Technical Report No. 6

COPERT II Computer Programme to calculate Emissions from Road Transport

Methodology and Emission Factors

Prepared by: P. Ahlvik (MTC), S. Eggleston (AEA Technology),
N. Gorißen (UBA), D. Hassel (TÜV Rheinland),
A.-J. Hickman (TRL), R. Joumard (INRETS),
L. Ntziachristos (LAT/AUTH), R. Rijkeboer (TNO),
Z. Samaras (LAT/AUTH) and K.-H. Zierock (UBA)

ETC/AEM

November 1997

European Environment Agency

Cover design: Rolf Kuchling, EEA

Legal notice

Printed in Copenhagen

Printed on recycled and chlorine-free bleached paper

European Environment Agency
Kongens Nytorv 6
DK-1050 Copenhagen K
Denmark
Tel: +45 33 36 71 00
Fax: +45 33 36 71 99
E-mail: eea@eea.eu.int

CONTENTS

1. Introduction

This report describes the methodology and the 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 II (Ntziachristos and Samaras 1997), which facilitates its application. The development of COPERT II 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 the EEA member countries for the compilation of the CORINAIR emission inventories. In principle COPERT II methodology can be applied for the calculation of traffic emission estimates at a relatively high aggregation level, both temporally and spatially, i.e. 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, i.e. 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 second 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 updated methodology is largely based on the work of a working group which was set up for this purpose; however, it draws its main principles from two ongoing European activities:

- The action COST 319 on The Estimation of Emissions from Transport and
- 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

both aimed at harmonising emission factors and national methodologies concurrently and independently developed in the last years.

In this respect the methodology presented here should be considered as an anticipation of the final product of the above activities, especially MEET, which, after it is completed, should be fully adopted in an eventual future update of COPERT.

In comparison with the 1990 approach the following significant modifications have been made:

1. The methodology includes all necessary technological data for the estimation of the emissions from road traffic for a single year. The methodology can also be applied for a year in the near future, as emission factors for future (known) regulations are also included. However, the activity data, needed for the emissions estimates, have to be provided by national experts.
2. The vehicle category split has been revised, including a number of weight classes for heavy duty trucks, and considering urban buses and coaches separately.
3. Speed dependent emission and fuel consumption factors are introduced for all vehicle categories (except mopeds <50cm³). As far as the emission factors of improved or future technologies are concerned an appropriate pollutant related reduction factor is introduced, applicable to the emission factor of the best current technology.
4. The emissions calculations of heavy duty vehicles are updated, in order to account for the gradient of the road and the weight carried.
5. The list of pollutants covered has been extended. The report includes emission factors for all the pollutants of 1990 report with the addition of heavy metals (cadmium, copper, chromium, nickel, selenium and zinc) related to the fuel consumption factors.

As in the previous approaches, emissions from road traffic are divided into three types. The first are the “hot emissions”. These are the emissions from vehicles after they have warmed up to their normal operating temperature. The second are the so-called “cold-start emissions” which are the emissions from vehicles while they are warming up. The third type are evaporative emissions. These only occur in relevant quantities for gasoline vehicles in the form of NMVOC emissions. For some vehicle classes and some pollutants, the different types of emissions are lumped together into one emission factor, for some others, individual emission factors are proposed.

2. Vehicle Category Split

The vehicle category split required for reporting in CORINAIR, presented in Table II-1 (EMEP / CORINAIR 1996), does not meet all aspects of vehicle emissions considered important. In particular, the age of vehicle (year of production) and the engine technology, especially for the categories equipped with diesel engines, is not sufficiently reflected. Thus, for the purpose of the work only, a more detailed vehicle category split has been developed, presented in Table II-2.

Remarkable differences occur in all vehicle categories, where the different steps of international legal conformity are reflected. In addition, as in 1990 report, in the category Passenger Cars national legislation is taken into account with the classes ‘Improved Conventional’ and ‘Open Loop’. In contrast with the previous reports, the category ‘Buses’ is specifically differentiated.

In order to help identifying the vehicle categories, Table II-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

3. Pollutants Covered

The report contains emission factors for NO_x, N_2O, SO_x, VOC, CH_4, CO, CO_2, NH_3, diesel particulates , and heavy metals (lead, cadmium, copper, chromium, nickel, selenium and zinc). The following definitions apply:

NO_x (NO and NO_2): given as NO_2 equivalent
N_2O: given as N_2O equivalent
SO_x: given as SO_2 equivalent
VOC: given as $CH_{1,85}$ equivalent
CH_4: given as CH_4 equivalent
NMVOC: produced by subtracting CH_4 from total VOC emissions
CO: given as CO equivalent
CO_2: given as CO_2 equivalent
NH_3: given as NH_3 equivalent
Particulate matter: given as mass equivalent of filter measurements
Lead: given as Pb equivalent
Cadmium: given as Cd equivalent
Copper: given as Cu equivalent
Chromium: given as Cr equivalent
Selenium: given as Se equivalent
Nickel: given as Ni equivalent
Zinc: given as Zn equivalent

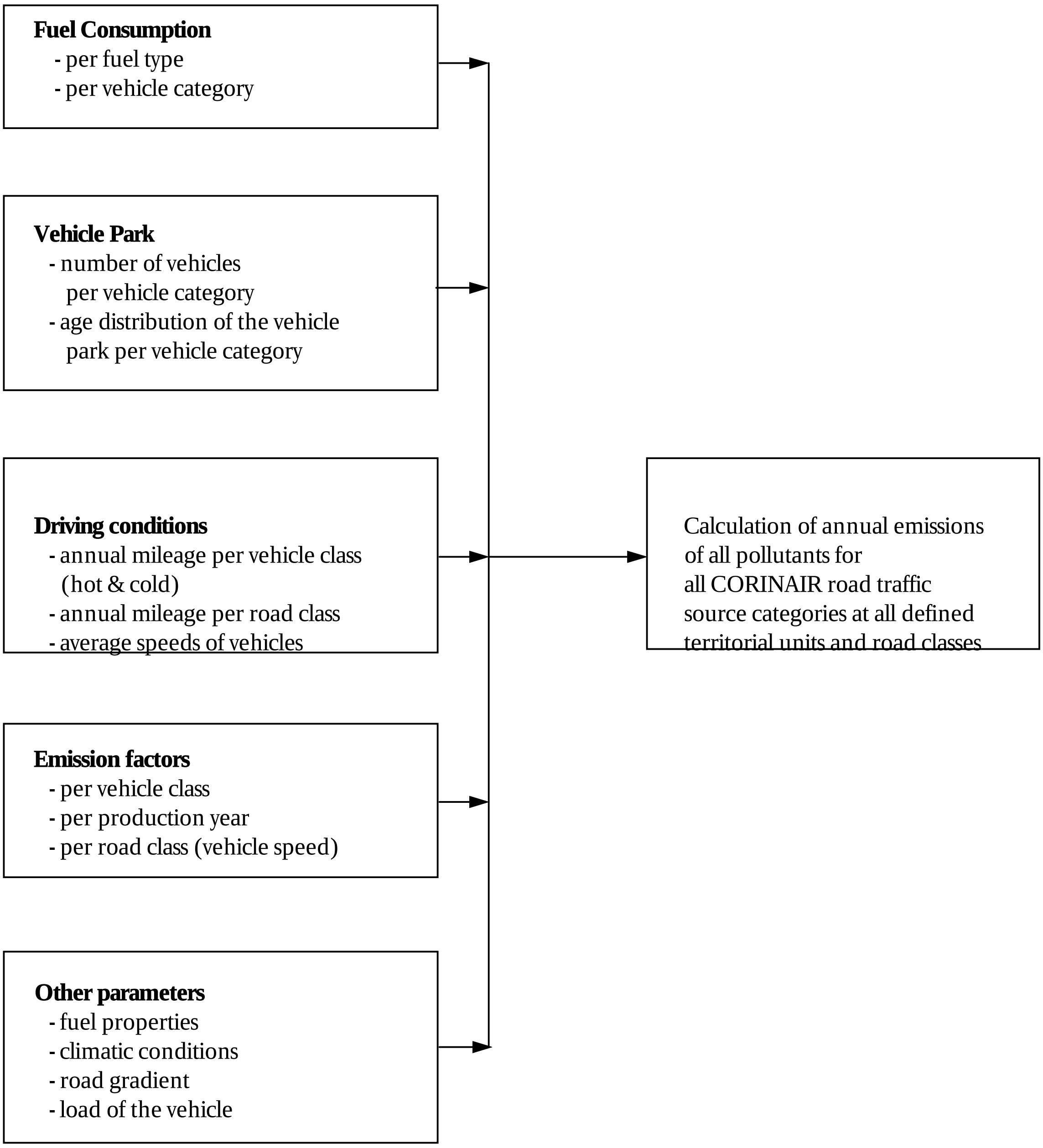
A more detailed VOC split is included in this report. Details on the speciation of VOC exhaust emissions are given in Chapter V.11.

4. Baseline Methodology

The methodology is defined in such a way that it uses the firm technical data and that national variations can be incorporated. The variations may include parameters such as the composition of vehicle park, vehicle age, driving patterns, some fuel parameters and climatic conditions. Other variations which may exist, e.g. variations in vehicle maintenance, are not accounted for, because there is not enough data available to do so. The calculation is based on five main types of input parameters:

- total fuel consumption
- vehicle park
- driving condition
- emission factors
- other parameters

For these main types of input parameters, additional information (e.g. on vehicle classes, production years, etc.) is needed in order to carry out the calculations. The picture following shows the calculation scheme:



In order to meet the CORINAIR requirements, 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 level III).

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 park, 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 (e.g. Zachariadis and Samaras 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.

4.1. Hot Emissions

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.

There are a number of other factors that may influence vehicle emissions, for example, state of maintenance. However, the data available so far (e.g. Samaras et al. 1997) about the influence of these parameters on European vehicles do not allow this influence to be specifically taken into account.

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

Emissions [g] = emission factor [g/km] · vehicle kilometers per year [km]

The emission factors and vehicle kilometers are in most cases split into certain classes of road types (as the use of the average speed for its calculation implies) and vehicle categories.

However, for many countries the only data known with any certainty is the total fuel consumption of petrol, diesel and LPG, not vehicle kilometers. It is therefore suggested that fuel consumption data are used to check vehicle mileage where they are known and to make a final fuel balance.

Since emission factors can be converted from [g/km] into [g/kg fuel], using consumption data for all vehicle classes and road types, the calculation can be carried out either on one or the other emission factor.

If fuel consumption is to be used, we have:

$$E_{hot,i,j,k} = g_{j,k,1} \,.\, b_{j,1} \,.\, e_{*hot,year,i,j,k} \tag{1}$$

where:

$E_{hot,i,j,k}$ = emissions of the pollutant i in [g], produced in the reference year by vehicles of category j driven on roads of type k with hot engines

$g_{j,k,1}$ = share of annual fuel consumption of type 1 used by vehicles of category j, driven on road type k

$b_{j,1}$ = total annual consumption of fuel type 1 in [kg] by vehicles of category j operated in the reference year

$e_{*hot,year,i,j,k}$ = average fleet representative baseline emission factor in [g/kg fuel] for the pollutant i, relevant for the vehicle category j, operated on roads of type k with hot engines (please note: these factors have been derived from emission factors of individual cars which were grouped together according to the national car park)

and:

i (pollutants) = 1-17 for the pollutants covered

j (vehicle category) = 1-77 for the on-road categories defined in the vehicle category split (Table II-2)

k (road classes) = 1-3 for 'urban', 'rural', and 'highway' driving (note that the road types imply certain speed patterns)

l (fuel type) = 1-3 for gasoline, diesel, LPG

The application of equation (1) requires statistical input data which are not available in several countries. Therefore, some data have to be estimated. It is proposed to apply as a principle for these estimations the rule that those parameters which are least known should be modified most. In practice this means to attribute uncertainties to parameters which are actually uncertain and to avoid modifications of parameters which are known somewhat more precisely. In the following, some practical explanations are given.

