D	A1
Heavy Duty Vehicles >3,5 t												
Gasoline Conventional	C	C	C	C	-	C	C	D	D	D	D	C
Diesel Conventional	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Diesel Euro I to Euro V	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Buses & Coaches Conventional	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Buses & Coaches Euro I to Euro V	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Two Wheelers												
Mopeds <50cm³	B2	B2	B2	C	-	C	C	D	D	D	D	B2
Motorcycles 2-st >50cm³	B1	B1	B1	C	-	C	C	D	D	D	D	B1
Motorcycles 4-st 50-250 cm³	B1	B1	B1	C	-	C	C	D	D	D	D	B1
Motorcycles 4-st 250-750cm³	B1	B1	B1	C	-	C	C	D	D	D	D	B1
Motorcycles 4-st >750cm³	B1	B1	B1	C	-	C	C	D	D	D	D	B1

Table 5.3: Speed dependency of CO emission factors for gasoline passenger cars

Vehicle Class	Engine Capacity	Speed Range [km/h]	CO Emission Factor [g/km]	R^2
PRE ECE	All capacities	10-100	$281V^{-0,630}$	0,924
	All capacities	100-130	0,112V + 4,32	-
ECE 15-00/01	All capacities	10-50	$313V^{-0,760}$	0,898
	All capacities	50-130	$27,22 - 0,406V + 0,0032V^2$	0,158
ECE 15-02	All capacities	10-60	$300V^{-0,797}$	0,747
	All capacities	60-130	$26,260 - 0,440V + 0,0026V^2$	0,102
ECE 15-03	All capacities	10-19,3	161,36 - 45,62ln(V)	0,790
	All capacities	19,3-130	$37,92 - 0,680V + 0,00377V^2$	0,247
ECE 15-04	All capacities	10-60	$260,788\,V^{-0,910}$	0,825
	All capacities	60-130	$14,653 - 0,220V + 0,00116386V^2$	0,613
Improved Conventional	CC < 1,4 l	10-130	$14,577 - 0,294V + 0,002478V^2$	0,781
	1,4 l < CC < 2,0 l	10-130	$8,273 - 0,1511V + 0,000957V^2$	0,767
Open Loop	CC < 1,4 l	10-130	$17,882 - 0,377V + 0,002825V^2$	0,656
	1,4 l < CC < 2,0 l	10-130	$9,446 - 0,23012V + 0,002029V^2$	0,719
EURO I	CC < 1,4 l	5-130	$9,846 - 0,2867V + 0,0022V^2$	0,133
	1,4 l < CC < 2,0 l	5-130	$9,617 - 0,245V + 0,0017285V^2$	0,145
	CC > 2,0 l	5-130	$12,826- 0,2955V +0,00177V^2$	0,159

Table 5.4: Speed dependency of VOC emission factors for gasoline passenger cars

Vehicle Class	Engine Capacity	Speed Range [km/h]	VOC Emission Factor [g/km]	R^2
PRE ECE	All capacities	10-100	$30,34\,V^{-0,693}$	0,980
	All capacities	100-130	1,247	-
ECE 15-00/01	All capacities	10-50	$24,99V^{-0,704}$	0,901
	All capacities	50-130	$4,85V^{-0,318}$	0,095
ECE 15-02/03	All capacities	10-60	$25,75V^{-0,714}$	0,895
	All capacities	60-130	$1,95 - 0,019V + 0,00009V^2$	0,198
ECE 15-04	All capacities	10-60	$19,079V^{-0,693}$	0,838
	All capacities	60-130	$2,608 - 0,037V + 0,000179V^2$	0,341
Improved Conventional	CC < 1,4 l	10-130	$2,189 - 0,034V + 0,000201V^2$	0,766
	1,4 l < CC < 2,0 l	10-130	$1,999 - 0,034V + 0,000214V^2$	0,447
Open Loop	CC < 1,4 l	10-130	$2,185 - 0,0423V + 0,000256V^2$	0,636
	1,4 l < CC < 2,0 l	10-130	$0,808 - 0,016V + 0,000099V^2$	0,49
EURO I	CC < 1,4 l	5-130	$0,628 - 0,01377V + 8,52E-05V^2$	0,207
	1,4 l < CC < 2,0 l	5-130	$0,4494 - 0,00888V +5,21E-05V^2$	0,197
	CC > 2,0 l	5-130	$0,5086 - 0,00723V + 3,3E-05V^2$	0,0433

Table 5.5: Speed dependency of NO_x emission factors for gasoline passenger cars

Vehicle Class	Engine Capacity	Speed Range [km/h]	NO_x Emission Factor [g/km]	R^2
PRE ECE & ECE 15-00/01	CC < 1,4 l	10-130	$1,173 + 0,0225V - 0,00014V^2$	0,916
	1,4 l < CC < 2,0 l	10-130	$1,360 + 0,0217V - 0,00004V^2$	0,960
	CC > 2,0 l	10-130	$1,5 + 0,03V + 0,0001V^2$	0,972
ECE 15-02	CC < 1,4 l	10-130	$1,479 - 0,0037V + 0,00018V^2$	0,711
	1,4 l < CC < 2,0 l	10-130	$1,663 - 0,0038V + 0,00020V^2$	0,839
	CC > 2,0 l	10-130	$1,87 - 0,0039V + 0,00022V^2$	-
ECE 15-03	CC < 1,4 l	10-130	$1,616 - 0,0084V + 0,00025V^2$	0,844
	1,4 l < CC < 2,0 l	10-130	$1,29e^{0,0099V}$	0,798
	CC > 2,0 l	10-130	$2,784 - 0,0112V + 0,000294V^2$	0,577
ECE 15-04	CC < 1,4 l	10-130	$1,432 + 0,0026V + 0,000097V^2$	0,669
	1,4 l < CC < 2,0 l	10-130	$1,484 + 0,013V + 0,000074V^2$	0,722
	CC > 2,0 l	10-130	$2,427 - 0,014V + 0,000266V^2$	0,803
Improved Conventional	CC < 1,4 l	10-130	$-0,926 + 0,7192\ln(V)$	0,883
	1,4 l < CC < 2,0 l	10-130	$1,387 - 0,0014V + 0,000247V^2$	0,876
Open Loop	CC < 1,4 l	10-130	$-0,921 + 0,616\ln(V)$	0,791
	1,4 l < CC < 2,0 l	10-130	$-0,761 + 0,515\ln(V)$	0,495
EURO I	CC < 1,4 l	5-130	$0,5595 - 0,01047V + 10,8E\text{-}05V^2$	0,122
	1,4 l < CC < 2,0 l	5-130	$0,526 - 0,0085V + 8,54E\text{-}05V^2$	0,0772
	CC > 2,0 l	5-130	$0,666 - 0,009V + 7,55E\text{-}05V^2$	0,0141

Table 5.6: Emission reduction percentage for improved and future gasoline & LPG passenger cars, applied to vehicles complying with directive 91/441/EEC

Engine Capacity	Gasoline & LPG Passenger Cars	CO [%]	NO_x [%]	VOC [%]
CC < 1,4 l	Euro II - 94/12/EC	32	64	79
	Euro III - 98/69/EC Stage 2000	44	76	85
	Euro IV - 98/69/EC Stage 2005	66	87	97
1,4 l < CC < 2,0 l	Euro II - 94/12/EC	32	64	79
	Euro III - 98/69/EC Stage 2000	44	76	86
	Euro IV - 98/69/EC Stage 2005	66	87	97
CC > 2,0 l	Euro II - 94/12/EC	32	64	76
	Euro III - 98/69/EC Stage 2000	44	76	84
	Euro IV - 98/69/EC Stage 2005	65	87	95

Note: The VOC reduction percentage has to be equally applied to the NMVOC emission factors (Table 5.4) and to the CH_4 emission factors (Table 5.33)

Table 5.7: Speed dependency of fuel consumption factors for gasoline passenger cars

Vehicle Class	Cylinder Capacity	Speed Range [km/h]	Fuel Consumption Factor [g/km]	R^2
PRE ECE	CC < 1,4 l	10-60	$521\ V^{-0,554}$	0,941
		60-80	55	-
		80-130	0,386V + 24,143	-
	1,4 l < CC < 2,0 l	10-60	$681V^{-0,583}$	0,936
		60-80	67	-
		80-130	0,471V + 29,286	-
	CC > 2,0 l	10-60	$979V^{-0,628}$	0,918
		60-80	80	-
		80-130	0,414V + 46,867	-
ECE 15-00/01	CC < 1,4 l	10-60	$595V^{-0,63}$	0,951
		60-130	$95 - 1,324V + 0,0086V^2$	0,289
	1,4 l < CC < 2,0 l	10-60	$864V^{-0,69}$	0,974
		60-130	$59 - 0,407V + 0,0042V^2$	0,647
	CC > 2,0 l	10-60	$1236V^{-0,764}$	0,976
		60-130	$65 - 0,407V + 0,0042V^2$	-
ECE 15-02/03	CC < 1,4 l	10-50	$544V^{-0,63}$	0,929
		50-130	$85 - 1,108V + 0,0077V^2$	0,641
	1,4 l < CC < 2,0 l	10-50	$879V^{-0,72}$	0,950
		50-130	$71 - 0,7032V + 0,0059V^2$	0,830
	CC > 2,0 l	10-50	$1224V^{-0,756}$	0,961
		50-130	$111 - 1,333V + 0,0093V^2$	0,847
ECE 15-04	CC < 1,4 l	10-17,9	296,7 - 80,21ln(V)	0,518
		17,9-130	$81,1 - 1,014V + 0,0068V^2$	0,760
	1,4 l < CC < 2,0 l	10-22,3	$606,1V^{-0,667}$	0,907
		22,3-130	$102,5 - 1,364V + 0,0086V^2$	0,927
	CC > 2,0 l	10-59,5	$819,9V^{-0,663}$	0,966
		59,5-130	$41,7 + 0,122V + 0,0016V^2$	0,650
Improved Conventional	CC < 1,4 l	10-130	$80,52 - 1,41V + 0,013V^2$	0,954
	1,4 l < CC < 2,0 l	10-130	$111,0 - 2,031V + 0,017V^2$	0,994
Open Loop	CC < 1,4 l	10-130	$85,55 - 1,383V + 0,0117V^2$	0,997
	1,4 l < CC < 2,0 l	10-130	$109,6 - 1,98V + 0,0168V^2$	0,997
EURO I and onwards	CC < 1,4 l	5-12,3	$329,451 - 39,093V + 1,531V^2$	0,958
		12,3-130	$98,336 - 1,604V + 0,0106V^2$	0,790
	1,4 l < CC < 2,0 l	5-13,1	$428,06 - 46,696V + 1,697V^2$	0,989
		13,1-130	$135,44 - 2,314V + 0,0144V^2$	0,777
	CC > 2,0 l	5-12,7	$605,57- 70,09V +2,645V^2$	0,976
		12,7-130	$181,85- 3,398V +0,0209V^2$	0,865

Table 5.8: Speed dependency of emission and consumption factors for conventional diesel vehicles <2,5 t