The factors $b_{j,1}$ and $g_{j,k,1}$ used in equation (1) cannot be introduced into the calculation from statistical data but have to be estimated with the help of other parameters. As outlined above, in most of the Member States the total fuel consumption is only known for different fuels, (e.g. gasoline, diesel, LPG) but not, as required, related to vehicle categories. In such a case it is proposed to distribute the total fuel figures to the vehicle categories in an iterating process, making assumptions concerning the average annual mileage driven per vehicle of a defined category and the distribution of the total annual mileage to different road types. The data on total fuel consumption of the different fuels, the number of vehicles in each category and the average fuel consumption for each vehicle category on the different road types remain the fixed points in this process. It is proposed to start with

(2) $m_j = h_j \cdot v_j$

where:

m_j = total annual mileage in [km] of vehicle category j
h_j = number of vehicles of category j
v_j = average annual mileage driven by each vehicle of category j

While h_j is considered as a well-known statistical figure, v_j, is not available as independent statistical data in many countries and has to be estimated.

In the next step, m_j is introduced into the formula:

(3) $m_{j,k} = m_j \,.\, d_{j,k}$

where:

$m_{j,k}$ = total annual mileage in [km] of vehicle category j on road class k
$d_{j,k}$ = share of annual mileage driven on road class k by vehicle category j

The parameter $d_{j,k}$ is rarely available as independent statistical data in any European country and therefore has to be estimated. The parameter $m_{j,k}$ should then be introduced into the formula:

(4) $$b_{j,l} = \sum_{k=1}^{3} m_{j,k} \cdot c_{j,k}$$

where:

$b_{j,1}$ = total annual consumption of fuel of type 1 in [kg] by vehicles of category j operated in the reference year
$c_{j,k}$ = average fuel consumption in [g/km] of vehicle category j on road class k

The figure $c_{j,k}$ is a measured value (figures can be taken from Tables given in this chapter), so that the calculation can be carried out easily.

(5) $$Q_l = \sum_j b_{j,l}$$

where:

O_l = total annual consumption of fuel type l

As a rule, the calculated Ol should be equal to the consumption statistics[1]. If now the calculated O1 does not match the true value, the 'soft' input parameters should be modified. 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 in most of the cases the parameters dj.k and/or vl are those to which most attention should be given (Table IV.1-1 provides an example of the values estimated by countries for the parameter dj,k in the COPERT1990 exercise, see Andrias et al. 1994). The factor gj,k can be calculated as follows:

(6)

$$g_{j,urban} = c_{j,urban} \cdot m_{j,urban} / \sum_{k=1}^{3} c_{j,k} \cdot m_{j,k} \quad for\ k = urban$$

---

[1] However, it should be noted that in some countries there might be a difference between the fuel sold and the fuel actually consumed in this country due to vehicles in transit. The official statistics always correspond to the fuel sold in a country and therefore have to be corrected if there are clear indications for a substantial import or export of fuel

$$g_{j,rural} = c_{j,rural} \cdot m_{j,rural} / \sum_{k=1}^{3} c_{j,k} \cdot m_{j,k} \quad for\ k = rural$$

$$g_{j,highway} = c_{j,highway} \cdot m_{j,highway} / \sum_{k=1}^{3} c_{j,k} \cdot m_{j,k} \quad for\ k = highway$$

where:

$c_{j,k}$ = average fuel consumption in [g/km] of vehicle category j on road class k

$m_{j,k}$ = total annual mileage in [km] of vehicle category j on road class k

All elements of these equations are known, so that the calculation can be carried out directly.
Generally, the emission factor $e_{hot,\ year,\ i,\ j,\ k}$ expressed in [g/km] is known from measurements and should be converted into [g/kg fuel] as follows:

(7) $e^{*}_{hot,\ year,\ i,\ j,\ k} = e_{hot,\ year,\ i,\ j,\ k} / c_{j,k}$

where:

$e_{hot,\ year,\ i,\ j,\ k}$ = average fleet representative baseline emission factor for the reference year in [g/km] for the pollutant i, for the vehicle category j, operated on roads of type k with hot engines

$c_{j,\ k}$ = average fuel consumption in [g/km] of vehicle category j on road class k

4.1.1. *Accounting for Vehicle Speed*

Vehicle speed, which is introduced into the calculation via the three road types, 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 fk(z) and to integrate over the emission curves,

(8) i.e.: $e_{hot,i,j,k,g} = \int e(z)\, f_{k,j}(z)$

where:

c = emission factor in [g/km] for pollutant i, relevant for vehicle category j, operated on roads of type k with hot engines, valid for regulatory step g

z = speed of vehicles on road classes ‘rural’, ‘urban’, ‘highway’

$e(z)$ = mathematical expression (e.g. ‘best fit’) of the speed-dependency of $e_{hot,i,j,k,g}$

$f_{k,j}(z)$ = 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’, $f_{k,j}(z)$ depends on road type k, vehicle category j and also, possibly, on engine size and weight class.

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. Table IV.1.1-1 shows as an example the speed selection of Member States applied in the COPERT 1990 exercise (Andrias et al. 1994).

4.1.2. *Accounting for Vehicle Age*

The emissions of vehicles have changed over time, mainly due to regulatory requirements. The composition of the national fleets differs because the evolution of national fleets and their replacement rates vary from one country to another. Therefore, in a second step, it is proposed to use the following equation in order to calculate emission factors representative of the national fleet:

(9) $$e_{hot,year,i,j,k} = \sum_{g} s_{j,g} \cdot e_{hot,i,j,k,g}$$

with:

(10) $$s_{j,g} = \frac{a_{j,g}}{\sum_{g} a_{j,g}}$$

for periods of legal or of technological conformity g with:

$a_{j,g}$ = number of vehicles of category j produced or will be produced within the period of legal or technological conformity g

The application of this equation requires detailed knowledge of the composition of the national fleet with regard to age and cylinder capacity.

As mentioned above, the study analysed with great care available emission data of individual vehicle tests. They were derived by grouping all available measurements carried out with on-road vehicles into periods of legal or technical conformity. In total, a considerable number of vehicles test data have been evaluated. As far as possible, only data obtained in transient mode test cycles were used. Only for high speed driving (80 km/h and more), data obtained under conditions of steady driving were taken into account as well.

4.2. 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 factor, the ratio of cold to hot emissions, is used and applied to the fraction of kilometers 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:

(11) $$E_{cold;i,j} = \beta_j \cdot m_j \cdot e^{hot} \cdot (e^{cold}/e^{hot} - 1)$$

where:

$E_{cold, i, j}$ = cold-start emissions of the pollutant i (for the reference year), caused by vehicle category j (assumption: all cold-start estimates are allocated to urban driving)

β_j = fraction of mileage driven with cold engines[2] or catalyst operated below the light-off temperature

m_j = total annual mileage of the vehicle category j

e^{cold}/e^{hot} = cold to hot ratio of emissions

The parameter β depends on ambient temperature 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 l_{trip}. However, since information on l_{trip} is not available in many countries for all vehicle classes, some simplifications have been introduced for some vehicle categories.

The ratio e^{cold}/e^{hot} also depends on the ambient temperature and pollutant considered.

For the calculation of extra cold-start emissions the same methodology introduced in COPERT90 is used, although a new, more detailed and accurate method has been recently developed in the framework of MEET (LAT/AUTH et al. 1997), which accounts for data and methods produced in a number of national programmes. However, the application of the

---

[2] ‘cold’ engines are defined as those with a water temperature below 70°C

new approach still needs to be further refined and tested, especially in view of the many and very detailed input requirements it has.

4.3. Evaporative VOC Emissions

There are three primary sources of evaporative emissions from vehicles:

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

These are estimated separately. Again they are affected by factors that vary from country to country.

4.3.1. 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 emission 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.

4.3.2. 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.

4.3.3. 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 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. The methodology used in order to estimate evaporative VOC emissions has been proposed by Concawe (1990) and it is the same that has been incorporated in COPERT90 report.

Evaporative VOC emissions from gasoline fuelled vehicles add to total NMVOC emissions.
The main equation for estimating the evaporative emissions is:

(12) $E_{eva,voc,j} = 365\, a_j\, (e^d + S^c + S^{fi}) + R$

where:

$E_{eva,\ voc\ ,j}$ = VOC emissions due to evaporative losses caused by vehicle category j
a_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

(13) $S^c = (1-q)\,(p \cdot x \cdot e^{s,hot} + w \cdot x \cdot e^{s,warm})$
(14) $S^{fi} = q \cdot e^{fi} \cdot x$
(15) $R = m_j\,(p \cdot e^{r,hot} + w \cdot e^{r,warm})$

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[3] (shorter trips) or with catalyst below its light-off temperature
x = mean number of trips of a vehicle per day, average over the year

---

[3] Engines are defined as 'cold' or 'warm' if the water temperature is below 70°C

(16) $x = v_j / (365 \cdot l_{trip})$

$e^{s,hot}$ = 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)

$e^{r,warm}$ = 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

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, i, w and x. Therefore, a few indications will be given in Chapter V.3 concerning the values of these parameters.

The fraction of trips finished with cold and warm engine, w, is connected with the parameter β 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:

$$w \sim \beta$$

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.

4.4. Road Gradient Influence

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 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).

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

Vehicle mass

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.

Road Gradient

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 IV.4-1. Positive road gradient corresponds to uphill driving and vice versa.

Pollutant or consumption

Gradient factors apply to all major pollutants (CO, VOC, NO_x, PM) as well as fuel consumption.

Mean speed

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

(17) $as_{i,j,k}=A6_{i,j,k}V^6 + A5_{i,j,k}V^5 + A4_{i,j,k}V^4 + A3_{i,j,k}V^3 + A2_{i,j,k}V^2 + A1_{i,j,k}V + A0_{i,j,k}$

where:

$as_{i,j,k}$ = the correction factor

V = the mean speed

$A0_{i,j,k}... A6_{i,j,k}$ = constants for each pollutant, weight and gradient class

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:

(18) $ec_{hot,i,j,k} = as_{i,j,k} \cdot e_{hot,i,j,k}$

where:

$ec_{hot,i,j,k}$ = 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

$e_{hot,i,j,k}$ = emission factor of the pollutant i in [g/km] of the vehicle of category j driven on roads of type k with hot engines

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

4.5. 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 calculated for a load of 50%, is corrected with use of the following formula:

(19) $ec(l)_{i,j} = e_{i,j}\,(50\%)\cdot\left[1 + 2cf_i \cdot (lp - 50) / 100\right]$

where,

$ec(l)_{i,j}$ = corrected emission factor of the pollutant i in [g/km] of the vehicle of category j

$e_{i,j}(50\%)$ = emission factor of the pollutant i in [g/km] of the vehicle of category j calculated for a load of 50%

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 full load)

cf_i = load correction factor of the pollutant i.

4.6. Application of the Baseline Methodology to the Different Vehicle Categories and Pollutants

Due to gaps in knowledge, the baseline methodology can not be applied in full and in the same way to all vehicle categories. Moreover, there are variations depending on the pollutant considered. In general, one can distinguish between four methods:

Method A:	**Hot emissions** are calculated based on the total annual kilometers driven per vehicle; the share of kilometers driven under the driving modes 'urban', 'rural', 'highway'; the average speed of the vehicles under the driving modes 'urban', 'rural', 'highway'; speed-dependent hot emission factors. **Cold-start emissions** are calculated based on the average trip length per vehicle trip; the average monthly temperature; temperature and trip length dependent cold-start correction factor. **Evaporative emissions** are calculated based on the fuel volatility (RVP); the average monthly temperature and the average monthly temperature variation; fuel volatility and temperature dependent emission factor.
Method B:	The total annual emissions per vehicle are calculated based on the total annual kilometers driven per vehicle; the share of kilometers driven under the driving modes 'urban', 'rural', 'highway'; the average speed of the vehicles under the driving modes 'urban', 'rural', 'highway'; speed-dependent emission factors. ________________________ **remark**: for diesel passenger cars, cold-start extra emissions for CO, NOx and NMVOC as well as extra fuel consumption are added using the method described under A. For LPG passenger cars a simplified method is used.
Method C:	The total annual emissions per vehicle are calculated based on the total annual kilometers driven per vehicles; the share of kilometers driven under the driving modes 'urban', 'rural', 'highway'; driving mode dependent emissions factors.
Method D:	The total annual emissions per vehicle category are calculated based on the total annual fuel consumption of the vehicle category and / or the total annual kilometers driven by the vehicle category; fuel consumption and / or kilometer related emission factors.

These methods are applied to the different vehicle categories and the different pollutants as shown in Table IV.6 - 1.

5. Emission Factors Proposed by the Working Group

The emission factors proposed can be distinguished into two classes: those for which detailed evaluations are necessary and possible and those for which only very simple ‘bulk’ emission factors or equations can be provided. The pollutants CO, VOC and NOx together with fuel consumption factors fall under the first category, while SO_2, NH_3, CO_2, N_2O, Heavy Metals and partly CH_4 fall under the second one. It should be noted that the reliability of emission factors differs substantially and this should be taken into account when interpreting the results of the emission estimates.

5.1. Hot Emissions Factors

The emission factors proposed in the following were jointly worked out by the members of the Working Group, taking into account the results of comprehensive studies carried out in France, Germany, Greece, the Netherlands, the United Kingdom, Austria, Sweden and Switzerland. Emission factors for 3W catalyst equipped as well as diesel powered passenger cars and light duty trucks were produced based on measured data on in-use vehicles, gathered in the framework of COST 319 from national or international projects (e.g. Hassel et al. 1993, TNO 1993, Samaras et al. 1997, Keller et al. 1995). The production of heavy duty vehicles emission factors are based on data from the Swiss / German Workbook (Hassel et al. 1995, Keller et al. 1995) and checked against the (unpublished) results of a British measurement campaign conducted by TRL.

For the application of the proposed methodology, one theoretically needs emission factors $e_{hot,year,i,j,k}$ for:

- pollutants (CO, NOx, N_2O, SO_2, VOC, CH_4, CO_2, NH_3, diesel particulates, heavy metals)
- vehicle categories
- road types

In practice, the picture looks somewhat different because:

- for some pollutants (e.g. CO_2, SO_2, NH_3, heavy metals, partly N_2O) emissions are calculated based on fuel consumption only so that no distinction with regard to road types is necessary,
- for some other pollutants, due to the lack of measured data, emissions can be reported only as fractions of other emissions (e.g. CH_4) or by applying lumped emission factors (partly N_2O) so that no separate full calculation is necessary,
- for some pollutants no emission factor could be derived for certain vehicle categories, so that the total number of emission factors is substantially smaller than theoretically necessary,
- for mopeds no distinction with regard to emission factors can be made for different road types.

5.1.1. Gasoline Passenger Cars <2,5 Tonnes

Gasoline passenger cars <2,5 tonnes certainly contribute to the largest part of emissions of road traffic. Therefore, special attention was given to this vehicle category with regard to emission factors and the methodology. The emission factors are presented in a fully speed-dependent form.

This is the only vehicle category in which the production year of vehicles has been taken into account by introducing different sub-categories, which reflect legislative steps (ECE) or technology steps (‘improved conventional’, ‘open loop’ and ‘closed loop’). The technology steps are of importance in particular for those countries which introduced emission limits in national legislation which are more stringent than the ECE 15/04 limits, or implemented special incentive programmes for the purchase of such vehicles.

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.

After 1985, the following technologies appeared, imposed by the EC legislation and national schemes:

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. This type of emission control technology also started to appear in Denmark from 1.1.1988.

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, Germany 1.7.1985, Greece 1.1.1990, the Netherlands 1.1.1987.

c. Closed Loop (91/441/EEC). It takes into account national incentive programmes (e.g. voluntary programmes in Germany carried out after 1.7.1985), where compliance with US 83 limits is required. In addition this category addresses the passenger cars complying with the Directive 91/441/EEC.

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, Germany 1.7.1985, the Netherlands 1.1.1987.

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, Germany 1.7.1985, Greece 1.1.1990, the Netherlands 1.1.1986.

c. Closed Loop (91/441/EEC). It takes into account national incentive programmes where compliance with US 83 limits is required. In addition this category addresses the passenger cars complying with the Directive 91/441/EEC.

Gasoline Passenger Cars >2,0 l

a. 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, Germany 1.7.1985.

b. Closed Loop (91/441/EEC). 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, Germany, Greece, the Netherlands). Effective date: Denmark 1.1.1987, 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. In addition this category addresses the passenger cars complying with Directive 91/441/EEC.

It is of importance to note that new emission standards for passenger cars have been adopted in the EU to be effective 1997 (Directive 94/12/EEC). Compared to 91/441/EEC the new emission standards impose a 30% and 55% reduction in CO and HC+NOx respectively. In addition the post 2000 emission standards are also under discussion: they aim at the introduction of early light-off three-way catalysts, complying with high durability requirements. The latest 94/12/EEC Directive and the future EC Proposal I are taken into account in this report as future legislative steps, and the passenger cars complying with these Directives are forming separate sub-categories. Emission factors for these sub-categories are calculated as a percentage of those factors proposed for the best currently used technology (i.e. 91/441/EEC).

The equations of the best-fit curves for the emission factors $e_{hot,i,j,g}$, as well as fuel consumption factors, are given in Tables V.1.1-1 to V.1.1-4. Table V.1.1-5 gives (pollutant related) reduction percentages for future legislation, which have to be applied on the emission and fuel consumption factors representative of the 91/441/EEC.

However, it should be noted that the emission factors have been derived from general test cycles which are not specific for driving at speeds above 130 km/h or below 10 km/h. Therefore they should not be applied for driving at very high and very low speeds. Moreover, 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 emission factor $e_{hot,year,i,j,k}$ introduced in equation (1) is by definition the average fleet representative factor of pollutant i, relevant for the vehicle category j (here this means vehicles with cylinder capacities of <1,4 l / 1,4-2,0 l / >2,0 l), operated on roads of type k with hot engines. The emission factors presented in this chapter describe the emissions of pollutant i for each vehicle category j and ten periods of legal conformity, that means: pre-ECE state and periods of application of ECE 15-00/01, 15-02, 15-03, 15-04, two post 15-04 technologies: improved conventional, open loop and three 3W catalyst technologies: 91/441/EEC, 94/12/EEC and EC Proposal I (post 2000).

This presentation allows countries to introduce into the calculation the composition of their fleet and ‘representative driving patterns’. 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[4].

5.1.2. Diesel Passenger Cars <2,5 Tonnes

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 vehicles. More recent measurements enable to produce a new set of speed dependent emission factors for diesel passenger cars <2,5 tonnes equipped with oxidation catalysts (Tables V.1.2-1 to V.1.2-2). Moreover, with respect to the future legislation (i.e. 94/12/EEC and EC Proposal I) appropriate reduction percentages are proposed. It should be mentioned that apart from

---

[4] It is possible that driving patterns depend on additional parameters, such as age of the vehicle or cylinder capacity. However, such dependencies should only be taken into account if sound statistical data are available.

other parameters, the emission factors, in particular for particulates can vary substantially, depending on fuel quality and state of maintenance (see Table V.1.2-3).

5.1.3. LPG Passenger Cars <2,5 Tonnes

As in the case of gasoline and diesel passenger cars <2,5 tonnes, emission factors are provided for LPG fuelled cars, see Table V.1.3-1. Moreover, speed depended emission factors are proposed for LPG cars complying the 91/441/EEC Directive, see Table V.1.3-2. As far as the future legislation is concerned (i.e. 94/12/EEC and EC Proposal I) appropriate reduction percentages are introduced (Table V.1.1-5).

It should be mentioned that the given emission factors are valid for well-adjusted engines, otherwise they are of the same order of magnitude as those valid for gasoline vehicles <2,5 tonnes.

5.1.4. Gasoline Two-Stroke Passenger Cars

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.

The emission factors are given in Table V.1.4-1 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.

5.1.5. Gasoline Light Duty Vehicles

In the EU the emissions of these vehicles were covered by the different ECE steps. From 1995 onwards new emission standards are applicable (Directive 93/59/EEC), which ask for catalytic converters on the gasoline powered vehicles. The recently adopted 96/69 Directive introduces stricter emission standards to light duty trucks by 1998/99, referred as EC Proposal II in this report.

New sets of speed depended emission factors for gasoline light duty vehicles are given in Table V.1.5-1. As far as the future legislation is concerned (i.e. EC Proposal II - 96/69/EEC) appropriate reduction percentages are introduced (Table V.1.5-2).

5.1.6. Diesel Light Duty Vehicles

From 1995 onwards new emission standards are applicable (Directive 93/59/EEC), which ask for engine modifications on the diesel vehicles. As in the case of gasoline light duty vehicles, new emission standards are introduced (96/69/EEC Directive) to light duty trucks by 1998/99.

Table V.1.6-1 displays the speed depended emission factors proposed. As far as the future legislation is concerned (i.e. EC Proposal II - 96/69/EEC) appropriate reduction percentages are introduced (Table V.1.6-2).

5.1.7. Gasoline Heavy Duty Vehicles

Heavy duty gasoline vehicles >3,5 tonnes play a negligible role in European emissions from road traffic. Emission factors derived from an extrapolation of results from smaller vehicles are presented in Table V.1.7-1.

5.1.8. Diesel Heavy Duty Vehicles

In the EC, emission standards for the gaseous pollutants CO, HC and NOx have been promulgated since 1988, only for the diesel powered commercial vehicles >3,5 t GVW. However a 1991 Directive (91/542/EEC) adopted a two stage approach (effective 1994 and 1997) for a more stringent control of the emissions (in particular NOx and PM) of these vehicles. It is expected that the emission standards of both stages will be met with engine modifications (such as turbocharging and exhaust gas recirculation) and in some cases with oxidation catalysts. It should be mentioned that a significant revision of the methodology followed in COPERT90 report has been made, as far as the classification of the heavy duty vehicles is concerned. As Table II-2 presents additional sub-categories of heavy duty vehicles are introduced. Moreover, speed dependent emission functions are proposed from the data of Swiss/German Workbook (Hassel et al. 1995, Keller et al. 1995). Table V.1.8-1 displays the proposed factors for all weight classes. As far as the latest and future legislation are concerned (i.e. 91/542/EEC Stages I and II) appropriate reduction percentages are suggested (Table V.1.8-2). As Urban Buses and Coaches are considered as a separated sub-category of Heavy Duty vehicles in this report, a second set of speed dependent functions for the calculation of the emission factors is presented in Table V.1.8-3. In order to comply to the latest and future standards, imposed by the 91/542/EEC Directive, Table V.1.8-4 presents the reduction percentages suggested.