Pollutant	Engine Capacity	Speed Range [km/h]	Emission Factor [g/km]	R^2
CO	All capacities	10-130	$5{,}41301V^{-0{,}574}$	0,745
NO_x	CC < 2,0l	10-130	$0{,}918 - 0{,}014V + 0{,}000101V^2$	0,949
	CC > 2,0l	10-130	$1{,}331 - 0{,}018V + 0{,}000133V^2$	0,927
VOC	All capacities	10-130	$4{,}61\ V^{-0{,}937}$	0,794
PM	All capacities	10-130	$0{,}45 - 0{,}0086V + 0{,}000058V^2$	0,439
Fuel Consumption	All capacities	10-130	$118{,}489 - 2{,}084V + 0{,}014V^2$	0,583

Table 5.9: Speed dependency of emission and consumption factors for diesel passenger cars <2,5 t, complying with directive 91/441/EEC

Pollutant	Engine Capacity	Speed Range [km/h]	Emission Factor [g/km]	R^2
CO	All capacities	10-120	$1{,}4497 - 0{,}03385V + 21E\text{-}05V^2$	0,550
NO_x	All capacities	10-120	$1{,}4335 - 0{,}026V + 17{,}85E\text{-}05V^2$	0,262
VOC	All capacities	10-130	$0{,}1978 - 0{,}003925V + 2{,}24E\text{-}05V^2$	0,342
PM	All capacities	10-130	$0{,}1804 - 0{,}004415V + 3{,}33E\text{-}05V^2$	0,294
Fuel Consumption	All capacities	10-130	$91{,}106 - 1{,}308V + 0{,}00871V^2$	0,526

Table 5.10: Emission reduction percentage for improved and future diesel passenger cars applied to vehicles complying with directive 91/441/EEC

Diesel Passenger Cars	CO [%]	NO_x [%]	VOC [%]	PM [%]
Euro II - 94/12/EC	0	0	0	0
Euro III - 98/69/EC Stage 2000	0	23	15	28
Euro IV - 98/69/EC Stage 2005	0	47	31	55

Note: The VOC reduction percentage has to be equally applied to the NMVOC emission factors (Table 5.9) and to the CH_4 emission factors (Table 5.33).

Table 5.11: Speed dependency of emission and consumption factors for conventional LPG Vehicles <2,5 t

Pollutant	Cylinder Capacity	Speed Range	Emission Factor [g/km]	R^2
CO	All categories	10-130 km/h	$12{,}523 - 0{,}418V + 0{,}0039V^2$	0,893
NO_x	All categories	10-130 km/h	$0{,}77\ V^{0{,}285}$	0,598
VOC	All categories	10-130 km/h	$26{,}3\ V^{-0{,}865}$	0,967
Fuel Consumption	All categories	Urban	59	-
		Rural	45	-
		Highway	54	-

Table 5.12: Speed dependency of emission and consumption factors for LPG vehicles <2,5t, complying with directive 91/441/EEC

Pollutant	Cylinder Capacity	Speed Range [km/h]	Emission Factor [g/km]
CO	All categories	10-130	$0{,}00110V^2 - 0{,}1165V + 4{,}2098$
NO_x	All categories	10-130	$0{,}00004V^2 - 0{,}0063V + 0{,}5278$
VOC	All categories	10-130	$0{,}00010V^2 - 0{,}0166V + 0{,}7431$
Fuel Consumption	All categories	10-130	$0{,}00720V^2 - 0{,}9250V + 74{,}625$

Table 5.13: Emission and consumption factors for gasoline 2-stroke vehicles <2,5 t

Road Class	CO [g/km]	NO_x [g/km]	VOC [g/km]	Fuel Consumption [g/km]
Urban	20,7	0,30	15,4	111,5
Rural	7,50	1,02	7,20	66,0
Highway	8,70	0,72	5,90	56,9

Table 5.14: Speed dependency of emission and consumption factors for gasoline light duty vehicles <3,5 t

Pollutant	Vehicle Class	Speed Range [km/h]	Emission Factor [g/km]	R^2
CO	Conventional	10-110	$0{,}01104V^2 - 1{,}5132V + 57{,}789$	0,732
	EURO I	10-120	$0{,}0037V^2 - 0{,}5215V + 19{,}127$	0,394
NO_x	Conventional	10-110	$0{,}0179V + 1{,}9547$	0,142
	EURO I	10-120	$7{,}55E\text{-}05V^2 - 0{,}009V + 0{,}666$	0,0141
VOC	Conventional	10-110	$67{,}7E\text{-}05V^2 - 0{,}117V + 5{,}4734$	0,771
	EURO I	10-120	$5{,}77E\text{-}05V^2 - 0{,}01047V + 0{,}5462$	0,358
Fuel Consumption	Conventional	10-110	$0{,}0167V^2 – 2{,}649V + 161{,}51$	0,787
	EURO I	10-120	$0{,}0195V^2 – 3{,}09V + 188{,}85$	0,723

Note:
Due to limited available data, the function in the case of NO_x Euro I Gasoline is a mere copy of this applied in the case of gasoline passenger cars >2.0l Euro I. However, it seems to be in good compliance with both the measured data and the emission standards.

Table 5.15: Emission reduction percentage for future gasoline light duty vehicles applied to vehicles complying with directive 93/59/EEC

Gasoline Light Duty Vehicles	CO [%]	NO_x [%]	VOC [%]
Euro II - 96/69/EC	39	66	76
Euro III - 98/69/EC Stage 2000	48	79	86
Euro IV - 98/69/EC Stage 2005	72	90	94

Note: The VOC reduction percentage has to be equally applied to the NMVOC emission factors (Table 5.14) and to the CH_4 emission factors (Table 5.33)

Table 5.16: Speed dependency of emission and consumption factors for diesel light duty vehicles <3,5 t

Pollutant	Vehicle Class	Speed Range [km/h]	Emission Factor [g/km]	R^2
CO	Conventional	10-110	$20E\text{-}05V^2 - 0{,}0256V + 1{,}8281$	0,136
	EURO I	10-110	$22{,}3E\text{-}05V^2 - 0{,}026V + 1{,}076$	0,301
NO_x	Conventional	10-110	$81{,}6E\text{-}05V^2 - 0{,}1189V + 5{,}1234$	0,402
	EURO I	10-110	$24{,}1E\text{-}05V^2 - 0{,}03181V + 2{,}0247$	0,0723
VOC	Conventional	10-110	$1{,}75E\text{-}05V^2 - 0{,}00284V + 0{,}2162$	0,0373
	EURO I	10-110	$1{,}75E\text{-}05V^2 - 0{,}00284V + 0{,}2162$	0,0373
PM	Conventional	10-110	$1{,}25E\text{-}05V^2 - 0{,}000577V + 0{,}288$	0,0230
	EURO I	10-110	$4{,}5E\text{-}05V^2 - 0{,}004885V + 0{,}1932$	0,224
Fuel Consumption	Conventional	10-110	$0{,}02113V^2 - 2{,}65V + 148{,}91$	0,486
	EURO I	10-110	$0{,}0198V^2 - 2{,}506V + 137{,}42$	0,422

Note: Due to limited available data, the same VOC emission factor function has been used in both Conventional and Euro I vehicles.

Table 5.17: Emission reduction percentage for future diesel light duty vehicles applied to vehicles complying with directive 93/59/EEC

Diesel Light Duty Vehicles	CO [%]	NO_x [%]	VOC [%]	PM [%]
Euro II - 96/69/EC	0	0	0	0
Euro III - 98/69/EC Stage 2000	18	16	38	33
Euro IV - 98/69/EC Stage 2005	35	32	77	65

Note: The VOC reduction percentage has to be equally applied to the NMVOC emission factors (Table 5.16) and to the CH_4 emission factors (Table 5.33)

Table 5.18: Emission factors for gasoline heavy duty vehicles >3,5 t

Road Classes	CO [g/km]	NO_x [g/km]	VOC [g/km]	Fuel Consumption [g/km]
Urban	70	4,5	7,0	225
Rural	55	7,5	5,5	150
Highway	55	7,5	3,5	165

Table 5.19: Speed dependency of emission and consumption factors for diesel heavy duty vehicles >3,5 t

Pollutant	Weight Class	Speed Range [km/h]	Emission Factor [g/km]	R^2
CO	All Weight Categories	0-100	$37,280V^{-0,6945}$	0,880
NO_x	Weight<7,5t	0 - 46,7	$50,305V^{-0,7708}$	0,902
		46,7 - 100	$0,0014V^2 - 0,1737V + 7,5506$	0,260
	7,5<Weight<16t	0 - 58,8	$92,584V^{-0,7393}$	0,940
		58,8 - 100	$0,0006V^2 - 0,0941V + 7,7785$	0,440
	16<Weight<32t	0 - 100	$108,36V^{-0,6061}$	0,650
	Weight>32t	0 - 100	$132,88V^{-0,5581}$	0,894
VOC	All Weight Categories	0-100	$40,120V^{-0,8774}$	0,976
PM	Weight<7,5t	0 - 100	$4,5563V^{-0,7070}$	0,944
	7,5<Weight<16t	0 - 100	$9,6037V^{-0,7259}$	0,974
	16<Weight<32t	0 - 100	$10,890V^{-0,7105}$	0,946
	Weight>32t	0 - 100	$11,028V^{-0,6960}$	0,961
Fuel Consumption	Weight<7,5t	0 - 47	$1425,2V^{-0,7593}$	0,990
		47 - 100	$0,0082V^2 - 0,0430V + 60,12$	0,798
	7,5<Weight<16t	0 - 59	$1068,4V^{-0,4905}$	0,628
		59 - 100	$0,0126V^2 - 0,6589V + 141,18$	0,037
	16<Weight<32t	0 - 59	$1595,1V^{-0,4744}$	0,628
		59 - 100	$0,0382V^2 - 5,1630V + 399,3$	0,037
	Weight>32t	0 - 58	$1855,7V^{-0,4367}$	0,914
		58 - 100	$0,0765V^2 - 11,414V + 720,9$	0,187

Table 5.20: Emission reduction percentage for improved diesel heavy-duty vehicles applied to conventional ones (U: urban, R: rural, H: highway)