5.1.9. *Mopeds <50cm³ and Motorcycles >50cm³*

So far, emissions from these vehicles have been uncontrolled in the EU. Only some countries (e.g. Switzerland and Austria) have adopted stringent emission standards imposing the application of catalytic converters on two stroke engines. The EU is about to adopt legislation (COM(93)449), to be implemented from 1997 onwards.

Two-wheelers are differentiated further into two classes: motor cycles <50cm³ cylinder capacity (two stroke only) and motor cycles >50cm³ cylinder capacity. Moreover, it has been shown worthwhile to distinguish for the second group between two stroke and four stroke engines. While mopeds are mostly driven under 'urban' driving conditions, motor cycles are also used for 'rural' and 'highway' driving.

Table V.1.9-1 displays the emission factors proposed for mopeds and table V.1.9-2 presents the percentage reduction of these emission factor in order to comply with future legislation.

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 V.1.9-3 and V.1.9-4 display the emission factors proposed for 2-sroke and 4-stroke motorcycles.

5.2. Cold-start Emissions Factors

Since cold-start emissions are quite sensitive to ambient temperatures, the estimates are made on a monthly basis.

5.2.1. *Conventional Gasoline Passenger Cars*

All non-closed loop 3-way catalyst equipped vehicles belong to this category. The application of the methodology which was outlined requires values for the parameter β (cold mileage percentage) and the ratio e^{cold} / e^{hot}. Table V.2.1-1 provides estimates for β. It should be mentioned that this table applies to all vehicle categories considered. Table V.2.1-2 provides estimates for e^{cold} / e^{hot}. Both tables have been derived from French, German, Dutch and English measurements and are identical to those of the 1985 report (Delsey 1980, Vallet et al. 1982, André et al. 1987, Potter et al. 1983, Hassel et al. 1987, Journard et al. 1990, Rijkeboer et al. 1989). For application of Table V.2.1-1, a value for the average trip length has to be determined (compare Table V.2.1-3 showing values taken by EC Member States in the COPERT 1990 exercise - Andrias et al. 1994).

5.2.2. *Catalyst Gasoline Passenger Cars*

For closed loop 3-way catalyst gasoline passenger cars the extra cold-start emissions differ significantly from those of conventional gasoline cars (Rijkeboer et al. 1989, AQA 1990, Laurikko et al. 1987). The methodology as such, however, does not require modifications (at least as long as no further measurements are available). Table V.2.2-1 provides an overview of the cold-start emission factors.

5.2.3. *Diesel Passenger Cars*

The relative extra emissions of diesel passenger cars are shown in Table V.2.3-1.

5.2.4. *LPG Passenger Cars*

For LPG passenger cars the available data base is very small (AQA 1990, Hauger et al. 1991). Therefore a temperature dependent emission factor, is provided assuming that the cold-start behaviour of these cars is similar to that of conventional gasoline vehicles (Table V.2.4-1).

5.2.5. *Light Duty Vehicles*

Due to the lack of better data, gasoline and diesel light duty vehicles are treated in the same way as the corresponding passenger cars. This implies that the vehicle usage data for passenger cars are also applied for light duty vehicles. However, it should be underlined that this is a very rough approach, which was chosen only because the working group considered as more appropriate to allocate some cold-start emissions to this category rather than to neglect them.

5.3. Evaporative Emissions Factors

Due to the lack of data, evaporative emissions can be estimated only for gasoline passenger cars, gasoline light duty vehicles and Two-wheelers. However, the methodology outlined in chapter IV.3 can only be fully applied for gasoline passenger cars. For the other two vehicle categories simplifications have to be made. Since evaporative emissions are very sensitive to temperature, the estimates are made on a monthly basis.

5.3.1. Gasoline Passenger Cars

The evaporative 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 V.3.1-1 for uncontrolled and controlled vehicles (based mainly on Concawe 1987, 1990, Heine 1987, US EPA 1990). However, it should be mentioned that the working group considers 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.

The application of the proposed methodology requires detailed knowledge of driving behaviour and vehicle park composition. In order to help those Member States which have no, or only little, information about these input parameters, some data estimated in some EC countries are given in Table V.3.1-2.

5.3.2. Light Duty Vehicles

For estimating evaporative emissions of this category, all vehicles are treated like uncontrolled gasoline passenger cars with regard to emission factors and driving pattern. As in the case of cold-start emissions, this is a drastic simplification, because it implies the assumption that light duty vehicles are used in the same way as passenger cars.

5.3.3. Motorcycles

For estimating evaporative emissions of Two-wheelers, the latter are treated like uncontrolled gasoline passenger cars with regard to the driving pattern. Due to the smaller fuel tanks of Two-wheelers, it is assumed that the emissions are 0,2 times those of passenger cars for motor cycles <50cm³ and 0,4 times those of passenger cars for motor cycles >50cm³. Again this approach has to be considered as a drastic simplification, which has been chosen only because the required data are not available.

5.4. Correction Factors Related to Road Gradient and Weight Load

5.4.1. Road Gradient Effect on Heavy Duty Vehicles Emissions

Road gradient has a considerable effect on heavy duty vehicles emissions, as already mentioned in chapter IV.4. As the calculation is allowed for the speed range which is covered by the regression analysis, the mean speed can only range between specific values. Those values are presented in Tables V.4.1-1 to V.4.1-6 along with the constants for each weight class, required for the calculation of the appr opriate correction factor.

5.4.2. Weight Load Effect on Heavy Duty Vehicles Emissions

As described in chapter IV.5, weigh load affects on heavy duty vehicles emissions, inducing the calculated (pollutant related) emission factor of a 50% loaded heavy duty vehicle, applying the appropriate correction factor The correction factors (cf) used, originate from data available through TRL relevant measurements and are presented in Table V.4.2-1.

5.5. Methane Emissions

Methane emission factors could be derived from the literature for all types of vehicles (Bailey et al. 1989, Volkswagen 1989, OECD 1991, Zajontz et al. 1991). It should be reminded that non methane VOC emissions are produced by deducting the CH_4 emissions from total VOC. Table V.5-1 provides an overview of CH_4 emission factors. Additional cold-start emissions are not taken into account separately but are assumed to be included in the bulk emission factors.

5.6. Nitrous Oxide Emissions

Emission factors for N2O 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). Again these data are still quite unreliable and need further confirmation by measurements. Cold-start emissions are not taken into account separately but are assumed to be already incorporated in the bulk emission factors. The emission factors are shown in Table V.6-1.

5.7. 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 to CO_2**.** The following formula is applied

(20) mass of CO_2 = 44,011 (mass of fuel / (12,011 + 1,008 . $r_{H/C}$))

with

$r_{H/C}$ = 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:

(20a) mass of CO_2 = 44,011 (mass of fuel / (12,011 + 1,008 . $r_{H/C}$))
- mass of CO / 28,011 - mass of VOC / 13,85
- mass of particulates / 12,011)

5.8. 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:

(21) $$E_{SO2} = 2\sum_j \sum_l k_{S,l} \; b_{j,l}$$

with

$k_{S,l}$ = weight related sulphur content of fuel of type l [kg/kg]

$b_{j,l}$ = total annual consumption of fuel of type l in [kg] by vehicles of category j. For the actual $b_{j,l}$ the calculated fuel consumption is taken.

5.9. 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 kilometers driven.

These emission factors are based on literature review only and should be considered as broad estimates (de Reydellet 1990, Volkswagen 1989). Table V.9-1 shows the emission factors proposed.

5.10. 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:

(22) $$E_{Pb} = 0{,}75 \sum k_{Pb} \cdot b_j$$

where:

k_{Pb} = weight related lead content of gasoline in [kg/kg]

b_j = total annual consumption of gasoline in [kg] by vehicles of category j operated in the reference year

For the actual figure of b_j the statistical fuel consumption should be taken.

Table V.10-1 presents emission factors expressed 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.

5.11. Species Profiles

There is no systematic approach concerning the evaluation and the reporting of species profiles, e.g. it is not clear whether individual compounds, chemical groups or reactivity classes should be reported.

With regard to VOC profiles, Table V.11-1 provide information as used by Veldt, in their work on emission estimates for the sector road traffic. In principle the composition given there can also be used for the sectors covered by CORINAIR Guidebook.

6. References

André M., J.P. Roumegoux, J. Delsey, J.P. Guitton and R. Vidon (1987): Etude expérimentale sur les utilisations réelles des véhicules (EUREV). Rapport INRETS No. 48, Bron, France.

Andrias A., Z. Samaras and K.-H. Zierock (1994): *Further Development of Emission Inventories for the Sector Road Transport: The Evaluation of European Emission Data Concerning the Sector Road Transport,* Final Report to the EEA, EC Study Contract B93/93/B4-3102-11/000819, 134 pp.

Appel H. and Stendel D. (1989): *Abgasemissionen von Wartburg und Trabant.* Veröffentlichung der Senatsverwaltung für Stadtentwicklung und Umweltschutz, Berlin. December 1989.

AQA (1990): Final Report, Convention SPP 88248, Paris, 20p.

Bailey J.C. and B. Schmidl (1989): *A Survey of Hydrocarbons Emitted in Vehicle Exhaust Gases, over a Range of Driving Speeds and Conditions from a Representative Sample of the 86/87 UK Vehicle Fleet.* Warren Spring Laboratory. Report LR673(AP)M, Stevenage, UK.

CONCAWE (1987): *An investigation onto evaporative hydrocarbon emissions from European vehicles.* Report N° 87/60.

CONCAWE (1990): *The effects of temperature and fuel volatility on vehicle evaporative emissions.* Report N° 90/51.

Committee of Common Market Automobile Constructors (CCMC) (1989): *CCMC ECE/EUDC Test Programme.* Ref. AE/11/89 VE/CCMC/29, Brussels. February 1989.

Delsey J. (1980): *Modelisation de la pollution due a la circulation automobile; évaluation expérimentale des émissions par les automobiles.* Rapport IRT, INRETS, Bron, France.

Eggleston S., N. Gorißen, R. Joumard, R.C. Rijkeboer, Z. Samaras and K.-H. Zierock (1989): *CORINAIR Working Group on Emissions Factors for Calculating 1985 Emissions from Road Traffic. Volume 1: Methodology and Emission Factors.* Final Report Contract No. 88/6611/0067, EUR 12260 EN.

Eggleston S., D. Gaudioso, N. Gorißen, R. Joumard, R.C. Rijkeboer, Z. Samaras and K.-H. Zierock (1993): *CORINAIR Working Group on Emissions Factors for Calculating 1990 Emissions from Road Traffic. Volume 1: Methodology and Emission Factors.* Final Report, Document of the European Commission ISBN 92-826-5571-X.

EMEP/CORINAIR (1996): Atmospheric Emission Inventory Guidebook, G.McInnes (ed.), First Edition, European Environment Agency, Copenhagen.