Veh. Class	Weight Class	CO			NO_x			VOC			PM		
		U	R	H	U	R	H	U	R	H	U	R	H
Euro I	Weight<7,5t	50,0	40,0	45,0	30,0	30,0	10,0	25,0	25,0	25,0	35,0	35,0	35,0
	7,5<Weight<16t	50,0	40,0	45,0	30,0	30,0	10,0	25,0	25,0	25,0	35,0	35,0	35,0
	16<Weight<32t	45,0	40,0	35,0	45,0	40,0	45,0	50,0	35,0	25,0	35,0	35,0	35,0
	Weight>32t	45,0	40,0	35,0	45,0	40,0	45,0	50,0	35,0	25,0	35,0	35,0	35,0
Euro II	Weight<7,5t	60,0	45,0	50,0	50,0	45,0	35,0	30,0	30,0	30,0	60,0	60,0	60,0
	7,5<Weight<16t	60,0	45,0	50,0	50,0	45,0	35,0	30,0	30,0	30,0	60,0	60,0	60,0
	16<Weight<32t	55,0	50,0	35,0	60,0	55,0	55,0	55,0	40,0	35,0	75,0	75,0	75,0
	Weight>32t	55,0	50,0	35,0	60,0	55,0	55,0	55,0	40,0	35,0	75,0	75,0	75,0
Euro III	Weight<7,5t	72,0	61,5	65,0	65,0	61,5	54,5	51,0	51,0	51,0	72,0	72,0	72,0
	7,5<Weight<16t	72,0	61,5	65,0	65,0	61,5	54,5	51,0	51,0	51,0	72,0	72,0	72,0
	16<Weight<32t	68,5	65,0	54,5	72,0	68,5	68,5	68,5	58,0	54,5	82,5	82,5	82,5
	Weight>32t	68,5	65,0	54,5	72,0	68,5	68,5	68,5	58,0	54,5	82,5	82,5	82,5
Euro IV	Weight<7,5t	79,6	71,9	74,5	75,5	73,1	68,2	65,7	65,7	65,7	94,7	94,7	94,7
	7,5<Weight<16t	79,6	71,9	74,5	75,5	73,1	68,2	65,7	65,7	65,7	94,7	94,7	94,7
	16<Weight<32t	77,0	74,5	66,8	80,4	78,0	78,0	78,0	70,6	68,2	96,7	96,7	96,7
	Weight>32t	77,0	74,5	66,8	80,4	78,0	78,0	78,0	70,6	68,2	96,7	96,7	96,7
Euro V	Weight<7,5t	79,6	71,9	74,5	86,0	84,6	81,8	65,7	65,7	65,7	94,7	94,7	94,7
	7,5<Weight<16t	79,6	71,9	74,5	86,0	84,6	81,8	65,7	65,7	65,7	94,7	94,7	94,7
	16<Weight<32t	77,0	74,5	66,8	88,8	87,4	87,4	78,0	70,6	68,2	96,7	96,7	96,7
	Weight>32t	77,0	74,5	66,8	88,8	87,4	87,4	78,0	70,6	68,2	96,7	96,7	96,7
Euro I	Urban Busses	50,0	40,0	45,0	30,0	30,0	10,0	25,0	25,0	25,0	35,0	35,0	35,0
	Coaches	45,0	40,0	35,0	45,0	40,0	45,0	50,0	35,0	25,0	35,0	35,0	35,0
Euro II	Urban Busses	60,0	45,0	50,0	50,0	45,0	35,0	30,0	30,0	30,0	60,0	60,0	60,0
	Coaches	55,0	50,0	35,0	60,0	55,0	55,0	55,0	40,0	35,0	75,0	75,0	75,0
Euro III	Urban Busses	72,0	61,5	65,0	65,0	61,5	54,5	51,0	51,0	51,0	72,0	72,0	72,0
	Coaches	68,5	65,0	54,5	72,0	68,5	68,5	68,5	58,0	54,5	82,5	82,5	82,5
Euro IV	Urban Busses	79,6	71,9	74,5	75,5	73,1	68,2	65,7	65,7	65,7	94,7	94,7	94,7
	Coaches	77,0	74,5	66,8	80,4	78,0	78,0	78,0	70,6	68,2	96,7	96,7	96,7
Euro V	Urban Busses	79,6	71,9	74,5	86,0	84,6	81,8	65,7	65,7	65,7	94,7	94,7	94,7
	Coaches	77,0	74,5	66,8	88,8	87,4	87,4	78,0	70,6	68,2	96,7	96,7	96,7

Note: The VOC reduction percentage has to be equally applied to the NMVOC emission factors (Table 5.19 and Table 5.21) and to the CH_4 emission factors (Table 5.33)

Table 5.21: Speed dependency of emission and consumption factors for conventional diesel urban busses and coaches

Pollutant	Vehicle Class	Speed Range [km/h]	Emission Factor [g/km]	R^2
CO	Urban Buses	0 - 50	$59{,}003\ V^{-0{,}7447}$	0,895
	Coaches	0 - 120	$63{,}791\ V^{-0{,}8393}$	0,978
NO_x	Urban Buses	0 - 50	$89{,}174\ V^{-0{,}5185}$	0,534
	Coaches	0 – 58,8	$125{,}87\ V^{-0{,}6562}$	0,848
		58,8 – 120	$0{,}0010\ V^2 - 0{,}1608\ V + 14{,}308$	0,073
VOC	Urban Buses	0 - 50	$43{,}647\ V^{-1{,}0301}$	0,992
	Coaches	0 - 120	$44{,}217\ V^{-0{,}8870}$	0,993
PM	Urban Buses	0 - 50	$7{,}8609\ V^{-0{,}7360}$	0,920
	Coaches	0 - 120	$9{,}2934\ V^{-0{,}7373}$	0,975
Fuel Consumption	Urban Buses	0 - 50	$1371{,}6\ V^{-0{,}4318}$	0,502
	Coaches	0 -59	$1919{,}0\ V^{-0{,}5396}$	0,786
		59 - 120	$0{,}0447\ V^2 - 7{,}072\ V + 478$	0,026

Table 5.22: Speed dependency of emission and consumption factors for 2 stroke motorcycles of engine displacement over 50cm³

Pollutant	Vehicle Class	Speed Range [km/h]	Emission Factor [g/km]
CO	Conventional	10 - 60	$-0{,}00100\ V^2 + 0{,}1720\ V + 18{,}10$
		60 - 110	$0{,}00010\ V^2 + 0{,}0500\ V + 21{,}50$
	97/24/EC	10 - 60	$-0{,}00630\ V^2 + 0{,}7150\ V - 6{,}900$
		60 - 110	$0{,}00070\ V^2 + 0{,}1570\ V + 6{,}000$
NO_x	Conventional	10 - 60	$0{,}00003\ V^2 - 0{,}0020\ V + 0{,}064$
		60 - 110	$-0{,}00002\ V^2 + 0{,}0049\ V - 0{,}157$
	97/24/EC	10 - 60	$0{,}00002\ V^2 - 0{,}0010\ V + 0{,}032$
		60 - 110	$-0{,}00002\ V^2 + 0{,}0041\ V - 0{,}152$
VOC	Conventional	10 - 60	$0{,}00350\ V^2 - 0{,}4090\ V + 20{,}10$
		60 - 110	$0{,}00030\ V^2 - 0{,}0524\ V + 10{,}60$
	97/24/EC	10 - 60	$-0{,}00100\ V^2 + 0{,}0970\ V + 3{,}900$
		60 - 110	$-0{,}00030\ V^2 + 0{,}0325\ V + 5{,}200$
Fuel Consumption	Conventional	10 - 60	$0{,}006300\ V^2 - 0{,}6028\ V + 44{,}40$
		60 - 110	$-0{,}00050\ V^2 + 0{,}2375\ V + 18{,}20$
	97/24/EC	10 - 60	$-0{,}00110\ V^2 + 0{,}2008\ V + 17{,}80$
		60 - 110	$-0{,}00100\ V^2 + 0{,}2425\ V + 14{,}60$

Table 5.23: Emission and consumption factors for conventional mopeds (corresponding to urban driving conditions)

Mopeds	CO [g/km]	NO_x [g/km]	VOC [g/km]	Fuel Consumption [g/km]
< 50 cm³	15,0	0,03	9,00	25,0

Table 5.24: Emission and consumption reduction percentage for improved mopeds applied to conventional ones

Mopeds <50cc	Road Classes	CO [%]	NO_x [%]	VOC [%]	FC [%]
97/24/EC Stage I	All	50	0	55	40
97/24/EC Stage II	All	90	67	78	56

Note: The VOC reduction percentage has to be equally applied to the NMVOC emission factors (Table 5.23) and to the CH_4 emission factors (Table 5.33)

Table 5.25: Speed dependency of emission and consumption factors for 4 stroke motorcycles of engine displacement over 50cm³

Pollutant	Cylinder Capacity	Speed Range [km/h]	Emission Factor [g/km]
CO	Conventional <250cm³	10 - 60	$0{,}01930V^2 - 1{,}9200V + 68{,}30$
		60 - 110	$0{,}00170V^2 + 0{,}1210V + 9{,}500$
	Conventional 250<cc<750cm³	10 - 60	$0{,}01390V^2 - 1{,}4200V + 55{,}00$
		60 - 110	$0{,}00090V^2 - 0{,}0099V + 17{,}80$
	Conventional >750cm³	10 - 60	$0{,}01230V^2 - 1{,}1900V + 42{,}80$
		60 - 110	$0{,}00050V^2 + 0{,}1240V + 6{,}900$
	97/24/EC All Capacities	10 - 60	$0{,}00760V^2 - 0{,}7300V + 23{,}50$
		60 - 110	$0{,}00100V^2 + 0{,}0510V + 0{,}800$
NO_x	Conventional <250cm³	10 - 60	$0{,}00005V^2 - 0{,}0010V + 0{,}090$
		60 - 110	$0{,}00002V^2 + 0{,}0006V + 0{,}102$
	Conventional 250<cc<750cm³	10 - 60	$0{,}00005V^2 - 0{,}0009V + 0{,}092$
		60 - 110	$0{,}00002V^2 + 0{,}0007V + 0{,}104$
	Conventional >750cm³	10 - 60	$0{,}00005V^2 - 0{,}0008V + 0{,}100$
		60 - 110	$0{,}00002V^2 + 0{,}0008V + 0{,}112$
	97/24/EC All Capacities	10 - 60	$0{,}00005V^2 -0{,}0007V + 0{,}137$
		60 - 110	$0{,}00002V^2 + 0{,}001V + 0{,}143$
VOC	Conventional <250cm³	10 - 60	$0{,}00190V^2 - 0{,}2110V + 6{,}950$
		60 - 110	$0{,}00090V^2 - 0{,}1410V + 6{,}420$
	Conventional 250<cc<750cm³	10 - 60	$0{,}00150V^2 - 0{,}1640V + 5{,}510$
		60 - 110	$0{,}00001V^2 + 0{,}0005V + 0{,}860$
	Conventional >750cm³	10 - 60	$0{,}00220V^2 - 0{,}2570V + 9{,}280$
		60 - 110	$0{,}00010V^2 - 0{,}0310V + 3{,}290$
	97/24/EC All Capacities	10 - 60	$0{,}00070V^2 - 0{,}0755V + 2{,}630$
		60 - 110	$0{,}00007V^2 - 0{,}0152V + 1{,}190$
Fuel Consumption	Conventional <250cm³	10 - 60	$0{,}01890V^2 - 1{,}8740V + 67{,}90$
		60 - 110	$0{,}00080V^2 + 0{,}1614V + 11{,}50$
	Conventional 250<cc<750cm³	10 - 60	$0{,}02730V^2 - 2{,}8490V + 98{,}90$
		60 - 110	$0{,}00210V^2 - 0{,}1550V + 29{,}20$
	Conventional >750cm³	10 - 60	$0{,}02870V^2 - 3{,}1080V + 115{,}9$
		60 - 110	$0{,}00180V^2 - 0{,}1638V + 37{,}00$
	97/24/EC All Capacities	10 - 60	$0{,}02000V^2 - 2{,}0750V + 77{,}10$
		60 - 110	$0{,}00130V^2 - 0{,}0391V + 23{,}50$