Hassel D., P. Jost, F. Dursbeck, J. Brosthaus and K.S. Sonnborn (1987): *Das Abgas-Emissionsverhalten von Personenkraftwagen in der Bundesrepublik Deutschland im Bezugsjahr 1985.* UBA Bericht 7/87. Erich Schmidt Verlag, Berlin.

Hassel D., P. Jost, F.-J. Weber, F. Dursbeck, K.-S. Sonnborn and D. Plettau (1993): *Exhaust Emission Factors for Motor Vehicles in the Federal Republic of Germany for the Reference Year 1990.* Final Report of a Study Carried Out on Behalf of the Federal Environmental Protection Agency, UFOPLAN Nr. 104 05 152 und 104 05 509, UBA-FB 91-042, TÜV Rheinland (English Translation made by COST319).

Hassel D., P. Jost, F.-J. Weber, F. Dursbeck, K.-S. Sonnborn and D. Plettau (1995): *Exhaust Emission Factors for Heavy Duty Vehicles in the Federal Republic of Germany for the Reference Year 1990.* Final Report of a Study Carried Out on Behalf of the Federal Environmental Protection Agency, UFOPLAN Nr. 104 05 151/2, TÜV Rheinland (English Translation made by COST319).

Hauger A. and R. Joumard (1991): *LPG pollutant emissions.* Use of Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG) as fuel for internal combustion engines, UN-ECE Symposium, Kiev, Ukraine.

Heine P. and Baretti A. (1987): *Emissionsfaktoren für die Verdampfungsemissionen von Kraftfahrzeugen mit Ottomotoren.* Im Auftrag des Umweltbundesamtes Berlin, November 1988.

Jileh P. (1991). Data of the Ministry of the Environment of the Czech Republic supplied to Mr. Bouscaren (Citepa).

Joumard R., L. Paturel, R. Vidon, J.-P. Guitton, A.I. Saber and E. Combet (1990): *Emissions unitaires de polluants des véhicules légers.* Rapport INRETS No 116, Bron, France.

Keller M., R. Evéquoz, J. Heldstab and H. Kessler (1995): *Luftschadstoffemissionen des Straßenverkehrs 1950-2010,* Schriftenreihe Umwelt Nr. 255 des BUWAL - Bundesamt für Umwelt, Wald und Landschaft, 3003 Bern (in German, also available in French).

LAT/AUTH, INRETS, TNO, TSU GmbH, TRL, TU Graz, MIRA, University of Limerick (1997): *Methodologies for Estimating Air Pollutant Emissions From Transport - MEET,* Deliverable No 3: Final data structure of road emission factors, TÜV Rheinland, Köln, Germany.

Laurikko J., N.O. Nylund and K. Spila (1987): *Automotive exhaust emissions at low ambient temperatures.* Technical Research Centre of Finland, Report No 496, Espoo, Finland.

Ntziachristos L. and Z. Samaras (1997): COPERTII Computer Programme to Calculate Emissions from Road Traffic - User’s Manual, Final Draft, European Topic Center on Air Emissions, Thessaloniki, 50 pp.

Organisation for Economic Co-operation and Development (OECD); *Estimation of Greenhouse Gas Emissions and Sinks*, Final Report, prepared for the Intergovernmental Panel on Climate Change, revised August 1991.

Pattas K. and N. Kyriakis (1983): *Exhaust Gas Emission Study of Current Vehicle Fleet in Athens (Phase I).* Final Report to PERPA / EEC, Thessaloniki.

Pattas K., N. Kyriakis and Z. Samaras (1985): *Exhaust Gas Emission Study of Current Vehicle Fleet in Athens (PHASE II).* Volumes I, II, III, Final Report to PERPA / EEC, Thessaloniki.

Perby H. (1990): *Lustgasemission från vägtrafik.* Swedish Road and Traffic Research Institute, Report 629, Linköping, Sweden.

Potter D. and C. Savage (1983): *A survey of gaseous pollutant emissions from tuned in-service gasoline engined cars over a range of road operating conditions.* WSL Report, LR 447 (AP) M, Stevenage.

Potter D. (1990): *Lustgasemission fran Katalysatorbilar*. Department of Inorganic Chemistry, Chalmers University of Technology and University of Gothenburg, Report OOK 90:02, Sweden
Pringent M. and G. De Soete (1989): *Nitrous Oxide* N_2O *in Engines Exhaust Gases - A First Appraisal of Catalyst Impact.* SAE Paper 890492.

De Reydellet. A. (1990): *Gaz a effet de serre Methane* CH_4 *et protoxyde d'azote* N_2O*, Facteurs d'emission*. Recherche bibliographique, IFE, Paris.

Rijkeboer R.C., P. Van Sloten and P. Schmal (1989): *Steekproef-controleprogramma, onderzoek naar luchtverontreininging door voertuigen in het verkeer, Jaarrapport 1988/89.* Nr. Lucht 87, IWT-TNO, Delft.

Rijkeboer R.C., M.F. Van der Haagen and P. Van Sloten (1990). *Results of Project on In-use Compliance Testing of Vehicles.* TNO report 733039000, Delft.

Samaras Z., T. Zachariadis, R. Joumard, I. Vernet, D. Hassel, F.-J. Weber, and R. Rijkeboer (1997): *Alternative short tests for Inspection & Maintenance of in-use cars with respect to their emissions performance*, Paper to be presented at the Conference “Transport and Air Pollution”, Avignon France.

TNO (1993): *Project In-Use Compliance - Air Pollution by Cars in Use, Annual Report 1991-1992 including data over the last five years.* Delft, the Netherlands.

U.S. Environmental Protection Agency (1990): *Volatile Organic Compounds from On-Road Vehicles - Sources and Control Options.* Draft Report.

Vallet M., J.-L. Ygnate and M. Maurin (1982): *Enquête sur l'utilisation réelle des voitures en France (EUREV).* Rapport IRT, NNE 50, INRETS, Bron, France.

Volkswagen AG (1989): *Nicht limitierte Automobil-Abgaskomponenten*, Wolfsburg, Germany.

Zachariadis T. and Z. Samaras (1996): *Comparative Assessment of European Tools to Estimate Traffic Emissions.* Proceedings of the 3rd International Symposium ‘Traffic Induced Air Pollution: Emissions, Impact and Air Quality’, Institute for Internal Combustion Engines and Thermodynamics, Technical University of Graz. Also in International Journal of Vehicle Design, 1997 (in press).

Zajontz J., V. Frey and C. Gutknecht (1991): *Emission of unregulated Exhaust Gas Components of Otto Engines equipped with Catalytic Converters.* Institute for Chemical Technology and Fuel Techniques, Technical University of Clausthal, Interim Status Report of 03 / 05 / 1991, Germany.

7. List of Tables

Table II-1: Motor vehicle categories as defined in the Atmospheric Emission Inventory Guidebook (EMEP / CORINAIR 1996)

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 < 50cm^3	
	07 04 01	Rural Driving
	07 04 02	Urban Driving
0705	MOTORCYCLES > 50cm^3	
	07 05 01	Highway Driving
	07 05 02	Rural Driving
	07 05 03	Urban Driving
0706	GASOLINE EVAPORATION FROM MOTOR VEHICLES	

Table II-2: Vehicle category split

Vehicle Category	Classification	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 91/441/EEC 94/12/EEC EC Proposal I (post 2000)
	Gasoline *1,4 - 2,0l*	PRE ECE ECE 15/00-01 ECE 15/02 ECE 15/03 ECE 15/04 Improved Conv. Open Loop 91/441/EEC 94/12/EEC EC Proposal I (post 2000)
	Gasoline *>2,0l*	PRE ECE ECE 15/00-01 ECE 15/02 ECE 15/03 ECE 15/04 91/441/EEC 94/12/EEC EC Proposal I (post 2000)
	Diesel *<2,0l*	Conventional 91/441/EEC 94/12/EEC EC Proposal I (post 2000)
	Diesel *>2,0l*	Conventional 91/441/EEC 94/12/EEC EC Proposal I (post 2000)
	LPG	Conventional 91/441/EEC 94/12/EEC EC Proposal I (post 2000)
	2-Stoke	Conventional

Vehicle Category	Classification	Legislation
Light Duty Vehicles	*Gasoline* *<3,5t*	Conventional 93/59/EEC EC Proposal II (96/69/EEC)
	Diesel *<3,5t*	Conventional 93/59/EEC EC Proposal II (96/69/EEC)
Heavy Duty Vehicles	*Gasoline >3,5t*	Conventional
	Diesel *<7,5t*	Conventional 91/542/EEC Stage I 91/542/EEC Stage II
	Diesel *7,5 - 16t*	Conventional 91/542/EEC Stage I 91/542/EEC Stage II
	Diesel *16-32t*	Conventional 91/542/EEC Stage I 91/542/EEC Stage II
	Diesel *>32t*	Conventional 91/542/EEC Stage I 91/542/EEC Stage II
Buses	*Urban buses*	Conventional 91/542/EEC Stage I 91/542/EEC Stage II
	Coaches	Conventional 91/542/EEC Stage I 91/542/EEC Stage II
Mopeds	*<50cm^3*	Conventional EC Proposal III - COM(93)449 Stage I EC Proposal IV - COM(93)449 Stage II
Motorcycles	*2 stroke* *>50cm^3*	Conventional EC Proposal V - COM(93) 449
	4 stroke *50 - 250cm^3*	Conventional EC Proposal V - COM(93)449
	4 stroke *250 - 750cm^3*	Conventional EC Proposal V - COM(93)449
	4 stroke *>750cm^3*	Conventional EC Proposal V - COM(93)449

Table II-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 IV.1 - 1: Examples of estimated share of mileage (in %) driven by different gasoline Vehicles <2,5 t on different road classes as provided in COPERT90 (Andrias et al. 1994)

Country	Vehicle Category	Road Class		
		Urban	Rural	Highway
A	< 1,4 l	31,00	43,50	25,50
	1,4 - 2,0 l	31,00	43,50	25,50
	> 2,0 l	31,00	43,50	25,50
B	< 1,4 l	26,92	48,88	24,20
	1,4 - 2,0 l	26,92	48,88	24,20
	> 2,0 l	26,92	48,88	24,20
D	< 1,4 l	30,90	43,60	25,50
	1,4 - 2,0 l	30,90	43,60	25,50
	> 2,0 l	30,90	43,60	25,50
DK	< 1,4 l	50,00	40,00	10,00
	1,4 - 2,0 l	50,00	40,00	10,00
	> 2,0 l	50,00	40,00	10,00
E	< 1,4 l	37,72	39,51	22,77
	1,4 - 2,0 l	37,72	39,51	22,77
	> 2,0 l	37,72	39,51	22,77
EW	< 1,4 l	45,00	55,00	-
	1,4 - 2,0 l	45,00	55,00	-
	> 2,0 l	55,00	45,00	-
F	< 1,4 l	40,00	50,00	10,00
	1,4 - 2,0 l	40,00	50,00	10,00
	> 2,0 l	40,00	50,00	10,00
SF	< 1,4 l	30,00	60,00	10,00
	1,4 - 2,0 l	30,00	60,00	10,00
	> 2,0 l	30,00	60,00	10,00
GR	< 1,4 l	44,00	42,00	14,00
	1,4 - 2,0 l	44,00	42,00	14,00
	> 2,0 l	44,00	42,00	14,00
H	< 1,4 l	32,10	61,30	6,60
	1,4 - 2,0 l	32,10	61,30	6,60
	> 2,0 l	32,10	61,30	6,60
I	< 1,4 l	54,00	41,00	5,00
	1,4 - 2,0 l	33,00	58,00	9,00
	> 2,0 l	20,00	60,00	20,00
IRL	< 1,4 l	25,00	55,00	20,00
	1,4 - 2,0 l	25,00	55,00	20,00
	> 2,0 l	25,00	55,00	20,00

Table IV.1 - 1(cont): Examples of estimated share of mileage (in %) driven by gasoline vehicles <2,5 t on different road classes as provided in COPERT90 (Andrias et al. 1994)

Country	Vehicle Category		Road Class	
		Urban	Rural	Highway
L	< 1,4 l	45,00	35,00	20,00
	1,4 - 2,0 l	45,00	35,00	20,00
	> 2,0 l	45,00	35,00	20,00
LT	< 1,4 l	35,00	55,00	10,00
	1,4 - 2,0 l	35,00	55,00	10,00
	> 2,0 l	35,00	55,00	10,00
LR	< 1,4 l	35,00	55,00	10,00
	1,4 - 2,0 l	35,00	55,00	10,00
	> 2,0 l	35,00	55,00	10,00
M	< 1,4 l	50,00	20,00	30,00
	1,4 - 2,0 l	50,00	20,00	30,00
	> 2,0 l	50,00	20,00	30,00
NL	< 1,4 l	32,70	38,00	29,30
	1,4 - 2,0 l	32,70	38,00	29,30
	> 2,0 l	32,70	38,00	29,30
P	< 1,4 l	44,00	56,00	0,0
	1,4 - 2,0 l	44,00	56,00	0,0
	> 2,0 l	44,00	56,00	0,0
PL	< 1,4 l	30,00	67,00	3,00
	1,4 - 2,0 l	30,00	67,00	3,00
	> 2,0 l	30,00	67,00	3,00
SL	< 1,4 l	45,00	53,00	2,00
	1,4 - 2,0 l	38,00	59,00	3,00
	> 2,0 l	38,00	59,00	3,00
GB	< 1,4 l	46,60	41,30	12,10
	1,4 - 2,0 l	46,60	41,30	12,10
	> 2,0 l	46,60	41,30	12,10

Table IV.1.1 - 1: Examples of vehicle speed (in km / h) considered as representative for the characterization of the driving behavior of gasoline vehicles <2,5t on different road classes as provided in COPERT 90 (Andrias et al. 1994).

Country	Vehicle Category		Road Class	
		Urban	Rural	Highway
A	< 1,4 l	32	75	106
	1,4 - 2,0 l	32	75	115
	> 2,0 l	32	75	115
B	< 1,4 l	25	50	103
	1,4 - 2,0 l	25	50	105
	> 2,0 l	25	50	110
D	< 1,4 l	37	75	106
	1,4 - 2,0 l	37	75	116
	> 2,0 l	37	75	125
DK	< 1,4 l	30	60	90
	1,4 - 2,0 l	30	60	90
	> 2,0 l	30	60	90
E	< 1,4 l	20	60	83
	1,4 - 2,0 l	20	60	83
	> 2,0 l	20	60	83
EW	< 1,4 l	35	70	-
	1,4 - 2,0 l	35	70	-
	> 2,0 l	35	70	-
F	< 1,4 l	30	70	95
	1,4 - 2,0 l	30	70	105
	> 2,0 l	30	70	115
SF	< 1,4 l	30	80	100
	1,4 - 2,0 l	30	80	100
	> 2,0 l	30	80	100
GR	< 1,4 l	19	60	90
	1,4 - 2,0 l	19	60	90
	> 2,0 l	19	60	90
H	< 1,4 l	45	70	90
	1,4 - 2,0 l	45	75	100
	> 2,0 l	80	85	120
I	< 1,4 l	20	65	105
	1,4 - 2,0 l	20	65	115
	> 2,0 l	20	65	125
IRL	< 1,4 l	30	50	85
	1,4 - 2,0 l	30	50	85
	> 2,0 l	30	50	85

Table IV.1 1- 1(cont): Examples of vehicle speed (in km / h) considered as representative for the characterization of the driving behavior of gasoline vehicles <2,5t on different road classes as provided in COPERT90 (Andrias et al. 1994)

Country	Vehicle Category		Road Class	
		Urban	Rural	Highway
L	< 1,4 l	40	60	95
	1,4 - 2,0 l	40	60	95
	> 2,0 l	40	60	95
LT	< 1,4 l	35	70	90
	1,4 - 2,0 l	35	70	90
	> 2,0 l	35	70	90
LR	< 1,4 l	35	70	90
	1,4 - 2,0 l	35	70	90
	> 2,0 l	35	70	90
M	< 1,4 l	30	35	70
	1,4 - 2,0 l	30	35	80
	> 2,0 l	30	35	80
NL	< 1,4 l	25	60	100
	1,4 - 2,0 l	25	60	100
	> 2,0 l	25	60	100
P	< 1,4 l	30	70	-
	1,4 - 2,0 l	30	70	-
	> 2,0 l	30	70	-
PL	< 1,4 l	25	70	80
	1,4 - 2,0 l	25	70	80
	> 2,0 l	25	70	80
SL	< 1,4 l	30	60	100
	1,4 - 2,0 l	30	60	100
	> 2,0 l	30	60	100
GB	< 1,4 l	40	77	115
	1,4 - 2,0 l	40	77	115
	> 2,0 l	40	77	115

Table V.4-1: Road gradient classes

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

Table V.6 - 1: Summary of calculation methods applied for the different vehicle categories and pollutants

Vehicle Category	NOx	CO	NMVOC	CH$_4$	PM	N$_2$O	NH$_3$	SO$_2$	CO$_2$	PB	HM	FC
Gasoline Passenger Cars												
Pre-ECE	A	A	A	C	-	C	D	D	D	D	D	A
ECE 15/00-01	A	A	A	C	-	C	D	D	D	D	D	A
ECE 15/02	A	A	A	C	-	C	D	D	D	D	D	A
ECE 15/03	A	A	A	C	-	C	D	D	D	D	D	A
ECE 15/04	A	A	A	C	-	C	D	D	D	D	D	A
Improved conventional	A	A	A	C	-	C	D	D	D	D	D	A
Open Loop	A	A	A	C	-	C	D	D	D	D	D	A
91/441/EEC	A	A	A	C	-	C	D	D	D	D	D	A
94/12/EEC	A	A	A	C	-	C	D	D	D	D	D	A
EC Proposal I	A	A	A	C	-	C	D	D	D	D	D	A
Diesel Passenger Cars												
Conventional	B	B	B	C	B	C	D	D	D	D	D	B
91/441/EEC	B	B	B	C	B	C	D	D	D	D	D	B
94/12/EEC	B	B	B	C	B	C	D	D	D	D	D	B
EC Proposal I	B	B	B	C	B	C	D	D	D	D	D	B
LPG Passenger Cars	B	B	B	-	-	–	-	-	D	-	-	B
2 Stroke Passenger Cars	C	C	C	C	-	C	D	D	D	D	D	C
Light Duty Vehicles												
Gasoline <3,5t Conv.	A	A	A	C	-	C	D	D	D	D	D	A
Gasoline <3,5t 93/59/EEC	A	A	A	C	-	C	D	D	D	D	D	A
Gasoline <3,5t EC Prop. II	A	A	A	C	-	C	D	D	D	D	D	A
Diesel <3,5t Conventional	B	B	B	C	B	C	D	D	D	D	D	B
Diesel <3,5t 93/59/EEC	B	B	B	C	B	C	D	D	D	D	D	B
Diesel <3,5t EC Prop. II	B	B	B	C	B	C	D	D	D	D	D	B
Heavy Duty Vehicles												
Gasoline >3,5t Conventional	B	B	B	C	-	C	D	D	D	D	D	B
Diesel Conventional	B	B	B	C	B	C	D	D	D	D	D	B
Diesel 91/542/EEC Stage I	B	B	B	C	B	C	D	D	D	D	D	B
Diesel 91/542/EECStage II	B	B	B	C	B	C	D	D	D	D	D	B
Buses	B	B	B	C	B	C	D	D	D	D	D	B
Coaches	B	B	B	C	B	C	D	D	D	D	D	B
Two-wheelers												
Mopeds <50cm^3	C	C	C	D	-	-	-	D	D	D	D	C
Motorcycles 2-st >50cm^3	B	B	B	D	-	-	-	D	D	D	D	B
Motorcycles 4-st 50-250 cm^3	B	B	B	D	-	-	-	D	D	D	D	B
Motorcycles 4-st 250-750cm^3	B	B	B	D	-	-	-	D	D	D	D	B
Motorcycles 4-st >750cm^3	B	B	B	D	-	-	-	D	D	D	D	B

Table V.1.1-1: Speed dependency of CO emission factors for gasoline passenger cars

Vehicle Class	Cylinder Capacity	Speed Range	CO Emission Factor [g/km]	R^2
PRE ECE	All categories	10-100	$281V^{-0,630}$	0,924
	All categories	100-130	$0,112V + 4,32$	-
ECE 15-00/01	All categories	10-50	$313V^{-0,760}$	0,898
	All categories	50-130	$27,22 - 0,406V + 0,0032V^2$	0,158
ECE 15-02	All categories	10-60	$300V^{-0,797}$	0,747
	All categories	60-130	$26,260 - 0,440V + 0,0026V^2$	0,102
ECE 15-03	All categories	10-20	$161,36 - 45,62\ln(V)$	0,790
	All categories	20-130	$37,92 - 0,680V + 0,00377V^2$	0,247
ECE 15-04	All categories	10-60	$260,788V^{-0,910}$	0,825
	All categories	60-130	$14,653 - 0,220V + 0,001163V^2$	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	$8,273 - 0,151V + 0,000957V^2$	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	$9,446 - 0,230V + 0,002029V^2$	0,719
91/441/EEC	CC < 1,4 l	10-130	$5,1534 - 0,1141V + 0,0009571V^2$	0,094
	1,4 l < CC < 2,0 l	10-130	$5,0786 - 0,15623V + 0,001375V^2$	0,171
	CC > 2,0 l	10-130	$3,5358 - 0,0793V + 0,0006092V^2$	0,109

V: Average speed expressed in km/h
R^2: Correlation coefficient

Table V.1.1-2: Speed dependency of VOC emission factors for gasoline passenger cars

Vehicle Class	Cylinder Capacity	Speed Range	VOC Emission Factor [g/km]	R^2
PRE ECE	All categories	10-100	$30,34V^{-0,693}$	0,980
	All categories	100-130	$1,247$	-
ECE 15-00/01	All categories	10-50	$24,99V^{-0,704}$	0,901
	All categories	50-130	$4,85V^{-0,318}$	0,095
ECE 15-02/03	All categories	10-60	$25,75V^{-0,714}$	0,895
	All categories	60-130	$1,95 - 0,019V + 0,00009V^2$	0,198
ECE 15-04	All categories	10-60	$19,079V^{-0,693}$	0,838
	All categories	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
91/441/EEC	CC < 1,4 l	10-130	$0,5278 - 0,0129V + 0,000087V^2$	0,219
	1,4 l < CC < 2,0 l	10-130	$0,4590 - 0,0106V + 0,0000672V^2$	0,258
	CC > 2,0 l	10-130	$0,2721 - 0,00566V + 0,0000376V^2$	0,101

V: Average speed expressed in km/h
R^2: Correlation coefficient

Table V.1.1-3: Speed dependency of NO_x emission factors for gasoline passenger cars