Table 5.26: Cold mileage percentage β

Calculations based on	β-parameter (Beta parameter)
Estimated l_{trip}	$0{,}6474 - 0{,}02545 \times l_{trip} - (0{,}00974 - 0{,}000385 \times l_{trip}) \times t_a$

Table 5.27: β-parameter reduction factors (bc) in case of post-Euro I gasoline vehicles for three main pollutants

Emission legislation	CO	NO_x	VOC
Euro II - 94/12/EC	0,72	0,72	0,56
Euro III - 98/69/EC Stage 2000	0,62	0,32	0,32
Euro IV - 98/69/EC Stage 2005	0,18	0,18	0,18

Table 5.28: Over-emission ratios e^{COLD} / e^{HOT} for Euro I and later gasoline vehicles (V: speed in km/h, t_a: temperature in °C)

Case	Category	Speed [km/h]	Temp [°C]	$e^{COLD}/e^{HOT} = A \times V + B \times t_a + C$ A	B	C
CO	CC<1,4 l	5 - 25	-20 : 15	0,156	-0,155	3,519
		26 - 45	-20 : 15	0,538	-0,373	-6,24
		5 - 45	>15	8,032E-02	-0,444	9,826
	1,4 l < CC < 2,0 l	5 - 25	-20 : 15	0,121	-0,146	3,766
		26 - 45	-20 : 15	0,299	-0,286	-0,58
		5 - 45	>15	5,03E-02	-0,363	8,604
	CC>2,0 l	5 - 25	-20 : 15	7,82E-02	-0,105	3,116
		26 - 45	-20 : 15	0,193	-0,194	0,305
		5 - 45	>15	3,21E-02	-0,252	6,332
NOx	CC<1,4 l	5 - 25	> -20	4,61E-02	7,38E-03	0,755
		26 - 45	> -20	5,13E-02	2,34E-02	0,616
	1,4 l < CC < 2,0 l	5 - 25	> -20	4,58E-02	7,47E-03	0,764
		26 - 45	> -20	4,84E-02	2,28E-02	0,685
	CC>2,0 l	5 - 25	> -20	3,43E-02	5,66E-03	0,827
		26 - 45	> -20	3,75E-02	1,72E-02	0,728
VOC	CC<1,4 l	5 - 25	-20 : 15	0,154	-0,134	4,937
		26 - 45	-20 : 15	0,323	-0,240	0,301
		5 - 45	>15	9,92E-02	-0,355	8,967
	1,4 l < CC < 2,0 l	5 - 25	-20 : 15	0,157	-0,207	7,009
		26 - 45	-20 : 15	0,282	-0,338	4,098
		5 - 45	>15	4,76E-02	-0,477	13,44
	CC>2,0 l	5 - 25	-20 : 15	8,14E-02	-0,165	6,464
		26 - 45	-20 : 15	0,116	-0,229	5,739
		5 - 45	>15	1,75E-02	-0,346	10,462
FC	All Classes	-	-10 : 30	0	-0,009	1,47

Note: In cases were the e^{COLD} /e^{HOT} ratio is calculated less than unit within the temperature and speed application limits, it should be replaced with unit

Table 5.29: Overemission ratios e^{COLD} / e^{HOT} for pre-Euro I gasoline vehicles

Conventional Gasoline Powered Passenger Cars and Light Duty Vehicles	Temperature [°C]	e^{COLD}/e^{HOT}
CO	-10 : 30	$3{,}7 - 0{,}09 \times t_a$
NO_x	-10 : 30	$1{,}14 - 0{,}006 \times t_a$
VOC	-10 : 30	$2{,}8 - 0{,}06 \times t_a$
Fuel Consumption	-10 : 30	$1{,}47 - 0{,}009 \times t_a$

Table 5.30: Over-emission ratios e^{COLD} / e^{HOT} for diesel passenger cars

Diesel Passenger Cars And Light Duty Vehicles	Temperature [°C]	e^{COLD}/e^{HOT}
CO	-10 : 30	$1{,}9 - 0{,}03 \times t_a$
NO_x	-10 : 30	$1{,}3 - 0{,}013 \times t_a$
VOC	-10 : 30	$3{,}1 - 0{,}09 \times t_a$ (1)
PM	-10 : 30	$3{,}1 - 0{,}1 \times t_a$ (2)
Fuel Consumption	-10 : 30	$1{,}34 - 0{,}008 \times t_a$

(1) VOC: if $t_a > 29°C$ then $\mathbf{e}^{COLD}/\mathbf{e}^{HOT} > 0{,}5$
(2) PM: if $t_a > 26°C$ then $\mathbf{e}^{COLD}/\mathbf{e}^{HOT} > 0{,}5$

Table 5.31: Over-emission ratios e^{COLD} / e^{HOT} for LPG passenger cars

LPG Passenger Cars	Temperature [°C]	e^{COLD}/e^{HOT}
CO	-10 : 30	$3{,}66 - 0{,}09 \times t_a$
NO_x	-10 : 30	$0{,}98 - 0{,}006 \times t_a$
VOC	-10 : 30	$2{,}24 - 0{,}06 \times t_a$ (1)
Fuel Consumption	-10 : 30	$1{,}47 - 0{,}009 \times t_a$

(1) VOC: if $t_a > 29°C$ then $\mathbf{e}^{COLD}/\mathbf{e}^{HOT} > 0{,}5$

Table 5.32: Summary of emission factors for estimating evaporative emissions of gasoline vehicles (all RVP in kPa, all temperatures in °C)

Emission factor (units)	Uncontrolled vehicle	Small carbon canister controlled vehicle
Diurnal (g/day)	$9{,}1 \times \exp(0{,}0158\,(RVP-61{,}2) + 0{,}0574\,(t_{a,min} - 22{,}5) + 0{,}0614 \times (t_{a,rise} - 11{,}7))$	$0{,}2 \times$ uncontrolled
warm soak (g/procedure)	$\exp(-1{,}644 + 0{,}01993\,RVP + 0{,}07521\,t_a)$	$0{,}2 \times \exp(-2{,}41 + 0{,}02302\,RVP + 0{,}09408\,t_a)$
hot soak (g/procedure)	$3{,}0042 \times \exp(0{,}02\,RVP)$	$0{,}3 \times \exp(-2{,}41 + 0{,}02302\,RVP + 0{,}09408\,t_a)$
warm and hot soak for fuel injected vehicles (g/procedure)	0,7	none
warm running losses (g/km)	$0{,}1 \times \exp(-5{,}967 + 0{,}04259\,RVP + 0{,}1773\,t_a)$	$0{,}1 \times$ uncontrolled
hot running losses (g/km)	$0{,}136 \times \exp(-5{,}967 + 0{,}04259\,RVP + 0{,}1773\,t_a)$	$0{,}1 \times$ uncontrolled

Note: $t_a = (t_{a,max} + t_{a,min}) / 2$ $\quad t_{a,rise} = t_{a,max} - t_{a,min}$

Table 5.33: Methane (CH_4) emission factors for stabilised (hot) thermal conditions

CH_4 Emission Factors [mg/km]	Speed Range [km/h]	Urban	Rural	Highway
Passenger Cars				
Gasoline Conventional	10 - 130	$0{,}0331V^2 - 5{,}73V + 268$		
Gas. Euro I CC < 1,4 l	10 - 130	$0{,}012969V^2 - 2{,}1098V + 101{,}995$		
Gas. Euro I 1,4 l<CC<2,0 l	10 - 130	$0{,}011176V^2 - 1{,}9573V + 99{,}652$		
Gas. Euro I CC > 2,0 l	10 - 130	$0{,}0093945V^2 - 1{,}8118V + 97{,}488$		
Diesel CC < 2,0 l	10 - 130	$0{,}0019V^2 - 0{,}1775V + 7{,}9936$		
Diesel CC > 2,0 l	10 - 130	$0{,}0019V^2 - 0{,}1775V + 7{,}9936$		
LPG		80	35	25
2 - stroke		150	40	25
Light Duty Vehicles				
Gasoline Conventional		150	40	25
Gasoline Euro I and on	10 - 130	$0{,}012969V^2 - 2{,}1098V + 101{,}995$		
Diesel		5	5	5
Heavy Duty Vehicles				
Gasoline > 3,5 t		140	110	70
Diesel < 7,5 t		85	23	20
Diesel 7,5 t < W < 16 t		85	23	20
Diesel 16 t < W < 32 t		175	80	70
Diesel W > 32 t		175	80	70
Urban Buses		175	-	-
Coaches		175	80	70
Mopeds and Motorcycles				
< 50 cm³		219	219	219
> 50 cm³ 2 stroke		150	150	150
> 50 cm³ 4 stroke		200	200	200

Note: Emission factors for later vehicle technologies should be derived according to the reduction factors of Tables 5.6, 5.10, 5.15, 5.17, 5.20 and 5.24 for different vehicle types.

Table 5.34: Bulk (hot + cold) nitrous oxide (N_2O) emission factors

N_2O Emission Factors [mg/km]	Urban	Rural	Highway
Passenger Cars			
Gasoline Conventional	5	5	5
Gasoline Euro I and on	53	16	35
Diesel CC < 2.0 l	27	27	27
Diesel CC > 2.0 l	27	27	27
LPG	15	15	15
2 - stroke	5	5	5
Light Duty Vehicles			
Gasoline Conventional	6	6	6
Gasoline Euro I and on	53	16	35
Diesel	17	17	17
Heavy Duty Vehicles			
Gasoline > 3.5 t	6	6	6
Diesel < 7.5 t	30	30	30
Diesel 7.5 t < W < 16 t	30	30	30
Diesel 16 t < W < 32 t	30	30	30
Diesel W > 32 t	30	30	30
Urban Buses	30	-	-
Coaches	30	30	30
Motorcycles			
< 50 cm³	1	1	1
> 50 cm³ 2 stroke	2	2	2
> 50 cm³ 4 stroke	2	2	2

Table 5.35: Bulk (hot + cold) ammonia (NH_3) emission factors

NH_3 Emission Factors [mg/km]	Urban	Rural	Highway
Passenger Cars			
Gasoline Conventional	2	2	2
Gasoline Euro I and on	70	100	100
Diesel CC < 2.0 l	1	1	1
Diesel CC > 2.0 l	1	1	1
LPG	nd	nd	nd
2 - stroke	2	2	2
Light Duty Vehicles			
Gasoline Conventional	2	2	2
Gasoline Euro I and on	70	100	100
Diesel	1	1	1
Heavy Duty Vehicles			
Gasoline Veh. > 3.5 t	2	2	2
Diesel < 7.5 t	3	3	3
Diesel 7.5 t < W < 16 t	3	3	3
Diesel 16 t < W < 32 t	3	3	3
Diesel W > 32 t	3	3	3
Urban Buses	3	-	-
Coaches	3	3	3
Motorcycles			
< 50 cm^3	1	1	1
> 50 cm^3 2 stroke	2	2	2
> 50 cm^3 4 stroke	2	2	2

Table 5.36a: Composition of NMVOC emissions of motor vehicles

Group	Species	NMVOC Fraction (% wt.)				
		Gasoline 4 stroke		Diesel PC & LDV	HDV	LPG
		Convent.	Euro I & on	IDI & DI		
ALKANES	ethane	1,65	3,19	0,33	0,03	2,34
	propane	0,47	0,65	0,11	0,10	49,85
	butane	2,90	5,24	0,11	0,15	15,50
	isobutane	1,29	1,59	0,07	0,14	6,95
	pentane	1,78	2,15	0,04	0,06	0,35
	isopentane	4,86	6,81	0,52		1,26
	hexane	1,29	1,61			
	heptane	0,36	0,74	0,20	0,30	0,18
	octane	0,56	0,53	0,25		0,04
	2-methylhexane	0,80	1,48	0,45	0,63	0,25
	nonane	0,06	0,16	0,67		0,01
	2-methylheptane		0,57	0,12	0,21	0,09
	3-methylhexane	0,56	1,14	0,22	0,35	0,19
	decane	0,22	0,19	1,18	1,79	
	3-methylheptane	0,40	0,54	0,20	0,27	0,08
	Alkanes C10-C12	0,03	1,76	2,15		0,01
	Alkanes C>13	0,06	1,45	17,91	27,50	
CYCLOALKANES	All	0,88	1,14	0,65	1,16	0,10
ALKENES	ethylene	8,71	7,30	10,97	7,01	5,20
	propylene	4,87	3,82	3,60	1,32	5,19
	propadiene		0,05			
	1-butene	0,50	0,73			
	isobutene	4,21	2,22	1,11	1,70	0,63
	2-butene	1,27	1,42	0,52		0,53
	1,3-butadiene	1,42	0,91	0,97	3,30	0,15
	1-pentene	0,09	0,11			
	2-pentene	0,23	0,34			
	1-hexene		0,17			
	dimethylhexene		0,15			
ALKINES	1-butine	0,05	0,21			
	propine	0,76	0,08			
	acetylene	5,50	2,81	2,34	1,05	1,28
ALDEHYDES	formaldehyde	2,08	1,70	12,00	8,40	1,56
	acetaldahyde	0,59	0,75	6,47	4,57	1,81
	acrolein	0,16	0,19	3,58	1,77	0,59
	benzaldehyde	0,60	0,22	0,86	1,37	0,03
	crotonaldehyde	0,02	0,04	1,10	1,48	0,36
	methacrolein		0,05	0,77	0,86	0,10
	butyraldehyde		0,05	0,85	0,88	0,11
	isobutanaldehyde			2,09	0,59	
	propionaldehyde	0,11	0,05	1,77	1,25	0,70
	hexanal			0,16	1,42	
	i-valeraldehyde			0,11	0,09	0,01
	valeraldehyde		0,01	0,41	0,40	
	o-tolualdehyde	0,19	0,07	0,24	0,80	
	m-tolualdehyde	0,38	0,13	0,34	0,59	
	p-tolualdehyde	0,19	0,06	0,35		
KETONES	acetone	0,21	0,61	2,94		0,78
	methylethlketone	0,11	0,05	1,20		

Table 5.36b: Composition of NMVOC emissions of motor vehicles (cont.)

Group	Species	NMVOC Fraction (% wt.)				
		Gasoline 4 stroke		Diesel PC & LDV	HDV	LPG
		Convent.	Euro I & on	IDI & DI		
AROMATICS	toluene	12,84	10,98	0,69	0,01	1,22
	ethylbenzene	4,78	1,89	0,29		0,24
	m,p-xylene	6,66	5,43	0,61	0,98	0,75
	o-xylene	4,52	2,26	0,27	0,40	0,26
	1,2,3 trimethylbenzene	0,59	0,86	0,25	0,30	0,05
	1,2,4 trimethylbenzene	2,53	4,21	0,57	0,86	0,25
	1,3,5 trimethylbenzene	1,11	1,42	0,31	0,45	0,08
	styrene	0,57	1,01	0,37	0,56	0,02
	benzene	6,83	5,61	1,98	0,07	0,63
	C9	3,12	4,21	0,78	1,17	0,25
	C10		3,07			
	C>13	6,01	3,46	13,37	20,37	
TOTALS (all NMVOC species)		**99,98**	**99,65**	**99,42**	**96,71**	**99,98**

Note: The remaining fraction to reach 100 % of NMVOC speciation is considered to consist of PAHs given in Table 5.38.

Table 5.37: Composition of NMVOC emissions from fuel evaporation

Group	Species	Evaporation emissions fraction [%]
ALKANES	Propane	1
	n-Butane	20
	i-Butane	10
	n-Pentane	15
	i-Pentane	25
	Hexane	15
	Heptane	2
ALKENES	1-Butene	1
	2-Butene	2
	1-Pentene	2
	2-Pentene	3
	1,3 Hexene	1,5
AROMATICS	Benzene	1
	Toluene	1
	m,p-Xylene	0,5

Table 5.38: PAHs and POPs bulk (hot + cold) emission factors

Group	Species	Bulk emission factors (µg/km)					
		Gasoline PC & LDV		Diesel PC &LDV		HDV	LPG
		Convent.	Euro I & on	DI	IDI	DI	
PAHs & POPs	indeno(1,2,3-cd)pyrene	1,03	0,39	0,70	2,54	1,40	0,01
	benzo(k)fluoranthene	0,30	0,26	0,19	2,87	6,09	0,01
	benzo(b)fluoranthene	0,88	0,36	0,60	3,30	5,45	
	benzo(ghi)perylene	2,90	0,56	0,95	6,00	0,77	0,02
	fluoranthene	18,22	2,80	18,00	38,32	21,39	1,36
	benzo(a)pyrene	0,48	0,32	0,63	2,85	0,90	0,01
	pyrene	5,78	1,80	12,30	38,96	31,59	1,06
	perylene	0,11	0,11	0,47	0,41	0,20	
	anthanthrene	0,07	0,01	0,07	0,17		
	benzo(b)fluorene	4,08	0,42	24,00	5,21	10,58	0,71
	benzo(e)pyrene	0,12	0,27	4,75	8,65	2,04	
	triphenylene	7,18	0,36	11,80	5,25	0,96	0,48
	benzo(j)fluoranthene	2,85	0,06	0,32	0,16	13,07	
	dibenzo(a,j)anthacene	0,28	0,05	0,11	0,12		
	dibenzo(a,l)pyrene	0,23	0,01		0,12		
	3,6-dimethyl-phenanthrene	4,37	0,09	4,85	1,25		0,18
	benzo(a)anthracene	0,84	0,43	3,30	2,71	2,39	0,05
	acenaphthylene			25,92	25,92		
	acenapthene			34,65	34,65		
	fluorene					39,99	
	chrysene	0,43	0,53	2,40	7,53	16,24	
	phenanthrene	61,72	4,68	85,50	27,63	23,00	4,91
	napthalene	11,20	610,19	2100	650,5	56,66	40,28
	anthracene	7,66	0,80	3,40	1,37	8,65	0,38
	coronene	0,90	0,05	0,06	0,05	0,15	
	dibenzo(ah)anthracene	0,01	0,03	0,24	0,56	0,34	

Table 5.39: Dioxins and Furans toxicity equivalence emission factors

	Toxicity Equivalent Emission Factors [pg/km]		
Polychlorinated Dibenzo Dioxins	**PC Gasoline Conventional**	**PC Diesel IDI**	**Heavy Duty Diesel**
TeCDD,TOTAL	3,8	0,2	1,4
PeCDD,TOTAL	5,2	0,2	0,9
HxCDD, TOTAL	1,0	0,1	0,3
HpCDD,TOTAL	0,2	0,0	0,2
OCDD	0,1	0,0	0,2
Total Dioxins	**10,3**	**0,5**	**3,0**
Polychlorinated Dibenzo Furans			
TeCDF,TOTAL	3,6	0,1	0,6
PeCDF,TOTAL	8,2	0,5	2,8
HxCDF,TOTAL	8,1	0,4	3,9
HpCDF,TOTAL	1,3	0,0	0,5
OCDF	0,0	0,0	0,1
Total Furans	**21,2**	**1,0**	**7,9**

Table 5.40: Heavy Metal emission factors for all vehicle categories in mg/kg fuel

Vehicle Category Split	Cadmium	Copper	Chromium	Nickel	Selenium	Zinc
Passenger cars, gasoline	0,01	1,7	0,05	0,07	0,01	1
Passenger cars, catalyst - gasoline	0,01	1,7	0,05	0,07	0,01	1
Passenger cars, diesel	0,01	1,7	0,05	0,07	0,01	1
Passenger cars, LPG	0,00	0,0	0,00	0,00	0,00	0
Light duty vehicles, gasoline	0,01	1,7	0,05	0,07	0,01	1
Light duty vehicles, diesel	0,01	1,7	0,05	0,07	0,01	1
Heavy duty vehicles, gasoline	0,01	1,7	0,05	0,07	0,01	1
Heavy duty vehicles, diesel	0,01	1,7	0,05	0,07	0,01	1
Motorcycles < 50cm³	0,01	1,7	0,05	0,07	0,01	1
Motorcycles > 50cm³	0,01	1,7	0,05	0,07	0,01	1

Table 6.1: Emission degradation due to vehicle age for Euro I and Euro II gasoline passenger cars and light duty vehicles

$MC = A^M \times M^{MEAN}\ B^M$	Capacity Class [l]	Average Mileage [km]	A^M	B^M (Value at 0 km)	Value at ≥120000 km
		Correction for V<19 km/h (MC_{UDC})			
CO - MC_{UDC}	≤1,4	29057	1,523E-05	0,557	2,39
	1,4-2,0	39837	1,148E-05	0,543	1,92
	>2,0	47028	9,243E-06	0,565	1,67
NO_x - **MC_{UDC}**	ALL	44931	1,598E-05	0,282	2,20
HC - MC_{UDC}	≤1,4	29057	1,215E-05	0,647	2,10
	1,4-2,0	39837	1,232E-05	0,509	1,99
	>2,0	47028	1,208E-05	0,432	1,88
		Correction for V>63 km/h (MC_{EUDC})			
CO - MC_{EUDC}	≤1,4	29057	1,689E-05	0,509	2,54
	1,4-2,0	39837	9,607E-06	0,617	1,77
	>2,0	47028	2,704E-06	0,873	1,20
NO_x - **MC_{EUDC}**	ALL	47186	1,220E-05	0,424	1,89
HC - MC_{EUDC}	≤1,4	29057	6,570E-06	0,809	1,60
	1,4-2,0	39837	9,815E-06	0,609	1,79
	>2,0	47028	6,224E-06	0,707	1,45

Table 6.2: Emission degradation due to vehicle age for Euro III and Euro IV gasoline passenger cars and light duty vehicles (and Euro I & II vehicles in case of an enhanced I&M scheme)