Vehicle Class	Cylinder Capacity	Speed Range	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	$1,500 + 0,0300V + 0,0001V^2$	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	$1,870 - 0,0039V + 0,00022V^2$	-
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	$1,432 + 0,003V + 0,000097V^2$	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	$-0,926 + 0,719\ln(V)$	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
91/441/EEC	CC < 1,4 l	10-130	$0,4880 - 0,00548V + 0,0000575V^2$	0,043
	1,4 l < CC < 2,0 l	10-130	$0,6089 - 0,01184V + 0,0001100V^2$	0,122
	CC > 2,0 l	10-130	$0,4767 - 0,01070V + 0,0001015V^2$	0,194

V: Average speed expressed in km/h
R^2: Correlation coefficient

Table V.1.1-4: Speed dependency of fuel consumption factors for gasoline passenger cars

Vehicle Class	Cylinder Capacity	Speed Range	Fuel Consumption Factor [g/km]	R^2
PRE ECE	CC < 1,4 l	10-60 60-80 80-130	$521V^{-0,554}$ 55 $0,386V + 24,143$	0,941 - -
	1,4 l < CC < 2,0 l	10-60 60-80 80-130	$681V^{-0,583}$ 67 $0,471V + 29,286$	0,936 - -
	CC > 2,0 l	10-60 60-80 80-130	$979V^{-0,628}$ 80 $0,414V + 46,867$	0,918 - -
ECE 15-00/01	CC < 1,4 l	10-60 60-130	$595V^{-0,63}$ $95 - 1,324V + 0,0086V^2$	0,951 0,289
	1,4 l < CC < 2,0 l	10-60 60-130	$864V^{-0,69}$ $59 - 0,407V + 0,0042V^2$	0,974 0,647
	CC > 2,0 l	10-60 60-130	$1236V^{-0,764}$ $65 - 0,407V + 0,0042V^2$	0,976 -
ECE 15-02/03	CC < 1,4 l	10-50 50-130	$544V^{-0,63}$ $85 - 1,108V + 0,0077V^2$	0,929 0,641
	1,4 l < CC < 2,0 l	10-50 50-130	$879V^{-0,72}$ $71 - 0,7032V + 0,0059V^2$	0,950 0,830
	CC > 2,0 l	10-50 50-130	$1224V^{-0,756}$ $111 - 1,333V + 0,0093V^2$	0,961 0,847
ECE 15-04	CC < 1,4 l	10-25 25-130	$296,7 - 80,21\ln(V)$ $81,1 - 1,014V + 0,0068V^2$	0,518 0,760
	1,4 l < CC < 2,0 l	10-60 60-130	$606,1V^{-0,667}$ $102,5 - 1,364V + 0,0086V^2$	0,907 0,927
	CC > 2,0 l	10-60 60-130	$819,9V^{-0,663}$ $41,7 + 0,122V + 0,0016V^2$	0,966 0,650
Improved Conventional	CC < 1,4 l 1,4 l < CC < 2,0 l	10-130 10-130	$80,52 - 1,41V + 0,013V^2$ $111,0 - 2,031V + 0,017V^2$	0,954 0,994
Open Loop	CC < 1,4 l 1,4 l < CC < 2,0 l	10-130 10-130	$85,55 - 1,383V + 0,0117V^2$ $109,6 - 1,98V + 0,0168V^2$	0,997 0,997
91/441/EEC	CC < 1,4 l 1,4 l < CC < 2,0 l CC > 2,0 l	10-130 10-130 10-130	$93,672 - 1,5100V + 0,01090V^2$ $135,42 - 2,4558V + 0,01740V^2$ $156,77 - 2,6974V + 0,01870V^2$	0,558 0,552 0,466

V: Average speed expressed in km/h
R^2: Correlation coefficient

Table V.1.1-5: Emission reduction percentage for improved and future gasoline & LPG passenger cars, applied to vehicles complying with directive 91/441/EEC

Gasoline & LPG Passenger Cars	CO [%]	NOx [%]	VOC [%]
94/12/EEC	30	56	56
EC Proposal I (Post - 2000)	85	60	60

Table V.1.2-1: Speed dependency of emission and consumption factors for conventional diesel vehicles <2,5 t

Pollutant	Cylinder Capacity	Speed Range	Emission Factor [g/km]	R^2
CO	All categories	10-130	$5{,}413V^{-0{,}574}$	0,745
NOx	CC < 2,0l CC > 2,0l	10-130 10-130	$0{,}918 - 0{,}014V + 0{,}000101V^2$ $1{,}331 - 0{,}018V + 0{,}000133V^2$	0,949 0,927
VOC	All categories	10-130	$4{,}61V^{-0{,}937}$	0,794
PM	All categories	10-130	$0{,}45 - 0{,}0086V + 0{,}000058V^2$	0,439
Fuel Consumption	All categories	10-130	$118{,}489 - 2{,}084V + 0{,}014V^2$	0,583

V: Average speed expressed in km/h
R^2: Correlation coefficient

Table V.1.2-2: Speed dependency of emission and consumption factors for diesel vehicles <2,5 t, complying with directive 91/441/EEC

Pollutant	Cylinder Capacity	Speed Range	Emission Factor [g/km]	R^2
CO	All categories	10-130	$0{,}9337 - 0{,}0170V + 0{,}0000961V^2$	0,674
NOx	All categories	10-130	$0{,}9037 - 0{,}01674V + 0{,}000127V^2$	0,424
VOC	All categories	10-130	$0{,}1354 - 0{,}0022V + 0{,}0000113V^2$	0,618
PM	All categories	10-130	$0{,}1208- 0{,}00277V + 0{,}0000226V^2$	0,590
Fuel Consumption	All categories	10-130	$83{,}660 - 1{,}3123V + 0{,}00790V^2$	0,610

V: Average speed expressed in km/h
R^2: Correlation coefficient

Table V.1.2-3: Emission reduction percentage for improved and future diesel passenger cars applied to vehicles complying with directive 91/441/EEC

Diesel Passenger Cars	CO [%]	NOx [%]	VOC [%]	PM [%]
94/12/EEC	30	56	30	56
EC Proposal I (Post - 2000)	60	80	75	63

Table V.1.3-1: 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	$12{,}523 - 0{,}418V + 0{,}0039V^2$	0,893
NOx	All categories	10-130	$0{,}77V^{0{,}285}$	0,598
VOC	All categories	10-130	$26{,}3V^{-0{,}865}$	0,967
Fuel Consumption	All categories	Urban Rural Highway	59 45 54	- - -

V: Average speed expressed in km/h
R^2: Correlation coefficient

Table V.1.3-2: Speed dependency of emission and consumption factors for LPG vehicles <2,5t, complying with directive 91/441/EEC

Pollutant	Cylinder Capacity	Speed Range	Emission Factor [g/km]
CO	All categories	10-130	$0,00110V^2 - 0,1165V + 4,2098$
NOx	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	$0,00720V^2 - 0,9250V + 74,625$

V: Average speed expressed in km/h

Table V.1.4-1: Emission and consumption factors for gasoline 2-stroke vehicles <2,5 t

	CO [g/km]	NOx [g/km]	VOC [g/km]	Fuel Consumption [g/km]
Urban	20,7	0,30	15,4	111,5
Rural	7,50	1,00	7,20	66,0
Highway	8,70	0,75	5,90	56,9

Table V.1.5-1: Speed dependency of emission and consumption factors for gasoline light duty vehicles <3,5 t

Pollutant	Vehicle Class	Speed Range	Emission Factor [g/km]	R^2
CO	Conventional	10-130	$0,01104V^2 - 1,5132V + 57,789$	0,731
	93/59/EEC	10-130	$0,00060V^2 - 0,0475V + 2,2195$	0,186
NOx	Conventional	10-130	$0,00009V^2 - 0,0079V + 1,9391$	0,158
	93/59/EEC	10-130	$0,0000575V^2 - 0,00548V + 0,4880$	0,043
VOC	Conventional	10-130	$0,000677V^2 - 0,1170V + 5,4734$	0,771
	93/59/EEC	10-130	$0,00007V^2 - 0,0067V + 0,2406$	0,063
Fuel Consumption	Conventional	10-130	$0,01870V^2 - 2,6974V + 156,77$	0,466
	93/59/EEC	10-130	$0,01870V^2 - 2,6974V + 156,77$	0,466

V: Average speed expressed in km/h
R^2: Correlation coefficient

Notes:
Due to limited available data, the functions for the following cases are a mere copy of those applied in passenger cars. In any case, they seem to be in good compliance with both the measured data and the emission standards.

1. NOx 93/59/EEC Gasoline, the emission factor function for Gasoline PC<1,4l 91/441/EEC has been adopted
2. FC 93/59/EEC Gasoline, the consumption factor function for Gasoline PC>2,0l 91/441/EEC has been adopted

Table V.1.5-2: Emission reduction percentage for future gasoline light duty vehicles applied to vehicles complying with directive 93/59/EEC

Gasoline Light Duty Vehicles	CO [%]	NOx [%]	VOC [%]
EC Proposal II (96/69/EEC)	30	56	56

Table V.1.6-1: Speed dependency of emission and consumption factors for diesel light duty vehicles <3,5 t

Pollutant	Vehicle Class	Speed Range	Emission Factor [g/km]	R^2
CO	Conventional	10-130	$0,00020V^2 - 0,0256V + 1,8281$	0,136
	93/59/EEC	10-130	$0,00020V^2 - 0,0313V + 1,7838$	0,350
NOx	Conventional	10-130	$0,00014V^2 - 0,01592V + 1,4921$	0,066
	93/59/EEC	10-130	$0,000127V^2 - 0,01674V + 0,9037$	0,219
VOC	Conventional	10-130	$0,000066V^2 - 0,0113V + 0,6024$	0,141
	93/59/EEC	10-130	$0,0000281V^2 - 0,0065V + 0,4505$	0,380
PM	Conventional	10-130	$0,0000125V^2 - 0,000577V + 0,2880$	0,023
	93/59/EEC	10-130	$0,00004V^2 - 0,0055V + 0,2687$	0,203
Fuel Consumption	Conventional	10-130	$0,02330V^2 - 2,5646V + 136,22$	0,284
	93/59/EEC	10-130	$0,01530V^2 - 2,1810V + 152,74$	0,304

V: Average speed expressed in km/h

R^2: Correlation coefficient

Notes:

Due to limited available data, the functions for the following cases are a mere copy of those applied in passenger cars. In any case, they seem to be in good compliance with both the measured data and the emission standards.