$MC = A^M \times M^{MEAN} + B^M$	Capacity Class [l]	A^M	B^M (Value at 0 km)	Value at 120000 km	Stabilisation Mileage [km]
		Correction for V<19 km/h (MC_{UDC})			
CO - MC_{UDC}	<1,4	1,146E-05	0,557	1,93	159.488
	1,4-2,0	8,346E-06	0,543	1,54	165.085
	>2,0	6,411E-06	0,565	1,33	173.001
NO_x - **MC_{UDC}**	ALL	1,295E-05	0,282	1,84	148.071
HC - MC_{UDC}	<1,4	8,872E-06	0,647	1,71	164.278
	1,4-2,0	9,332E-06	0,509	1,63	158.456
	>2,0	9,301E-06	0,432	1,55	155.881
		Correction for V>63 km/h (MC_{EUDC})			
CO - MC_{EUDC}	<1,4	1,297E-05	0,509	2,07	156.273
	1,4-2,0	6,592E-06	0,617	1,41	174.868
	>2,0	1,823E-07	0,873	0,89	*1.779.775*
NO_x - **MC_{EUDC}**	ALL	9,421E-06	0,424	1,55	155.436
HC - MC_{EUDC}	<1,4	3,770E-06	0,809	1,26	209.152
	1,4-2,0	6,977E-06	0,609	1,45	168.823
	>2,0	3,703E-06	0,707	1,15	201.667

Table 6.3: Euro I emission degradation functions of speed

Speed - V [km/h]	Mileage Correction - MCorr [-]
<=19	MC_{UDC}
>=63	MC_{EUDC}
>19 and <63	$MC_{UDC} + \frac{(V-19)\cdot(MC_{EUDC} - MC_{UDC})}{44}$

Table 6.4: Emission reduction with the introduction of an enhanced I&M scheme for Euro I vehicles

Pollutant	Reduction (%)
CO	16
NO_x	15
HC	15

Table 6.5: Emission reduction with the introduction of an improved I&M scheme for conventional, non-three-way catalyst equipped vehicles

Pollutant	Reduction (%)
CO	15
NO_x	8
HC	8

Table 6.6: Base fuels for each vehicle class

Vehicle Class	Base Fuel	Available Improved Fuel Qualities
Pre- Euro III	1996 Base Fuel	Fuel 2000 , Fuel 2005
Euro III	Fuel 2000	Fuel 2005
Euro IV	Fuel 2005	

Table 6.7: Relations between emissions and fuel properties for passenger cars and light duty vehicles

Pollutant	Correction factor equation
CO	FCorr = [2,459 - 0,05513 • (E100) + 0,0005343 • $(E100)^2$ + 0,009226 • (ARO)- 0,0003101 • (97-S)] • [1-0,037 • (O_2 - 1,75)] • [1-0,008 • (E150 - 90,2)]
VOC	FCorr = [0,1347 + 0,0005489 • (ARO) +25,7 • (ARO) • $e^{(-0,2642\ (E100))}$ - 0,0000406 • (97-S)] • [1-0,004 • (OLEFIN - 4,97)] • [1-0,022 • (O_2 - 1,75)] • [1-0,01 • (E150 - 90,2)]
NO_x	FCorr = [0,1884 - 0,001438 • (ARO) + 0,00001959 • (ARO) • (E100) - 0,00005302 • (97 - S)] • [1+0,004 • (OLEFIN - 4,97)] • [1+0,001 • (O_2 - 1,75)] • [1+0,008 • (E150 - 90,2)]

O_2 = Oxygenates in %
S = Sulphur content in ppm
ARO = Aromatics content in %
OLEFIN = Olefins content in %
E100 = Mid range volatility in %
E150 = Tail end volatility in %

Table 6.8: Relations between emissions and fuel properties for Diesel passenger cars and light duty vehicles

Pollutant	Correction factor equation
CO	$FCorr=-1,3250726 + 0,003037 \bullet DEN - 0,0025643 \bullet PAH - 0,015856 \bullet CN + 0,0001706 \bullet T_{95}$
VOC	$FCorr=-0,293192 + 0,0006759 \bullet DEN - 0,0007306 \bullet PAH - 0,0032733 \bullet CN - 0,000038 \bullet T_{95}$
NO_x	$FCorr=1,0039726 - 0,0003113 \bullet DEN + 0,0027263 \bullet PAH - 0,0000883 \bullet CN - 0,0005805 \bullet T_{95}$
PM	$FCorr=(-0,3879873 + 0,0004677 \bullet DEN + 0,0004488 \bullet PAH + 0,0004098 \bullet CN + 0,0000788 \bullet T_{95}) \bullet [1 - 0,015 \cdot (450 - S)/100]$

DEN = Density at 15°C [kg/m^3]
S = Sulphur content in ppm
PAH = Polycyclic aromatics content in %
CN = Cetane number
T_{95} = Back end distillation in °C

Table 6.9: Relations between emissions and fuel properties for Diesel heavy duty vehicles

Pollutant	Correction factor equation
CO	$FCorr = 2,24407 - 0,0011 \bullet DEN + 0,00007 \bullet PAH - 0,00768 \bullet CN - 0,00087 \bullet T_{95}$
VOC	$FCorr = 1,61466 - 0,00123 \bullet DEN + 0,00133 \bullet PAH - 0,00181 \bullet CN - 0,00068 \bullet T_{95}$
NO_x	$FCorr = -1,75444 + 0,00906 \bullet DEN - 0,0163 \bullet PAH + 0,00493 \bullet CN + 0,00266 \bullet T_{95}$
PM	$FCorr = [0,06959 + 0,00006 \bullet DEN + 0,00065 \bullet PAH - 0,00001 \bullet CN] \cdot [1-0,0086 \bullet (450 - S)/100]$

- DEN = Density at 15°C [kg/m^3]
- S = Sulphur content in ppm
- PAH = Polycyclic aromatics content in %
- CN = Cetane number
- T_{95} = Back end distillation in °C 223323

Table 6.10: Gasoline fuel specifications

Property	1996 Base Fuel (market average)	Fuel 2000	Fuel 2005
Sulphur [ppm]	165	130	40
RVP [kPa]	68 (summer) 81 (winter)	60 (summer) 70 (winter)	60 (summer) 70 (winter)
Aromatics [vol, %]	39	37	33
Benzene [vol, %]	2,1	0,8	0,8
Oxygen [wt %]	0,4	1,0	1,5
Olefins [vol, %]	10	10	10
E100 [%]	52	52	52
E150 [%]	86	86	86
Trace Lead [g/l]	0,005	0,003	0,003

Table 6.11: Diesel fuel specifications

Property	1996 Base Fuel (market average)	Fuel 2000	Fuel 2005
Cetane Number [-]	51	53	53
Density at 15°C [kg/m^3]	840	840	835
T_{95} [°C]	350	330	320
PAH [%]	9	7	5
Sulphur [ppm]	400	300	40
Total Aromatics [%]	28	26	24

Table 6.12: Gradient factor functions for heavy duty vehicles <7,5 t

A_6	A_5	A_4	A_3	A_2	A_1	A_0	case	slope [%]	V_{min} [km/h]	V_{max} [km/h]
0,00E+00	-4,33E-09	1,40E-06	-1,53E-04	6,22E-03	-1,01E-01	1,63E+00	VOC	4… 6	13,0	39,3
0,00E+00	-5,14E-08	9,90E-06	-7,17E-04	2,39E-02	-3,57E-01	2,95E+00	VOC	-6… -4	13,5	49,9
0,00E+00	-2,05E-08	4,25E-06	-3,30E-04	1,18E-02	-1,92E-01	2,16E+00	VOC	0… 4	15,1	69,9
0,00E+00	4,02E-09	-9,36E-07	8,39E-05	-3,66E-03	7,99E-02	3,98E-01	VOC	-4… 0	15,1	86,2
0,00E+00	1,51E-07	-1,93E-05	9,26E-04	-2,11E-02	2,57E-01	6,58E-02	CO	4… 6	13,0	39,3
0,00E+00	-7,00E-08	1,25E-05	-8,51E-04	2,71E-02	-3,96E-01	2,86E+00	CO	-6… -4	13,5	49,9
0,00E+00	-1,18E-08	2,49E-06	-1,95E-04	6,78E-03	-9,28E-02	1,52E+00	CO	0… 4	15,1	69,9
0,00E+00	-5,54E-10	1,80E-07	-1,82E-05	6,42E-04	-5,54E-03	8,14E-01	CO	-4… 0	15,1	86,2
0,00E+00	1,82E-08	-1,85E-06	3,32E-05	1,28E-03	-4,14E-03	1,43E+00	NO_x	4… 6	13,0	39,3
0,00E+00	-7,94E-08	1,37E-05	-9,08E-04	2,83E-02	-4,13E-01	2,78E+00	NO_x	-6… -4	13,5	49,9
0,00E+00	-6,87E-09	1,37E-06	-1,06E-04	3,74E-03	-4,19E-02	1,23E+00	NO_x	0… 4	15,1	69,9
0,00E+00	-3,00E-10	8,69E-08	-7,87E-06	2,26E-04	-2,07E-03	7,03E-01	NO_x	-4… 0	15,1	86,2
0,00E+00	4,27E-07	-5,74E-05	2,97E-03	-7,43E-02	9,35E-01	-3,03E+00	FC	4… 6	13,0	39,3
0,00E+00	-7,74E-08	1,33E-05	-8,78E-04	2,72E-02	-3,93E-01	2,65E+00	FC	-6… -4	13,5	49,9
0,00E+00	-3,01E-09	5,73E-07	-4,13E-05	1,13E-03	8,13E-03	9,14E-01	FC	0… 4	15,1	69,9
0,00E+00	-1,39E-10	5,03E-08	-4,18E-06	1,95E-05	3,68E-03	6,69E-01	FC	-4… 0	15,1	86,2
0,00E+00	-2,54E-07	3,58E-05	-1,99E-03	5,42E-02	-6,89E-01	4,54E+00	PM	4… 6	13,0	39,3
0,00E+00	-5,34E-08	9,97E-06	-7,05E-04	2,32E-02	-3,48E-01	2,71E+00	PM	-6… -4	13,5	49,9
0,00E+00	-1,96E-08	4,11E-06	-3,22E-04	1,16E-02	-1,83E-01	2,08E+00	PM	0… 4	15,1	69,9
0,00E+00	-1,89E-10	8,23E-08	-9,49E-06	3,25E-04	-2,54E-04	8,21E-01	PM	-4… 0	15,1	86,2

Table 6.13: Gradient factor functions for heavy duty vehicles 7,5 - 16 t

A_6	A_5	A_4	A_3	A_2	A_1	A_0	case	slope [%]	V_{min} [km/h]	V_{max} [km/h]
0,00E+00	1,28E-07	-1,65E-05	7,96E-04	-1,82E-02	2,04E-01	3,24E-01	VOC	4… 6	13,1	39,5
0,00E+00	-4,01E-08	8,12E-06	-6,01E-04	2,01E-02	-3,01E-01	2,76E+00	VOC	-6… -4	13,5	49,9
0,00E+00	-1,82E-08	3,70E-06	-2,78E-04	9,60E-03	-1,51E-01	1,94E+00	VOC	0… 4	15,1	70,3
0,00E+00	1,10E-09	-3,38E-07	3,94E-05	-2,13E-03	5,25E-02	6,52E-01	VOC	-4… 0	15,1	86,4
0,00E+00	3,28E-07	-4,35E-05	2,21E-03	-5,46E-02	6,73E-01	-1,88E+00	CO	4… 6	13,1	39,5
0,00E+00	-6,79E-08	1,21E-05	-8,24E-04	2,58E-02	-3,67E-01	2,89E+00	CO	-6… -4	13,5	49,9
0,00E+00	-1,09E-08	2,16E-06	-1,56E-04	4,85E-03	-5,79E-02	1,34E+00	CO	0… 4	15,1	70,3
0,00E+00	-1,11E-10	-3,21E-08	1,19E-05	-1,09E-03	3,34E-02	6,97E-01	CO	-4… 0	15,1	86,4
0,00E+00	-2,42E-07	3,49E-05	-1,96E-03	5,28E-02	-6,52E-01	4,60E+00	NO_x	4… 6	13,1	39,5
0,00E+00	-9,71E-08	1,70E-05	-1,14E-03	3,57E-02	-5,30E-01	3,81E+00	NO_x	-6… -4	13,5	49,9
0,00E+00	-1,21E-08	2,39E-06	-1,77E-04	6,00E-03	-8,29E-02	1,56E+00	NO_x	0… 4	15,1	70,3
0,00E+00	-8,49E-11	1,17E-08	3,94E-07	-1,38E-04	2,18E-03	9,09E-01	NO_x	-4… 0	15,1	86,4
0,00E+00	3,21E-07	-4,29E-05	2,23E-03	-5,75E-02	7,62E-01	-1,98E+00	FC	4… 6	13,1	39,5
0,00E+00	-1,24E-07	2,08E-05	-1,33E-03	4,00E-02	-5,65E-01	3,57E+00	FC	-6… -4	13,5	49,9
0,00E+00	-9,78E-10	-2,01E-09	1,91E-05	-1,63E-03	5,91E-02	7,70E-01	FC	0… 4	15,1	70,3
0,00E+00	-6,04E-11	-2,36E-08	7,76E-06	-6,83E-04	1,79E-02	6,12E-01	FC	-4… 0	15,1	86,4
0,00E+00	8,06E-09	3,61E-07	-1,27E-04	5,99E-03	-8,25E-02	1,76E+00	PM	4… 6	13,1	39,5
0,00E+00	-5,44E-08	1,01E-05	-7,06E-04	2,28E-02	-3,38E-01	2,86E+00	PM	-6… -4	13,5	49,9
0,00E+00	-1,61E-08	3,27E-06	-2,45E-04	8,30E-03	-1,18E-01	1,72E+00	PM	0… 4	15,1	70,3
0,00E+00	-7,69E-10	1,50E-07	-7,72E-06	-8,94E-05	1,04E-02	8,95E-01	PM	-4… 0	15,1	86,4

V_{min} and V_{max}: Speed range in which the correction is applicable

Table 6.14: Gradient factor functions for heavy duty vehicles 16 - 32 t

A_6	A_5	A_4	A_3	A_2	A_1	A_0	case	slope [%]	V_{min} [km/h]	V_{max} [km/h]
0,00E+00	0,00E+00	6,18E-06	-6,51E-04	2,39E-02	-3,66E-01	3,24E+00	VOC	4… 6	12,5	36,5
0,00E+00	-4,96E-08	9,03E-06	-6,37E-04	2,11E-02	-3,22E-01	3,08E+00	VOC	-6… -4	13,5	49,9
0,00E+00	-2,11E-08	4,32E-06	-3,30E-04	1,17E-02	-1,91E-01	2,25E+00	VOC	0… 4	14,9	64,7
0,00E+00	3,21E-09	-7,41E-07	6,58E-05	-2,82E-03	5,69E-02	7,55E-01	VOC	-4… 0	15,1	86,1
0,00E+00	0,00E+00	-1,50E-05	1,43E-03	-4,92E-02	7,32E-01	-2,31E+00	CO	4… 6	12,5	36,5
0,00E+00	-7,70E-08	1,30E-05	-8,51E-04	2,62E-02	-3,80E-01	3,15E+00	CO	-6… -4	13,5	49,9
0,00E+00	-2,46E-08	4,79E-06	-3,44E-04	1,13E-02	-1,66E-01	2,12E+00	CO	0… 4	14,9	64,7
0,00E+00	1,44E-09	-3,32E-07	3,06E-05	-1,45E-03	2,91E-02	8,76E-01	CO	-4… 0	15,1	86,1
0,00E+00	0,00E+00	2,30E-06	-2,49E-04	9,39E-03	-1,26E-01	2,51E+00	NO_x	4… 6	12,5	36,5
0,00E+00	-1,09E-07	1,84E-05	-1,20E-03	3,70E-02	-5,49E-01	3,83E+00	NO_x	-6… -4	13,5	49,9
0,00E+00	-2,00E-08	3,87E-06	-2,81E-04	9,57E-03	-1,43E-01	2,08E+00	NO_x	0… 4	14,9	64,7
0,00E+00	5,72E-11	1,59E-08	-4,09E-06	2,73E-04	-1,18E-02	9,79E-01	NO_x	-4… 0	15,1	86,1
0,00E+00	0,00E+00	-6,69E-06	6,55E-04	-2,31E-02	3,69E-01	1,07E-01	FC	4… 6	12,5	36,5
0,00E+00	-1,22E-07	2,03E-05	-1,30E-03	3,94E-02	-5,70E-01	3,75E+00	FC	-6… -4	13,5	49,9
0,00E+00	-5,25E-09	9,93E-07	-6,74E-05	2,06E-03	-1,96E-02	1,45E+00	FC	0… 4	14,9	64,7
0,00E+00	-8,24E-11	2,91E-08	-2,58E-06	5,76E-05	-4,74E-03	8,55E-01	FC	-4… 0	15,1	86,1
0,00E+00	0,00E+00	-1,05E-05	9,88E-04	-3,35E-02	5,10E-01	-1,09E+00	PM	4… 6	12,5	36,5
0,00E+00	-6,72E-08	1,16E-05	-7,82E-04	2,50E-02	-3,79E-01	3,23E+00	PM	-6… -4	13,5	49,9
0,00E+00	-3,60E-08	7,00E-06	-5,07E-04	1,69E-02	-2,49E-01	2,59E+00	PM	0… 4	14,9	64,7
0,00E+00	2,40E-11	3,95E-08	-6,78E-06	3,25E-04	-9,46E-03	1,12E+00	PM	-4… 0	15,1	86,1

Table 6.15: Gradient factor functions for heavy duty vehicles >32 t

A_6	A_5	A_4	A_3	A_2	A_1	A_0	case	slope [%]	V_{min} [km/h]	V_{max} [km/h]
0,00E+00	5,68E-08	-5,40E-06	1,24E-04	1,11E-03	-6,09E-02	1,80E+00	VOC	4… 6	12,4	35,0
0,00E+00	-2,50E-08	5,91E-06	-4,88E-04	1,79E-02	-2,98E-01	3,08E+00	VOC	-6… -4	13,5	49,9
0,00E+00	-2,02E-08	4,10E-06	-3,11E-04	1,09E-02	-1,76E-01	2,18E+00	VOC	0… 4	14,8	66,3
0,00E+00	1,95E-09	-4,68E-07	4,26E-05	-1,84E-03	3,52E-02	9,32E-01	VOC	-4… 0	15,1	86,3
0,00E+00	1,43E-06	-1,75E-04	8,27E-03	-1,89E-01	2,09E+00	-7,12E+00	CO	4… 6	12,4	35,0
0,00E+00	-6,48E-08	1,17E-05	-7,95E-04	2,51E-02	-3,71E-01	3,10E+00	CO	-6… -4	13,5	49,9
0,00E+00	-8,63E-09	1,50E-06	-9,50E-05	2,65E-03	-2,44E-02	1,35E+00	CO	0… 4	14,8	66,3
0,00E+00	1,28E-09	-3,07E-07	2,99E-05	-1,48E-03	3,00E-02	8,54E-01	CO	-4… 0	15,1	86,3
0,00E+00	2,42E-08	3,11E-06	-4,50E-04	1,79E-02	-2,70E-01	3,56E+00	NO_x	4… 6	12,4	35,0
0,00E+00	-9,96E-08	1,73E-05	-1,15E-03	3,63E-02	-5,48E-01	3,85E+00	NO_x	-6… -4	13,5	49,9
0,00E+00	-1,31E-08	2,49E-06	-1,82E-04	6,46E-03	-1,01E-01	1,94E+00	NO_x	0… 4	14,8	66,3
0,00E+00	-7,69E-10	2,13E-07	-2,19E-05	1,06E-03	-2,84E-02	1,08E+00	NO_x	-4… 0	15,1	86,3
0,00E+00	5,88E-07	-7,24E-05	3,45E-03	-7,86E-02	8,63E-01	-9,76E-01	FC	4… 6	12,4	35,0
0,00E+00	-1,18E-07	2,00E-05	-1,29E-03	3,96E-02	-5,78E-01	3,72E+00	FC	-6… -4	13,5	49,9
0,00E+00	-2,04E-09	4,35E-07	-3,69E-05	1,69E-03	-3,16E-02	1,77E+00	FC	0… 4	14,8	66,3
0,00E+00	-1,10E-09	2,69E-07	-2,38E-05	9,51E-04	-2,24E-02	9,16E-01	FC	-4… 0	15,1	86,3
0,00E+00	-3,23E-07	3,70E-05	-1,70E-03	3,89E-02	-4,15E-01	3,36E+00	PM	4… 6	12,4	35,0
0,00E+00	-4,37E-08	8,63E-06	-6,36E-04	2,17E-02	-3,46E-01	3,17E+00	PM	-6… -4	13,5	49,9
0,00E+00	-1,83E-08	3,60E-06	-2,65E-04	8,95E-03	-1,30E-01	1,92E+00	PM	0… 4	14,8	66,3
0,00E+00	4,10E-10	-7,06E-08	4,33E-06	-1,28E-04	-1,87E-03	1,11E+00	PM	-4… 0	15,1	86,3

V_{min} and V_{max}: Speed range in which the correction is applicable

Table 6.16: Gradient factor functions for urban busses

A_6	A_5	A_4	A_3	A_2	A_1	A_0	case	slope [%]	V_{min} [km/h]	V_{max} [km/h]
0,00E+00	-2,12E-06	2,15E-04	-8,50E-03	1,62E-01	-1,49E+00	6,19E+00	VOC	4… 6	11,4	31,2
0,00E+00	-3,13E-07	3,32E-05	-1,37E-03	2,70E-02	-2,45E-01	1,72E+00	VOC	-6… -4	11,7	35,3
0,00E+00	1,75E-08	-4,51E-06	3,08E-04	-8,79E-03	1,11E-01	5,33E-01	VOC	0… 4	13,1	37,5
0,00E+00	4,15E-07	-5,26E-05	2,59E-03	-6,16E-02	7,06E-01	-2,13E+00	VOC	-4… 0	13,2	39,5
0,00E+00	-1,59E-06	1,57E-04	-6,04E-03	1,14E-01	-1,03E+00	4,91E+00	CO	4… 6	11,4	31,2
0,00E+00	-3,26E-07	3,80E-05	-1,71E-03	3,64E-02	-3,61E-01	2,05E+00	CO	-6… -4	11,7	35,3
0,00E+00	-3,21E-07	3,94E-05	-1,92E-03	4,65E-02	-5,57E-01	3,78E+00	CO	0… 4	13,1	37,5
0,00E+00	2,75E-07	-3,56E-05	1,79E-03	-4,36E-02	5,09E-01	-1,46E+00	CO	-4… 0	13,2	39,5
0,00E+00	7,96E-07	-9,09E-05	3,83E-03	-7,42E-02	6,63E-01	-2,96E-01	NO_x	4… 6	11,4	31,2
0,00E+00	-3,27E-07	4,10E-05	-2,00E-03	4,65E-02	-5,18E-01	2,99E+00	NO_x	-6… -4	11,7	35,3
0,00E+00	1,85E-07	-2,28E-05	1,08E-03	-2,47E-02	2,79E-01	9,98E-02	NO_x	0… 4	13,1	37,5
0,00E+00	4,52E-08	-5,67E-06	2,75E-04	-6,43E-03	6,72E-02	5,15E-01	NO_x	-4… 0	13,2	39,5
0,00E+00	1,25E-07	-1,82E-05	7,87E-04	-1,32E-02	7,18E-02	2,07E+00	FC	4… 6	11,4	31,2
0,00E+00	-3,77E-07	4,59E-05	-2,16E-03	4,83E-02	-5,14E-01	2,76E+00	FC	-6… -4	11,7	35,3
0,00E+00	8,21E-08	-9,61E-06	4,20E-04	-8,55E-03	8,22E-02	1,05E+00	FC	0… 4	13,1	37,5
0,00E+00	2,13E-07	-2,78E-05	1,41E-03	-3,45E-02	4,00E-01	-1,06E+00	FC	-4… 0	13,2	39,5
0,00E+00	-7,39E-07	5,92E-05	-1,83E-03	2,80E-02	-2,18E-01	1,78E+00	PM	4… 6	11,4	31,2
0,00E+00	2,54E-07	-2,61E-05	1,01E-03	-1,81E-02	1,54E-01	3,83E-01	PM	-6… -4	11,7	35,3
0,00E+00	1,39E-07	-1,87E-05	9,46E-04	-2,26E-02	2,60E-01	-1,14E-01	PM	0… 4	13,1	37,5
0,00E+00	2,02E-07	-2,43E-05	1,14E-03	-2,60E-02	2,86E-01	-3,34E-01	PM	-4… 0	13,2	39,5

Table 6.17: Gradient factor functions for coaches

A_6	A_5	A_4	A_3	A_2	A_1	A_0	case	slope [%]	V_{min} [km/h]	V_{max} [km/h]
0,00E+00	0,00E+00	4,15E-06	-5,14E-04	2,17E-02	-3,76E-01	3,43E+00	VOC	4… 6	9,7	34,8
0,00E+00	0,00E+00	3,03E-06	-4,09E-04	1,94E-02	-3,75E-01	3,98E+00	VOC	-6… -4	11,7	49,9
2,49E-10	-8,50E-08	1,14E-05	-7,66E-04	2,65E-02	-4,41E-01	3,80E+00	VOC	0… 4	13,1	95,3
1,42E-10	-5,47E-08	8,20E-06	-6,05E-04	2,27E-02	-4,01E-01	3,89E+00	VOC	-4… 0	13,1	102,9
0,00E+00	0,00E+00	5,20E-06	-6,07E-04	2,51E-02	-4,28E-01	3,56E+00	CO	4… 6	9,7	34,8
0,00E+00	0,00E+00	2,24E-06	-3,21E-04	1,61E-02	-3,30E-01	3,25E+00	CO	-6… -4	11,7	49,9
2,22E-10	-7,88E-08	1,10E-05	-7,63E-04	2,73E-02	-4,69E-01	3,99E+00	CO	0… 4	13,1	95,3
1,09E-10	-4,42E-08	6,93E-06	-5,33E-04	2,09E-02	-3,87E-01	3,60E+00	CO	-4… 0	13,1	102,9
0,00E+00	0,00E+00	-1,15E-05	9,84E-04	-3,02E-02	3,89E-01	7,29E-01	NO_x	4… 6	9,7	34,8
1,65E-08	-3,13E-06	2,39E-04	-9,44E-03	2,02E-01	-2,22E+00	1,04E+01	NO_x	-6… -4	11,7	49,9
2,97E-10	-9,51E-08	1,18E-05	-7,16E-04	2,18E-02	-3,07E-01	3,21E+00	NO_x	0… 4	13,1	95,3
1,27E-10	-4,61E-08	6,56E-06	-4,66E-04	1,71E-02	-3,00E-01	2,75E+00	NO_x	-4… 0	13,1	102,9
0,00E+00	0,00E+00	-1,34E-05	1,12E-03	-3,31E-02	4,00E-01	9,84E-01	FC	4… 6	9,7	34,8
1,61E-08	-3,07E-06	2,37E-04	-9,43E-03	2,04E-01	-2,25E+00	1,04E+01	FC	-6… -4	11,7	49,9
1,99E-10	-6,52E-08	8,32E-06	-5,20E-04	1,65E-02	-2,43E-01	3,02E+00	FC	0… 4	13,1	95,3
1,15E-10	-4,23E-08	6,16E-06	-4,48E-04	1,69E-02	-3,05E-01	2,70E+00	FC	-4… 0	13,1	102,9
0,00E+00	0,00E+00	4,91E-07	-1,88E-04	1,17E-02	-2,47E-01	3,11E+00	PM	4… 6	9,7	34,8
-3,03E-09	4,76E-07	-2,59E-05	4,46E-04	6,68E-03	-2,90E-01	3,25E+00	PM	-6… -4	11,7	49,9
2,83E-10	-9,69E-08	1,30E-05	-8,68E-04	2,97E-02	-4,88E-01	4,21E+00	PM	0… 4	13,1	95,3
1,40E-10	-5,29E-08	7,85E-06	-5,78E-04	2,18E-02	-3,91E-01	3,54E+00	PM	-4… 0	13,1	102,9

Vmin and Vmax: Speed range in which the correction is applicable

Table 6.18: Road gradient classes

Driving Conditions	Road Gradient
Uphill	0… 4 %
Steep uphill	4… 6 %
Downhill	-4… 0 %
Steep downhill	-6… -4 %

Table 6.19: Load correction factors ($LCorr_i$) applied to heavy duty vehicles

Pollutant	Load Factor
CO	0,21
NO_x	0,18
VOC	0,00
PM	0,08
Fuel Consumption	0,18

10. List of symbols and indices

10.1. List of symbols

$\mathbf{A_0 \ldots A_6}$	constants for the emission correction due to road gradient (Tables 6.12-6.17)
$\mathbf{A^M}$	emission performance degradation per kilometre (Tables 6.1 and 6.2)
$\mathbf{B^M}$	relative emission level of brand new vehicles (Tables 6.1 and 6.2)
bc	correction coefficient for the β-parameter to be applied for improved catalyst vehicles (Table 5.27)
$\mathbf{E_{HOT}}$	total emissions during thermally stabilised (hot) engine and exhaust aftertreatment conditions
$\mathbf{E^{CALC}}$	emission of a fuel dependent pollutant (CO_2, SO_2, Pb, HM) estimated on the basis of the calculated fuel consumption
$\mathbf{E^{CORR}}$	corrected emission of a fuel dependent pollutant (CO_2, SO_2, Pb, HM) on the basis of the statistical fuel consumption
$\mathbf{e^{COLD}/e^{HOT}}$	ratio of emissions of cold to hot engines
$\mathbf{e^d}$	mean emission factor for diurnal losses of gasoline powered vehicles equipped with metal tanks, depending on average monthly weighted temperature, temperature variation and fuel volatility (RVP)
$\mathbf{e_{HOT}}$	average fleet representative baseline emission factor in [g/km] for thermally stabilised (hot) engine and exhaust aftertreatment conditions
$\mathbf{e^{s,hot}}$	mean emission factor for hot soak emissions
$\mathbf{e^{s,warm}}$	mean emission factor for cold and warm soak emissions
$\mathbf{e^{fi}}$	mean emission factor for hot and warm soak emissions of gasoline powered vehicles equipped with fuel injection
$\mathbf{e^{r,hot}}$	average emission factor for hot running losses of gasoline powered vehicles
$\mathbf{e^{r,warm}}$	average emission factor for warm running losses of gasoline powered vehicles
ES	emission standard according to the legislation
e(V)	mathematical expression of the speed dependency of $\mathbf{e_{HOT}}$
f(V)	equation (e.g. formula of 'best fit'' curve) of the frequency distribution of the mean speeds which corresponds to the driving patterns of vehicles on road classes 'rural', 'urban' and 'highway'.
$\mathbf{FC^{CALC}}$	calculated fuel consumption)
$\mathbf{FCe_{HOT}}$	hot emission factor corrected for the use of improved fuel
FCorr	emission correction for the use of conventional or improved fuel
$\mathbf{FC^{STAT}}$	statistical (true) total consumption
GCorr	emission correction factor for the effect of road gradient
$\mathbf{GCe_{HOT}}$	corrected hot emission factor for road gradient
k	weight related content of any component in the fuel [kg/kg fuel]
$\mathbf{LCe_{HOT}}$	corrected hot emission factor for vehicle load
LCorr	vehicle load correction factor
LP	the actual vehicle load factor (expressed as a percentage of the maximum load. That is, **LP** = 0 denotes an unloaded vehicle and **LP** = 100 represents a totally laden one)
$\mathbf{l_{trip}}$	average trip length [km]
M	average mileage in [km]
$\mathbf{MCe_{HOT}}$	hot emission factor corrected for degraded vehicle performance due to mileage
MCorr	Correction coefficient for emission performance degradation due to mileage
$\mathbf{M^{MEAN}}$	mean fleet mileage [km]

N	number of vehicles [veh.]
p	fraction of trips, finished with hot engine (depending on the average monthly ambient temperature)
q	fraction of gasoline powered vehicles equipped with fuel injection
R	hot and warm running losses
$r_{H:C}$	ratio of hydrogen to carbon atoms in fuel
RF	reduction factor for emissions of pollutant of a class over a reference class
RVP	the fuel reid vapor pressure expressed in kPa (Corinair Standard approach) or mbar (Alternative approach)
S	share of mileage driven in different road types
S^c	average hot and warm soak emission factor of gasoline powered vehicles equipped with carburettor
S^{fi}	average hot and warm soak emission factor of gasoline powered vehicles equipped with fuel injection
t	ambient temperature [°C]
w	fraction of trips, finished with cold or warm engine
x	mean number of trips of a vehicle per day, average over the year
y	total number of trips of a vehicle per day
V	vehicle mean travelling speed in [km/h]
β	fraction of mileage driven with cold engines

10.2. List of indices

a	monthly mean
a,min	monthly mean minimum
a,rise	monthly mean rise
Base	referred to the base fuel quality
c	cycle (c= UDC, EUDC)
COLD	referring to cold start over-emissions
EVAP	referring to fuel evaporation
Fuel	referred to improved fuel quality
HIGHWAY	referring to highway driving conditions
HOT	referring to thermally stabilised engine conditions
i	pollutant index (i = 1-33)
j	vehicle classes (j = 1-99)
jm	vehicle class operating on fuel type m
k	road classes (k= urban, rural, highway)
m	fuel type (m= leaded gasoline, unleaded gasoline, diesel , LPG)
Pb	Lead content in fuel
RURAL	referring to rural driving conditions
S	Sulphur content in fuel
TOT	referring to total calculations
URBAN	referring to urban driving conditions