1. NOx 93/59/EEC Diesel, the emission factor function for Diesel PC 91/441/EEC has been adopted

Table V.1.6-2: Emission reduction percentage for future diesel light vehicles applied to vehicles complying with directive 93/59/EEC

Diesel Passenger Cars	CO [%]	NOx [%]	VOC [%]	PM [%]
EC Proposal II (96/69/EEC)	30	40	40	50

Table V.1.7-1: Emission factors for gasoline heavy duty vehicles >3,5 t

Road Classes	CO [g/km]	NOx [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 V.1.8-1: Speed dependency of emission and consumption factors for diesel heavy duty vehicles >3,5 t

Pollutant	Weight Class	Speed Range	Emission Factor [g/km]	R^2
CO	All Weight Categories	0-100	$37,280V^{-0,6945}$	0,880
NOx	Weight<7,5t	0 - 50	$50,305V^{-0,7708}$	0,902
		50 - 100	$0,0014V^2 - 0,1737V + 7,5506$	0,260
	7,5<Weight<16t	0 - 60	$92,584V^{-0,7393}$	0,940
		60 - 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 - 60	$1425,2V^{-0,7593}$	0,990
		60 - 100	$0,0082V^2 - 0,0430V + 60,12$	0,798
	7,5<Weight<16t	0 - 60	$1068,4V^{-0,4905}$	0,628
		60 - 100	$0,0126V^2 - 0,6589V + 141,2$	0,037
	16<Weight<32t	0 - 60	$1595,1V^{-0,4744}$	0,628
		60 - 100	$0,0382V^2 - 5,1630V + 399,3$	0,037
	Weight>32t	0 - 60	$1855,7V^{-0,4367}$	0,914
		60 - 100	$0,0765V^2 - 11,414V + 720,9$	0,187

V: Average speed expressed in km/h
R^2: Correlation coefficient

Table V.1.8-2: Emission reduction percentage for improved diesel heavy duty vehicles applied to conventional ones

Diesel Heavy Duty Trucks > 3,5 t	Weight Class	Road Classes	CO [%]	NOx [%]	VOC [%]	PM [%]
91/542/EEC	Weight<7,5t	URBAN	50	30	25	35
		RURAL	40	30	25	35
	7,5<Weight<16t	URBAN	50	30	25	35
		RURAL	40	30	25	35
	16<Weight<32t	URBAN	45	45	50	35
		RURAL	40	40	35	35
		URBAN	45	45	50	35
		RURAL	40	40	35	35
91/542/EEC	Weight<7,5t	URBAN	60	50	30	60
		RURAL	45	45	30	60
	7,5<Weight<16t	URBAN	60	50	30	60
		RURAL	45	45	30	60
	16<Weight<32t	URBAN	55	60	55	75
		RURAL	50	55	40	75
		URBAN	55	60	55	75
		RURAL	50	55	40	75

Table V.1.8-3: Speed dependency of emission and consumption factors for conventional diesel urban busses and coaches

Pollutant	Vehicle Class	Speed Range	Emission Factor [g/km]	R^2
CO	Urban Buses	0 - 50	$59,003V^{-0,7447}$	0,895
	Coaches	0 - 120	$63,791V^{-0,8393}$	0,978
NOx	Urban Buses	0 - 50	$89,174V^{-0,5185}$	0,534
	Coaches	0 - 60	$125,87V^{-0,6562}$	0,848
		60 - 120	$0,0010V^2 - 0,1608V + 14,308$	0,073
VOC	Urban Buses	0 - 50	$43,647V^{-1,0301}$	0,992
	Coaches	0 - 120	$44,217V^{-0,8870}$	0,993
PM	Urban Buses	0 - 50	$7,8609V^{-0,7360}$	0,920
	Coaches	0 - 120	$9,2934V^{-0,7373}$	0,975
Fuel Consumption	Urban Buses	0 - 50	$1371,6V^{-0,4318}$	0,502
	Coaches	0 -60	$1919,0V^{-0,5396}$	0,786
		60 - 120	$0,0447V^2 - 7,072V + 478$	0,026

V: Average speed expressed in km / h
R^2: Correlation coefficient

Table V.1.8-4: Emission reduction percentage for improved diesel urban busses and coaches applied to conventional vehicles

Diesel Heavy Duty Trucks > 3,5 t	Weight Class	Road Classes	CO [%]	NOx [%]	VOC [%]	PM [%]
91/542/EEC	URBAN BUSSES	URBAN	50	30	25	35
		RURAL	-	-	-	-
		HIGHWAY	-	-	-	-
	COACHES	URBAN	45	45	50	35
		RURAL	40	40	35	35
		HIGHWAY	35	45	25	35
91/542/EEC	URBAN BUSSES	URBAN	60	50	30	60
		RURAL	-	-	-	-
		HIGHWAY	-	-	-	-
	COACHES	URBAN	55	60	55	75
		RURAL	50	55	44	75

Table V.1.9-1: Emission and consumption factors for conventional mopeds

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

Table V.1.9-2: Emission and consumption reduction percentage for improved mopeds applied to conventional ones

Mopeds <50cc	Road Classes	CO [%]	NOx [%]	VOC [%]	FC [%]
EC Proposal III COM(93)449	All Categories	50	0	55	40
EC Proposal IV COM(93)449 Stage II	All Categories	90	67	78	56

Notes:
No reduction factors are proposed for fuel consumption (except mopeds). The consumption factor functions used for the most recent measured technology (e.g. PC - 91/441/EEC) are also applied to the improved or future ones (e.g. PC - 94/12/EEC, PC - EC Prop. I).

Table V.1.9-3: Speed dependency of emission and consumption factors for 2 stroke motorcycles of engine displacement over 50cm³

Pollutant	Vehicle Class	Speed Range	Emission Factor [g/km]
CO	Conventional	10 - 60	$-0,00100V^2 + 0,1720V + 18,10$
		60 - 110	$0,00010V^2 + 0,0500V + 21,50$
	EC Proposal V COM(93)449	10 - 60	$-0,00630V^2 + 0,7150V - 6,900$
		60 - 110	$0,00070V^2 + 0,1570V + 6,000$
NOx	Conventional	10 - 60	$0,00003V^2 - 0,0020V + 0,064$
		60 - 110	$-0,00002V^2 + 0,0049V - 0,157$
	EC Proposal V COM(93)449	10 - 60	$0,00002V^2 - 0,0010V + 0,032$
		60 - 110	$-0,00002V^2 + 0,0041V - 0,152$
VOC	Conventional	10 - 60	$0,00350V^2 - 0,4090V + 20,10$
		60 - 110	$0,00030V^2 - 0,0524V + 10,60$
	EC Proposal V COM(93)449	10 - 60	$-0,00100V^2 + 0,0970V + 3,900$
		60 - 110	$-0,00030V^2 + 0,0325V + 5,200$
Fuel Consumption	Conventional	10 - 60	$0,006300V^2 - 0,6028V + 44,40$
		60 - 110	$-0,00050V^2 + 0,2375V + 18,20$
	EC Proposal V COM(93)449	10 - 60	$-0,00110V^2 + 0,2008V + 17,80$
		60 - 110	$-0,00100V^2 + 0,2425V + 14,60$

V: Average speed expressed in km / h

Table V.1.9-4: Speed dependency of emission and consumption factors for 4 stroke motorcycles of engine displacement over 50cm³

Pollutant	Cylinder Capacity	Speed Range	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	$0,00050V^2 + 0,1240V + 6,900$
	EC Proposal V All Capacities	10 - 60	$0,00760V^2 - 0,7300V + 23,50$
		60 - 110	$0,00100V^2 + 0,0510V + 0,800$
NOx	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	$0,00002V^2 + 0,0008V + 0,112$
	EC Proposal V 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	$0,00010V^2 - 0,0310V + 3,290$
	EC Proposal V All Capacities	10 - 60	$0,00050V^2 - 0,0755V + 2,630$
		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	$0,00180V^2 - 0,1638V + 37,00$
	EC Proposal V All Capacities	10 - 60	$0,02000V^2 - 2,0750V + 77,10$
		60 - 110	$0,00130V^2 - 0,0391V + 23,50$

V: Average speed expressed in km / h

Table V.2.1-1: Cold mileage percentage β (Share of mileage driven with cold gasoline powered engines)

	Factor Beta β
Estimated l_{trip}	$0,647 - 0,025 \cdot l_{trip} - (0,00974 - 0,000385 \cdot l_{trip}) \cdot t_a$

Measured l_{trip}	$0{,}698 - 0{,}051 \cdot l\, l_{trip} - (0{,}01051 - 0{,}000770 \cdot l_{trip}) \cdot t_a$

Table V.2.1-2: Relative Emission Factors e^{cold} / e^{hot} (Only valid for conventional gasoline vehicles and temperature range from -10 ^{o}C to 30 ^{o}C)

Conventional Gasoline Powered Vehicles	e^{cold} / e^{hot}
CO	$3{,}7 - 0{,}09 \cdot t_a$
NOx	$1{,}14 - 0{,}006 \cdot t_a$
VOC	$2{,}8 - 0{,}06 \cdot t_a$
Fuel Consumption	$1{,}47 - 0{,}009 \cdot t_a$

Table V.2.1-3: Examples of values for average estimated trip length - l_{trip} - as taken by COPERT 90 updated run

COUNTRY	TRIP LENGTH [km]
A	12
B	12
DK	9
D	14
EW	12
F	12
SF	17
GR	12
H	12
IRL	14
I	12
L	15
LT	14
LR	14
M	18
NL	13,1
P	12
PL	10
SLO	13
E	6,31
GB	10

Table V.2.2-1: Relative Emission Factors e^{cold} / e^{hot} (Only valid for closed loop gasoline vehicles and temperature range from -10^{o}C to 30^{o}C)

Closed Loop Gasoline Powered Vehicles	e^{cold} / e^{hot}
CO	$9{,}04 - 0{,}09 \cdot t_a$
NOx	$3{,}66 - 0{,}006 \cdot t_a$
VOC	$12{,}59 - 0{,}06 \cdot t_a$
Fuel Consumption	$1{,}47 - 0{,}009 \cdot t_a$

Table V.2.3-1: Relative Emission Factors e^{cold} / e^{hot} (Only valid for diesel passenger cars and temperature range from -10 ^{o}C to 30 ^{o}C)

Diesel Passenger Cars	e^{cold} / e^{hot}
CO	$1,9 - 0,03 \cdot t_a$
NOx	$1,3 - 0,013 \cdot t_a$
VOC	$3,1 - 0,09 \cdot t_a$ (1)
PM	$3,1 - 0,1 \cdot t_a$ (2)
Fuel Consumption	$1,34 - 0,008 \cdot t_a$

(1) VOC: if ta > 29°C then $e^{cold} / e^{hot} > 0,5$

(2) PM: if ta > 26°C then $e^{cold} / e^{hot} > 0,5$

Table V.2.4-1: Relative Emission Factors e^{cold} / e^{hot} (Only valid for LPG passenger cars and temperature range from -10 ^{o}C to 30 ^{o}C)

LPG Passenger Cars	e^{cold} / e^{hot}
CO	$3,66 - 0,09 \cdot t_a$
NOx	$0,98 - 0,006 \cdot t_a$
VOC	$2,24 - 0,06 \cdot t_a$ (1)
Fuel Consumption	$1,47 - 0,009 \cdot t_a$

(1) VOC: if ta > 29°C then $e^{cold} / e^{hot} > 0,5$

Table V.3.1-1: Summary of emission factors for estimating evaporative emissions of gasoline vehicles (all RVP in kPa, all temperatures in ^{o}C)

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

Table V.3.1-2: Examples of statistical input data relevant for estimating evaporative emissions as used by EC Member States in COPERT 85 and 90

Country	Vehicle Category	Vehicles equipped with fuel injection [%]
B	< 1,4 l	0,0
	1,4 - 2,0 l	3,1
	> 2,0 l	1,8
D	< 1,4 l	8,4
	1,4 - 2,0 l	8,4
	> 2,0 l	8,4
DK	< 1,4 l	0,0
	1,4 - 2,0 l	0,0
	> 2,0 l	0,0
E	< 1,4 l	4,9
	1,4 - 2,0 l	4,9
	> 2,0 l	4,9
F	< 1,4 l	0,0
	1,4 - 2,0 l	4,2
	> 2,0 l	15,5
GR	< 1,4 l	1,0
	1,4 - 2,0 l	1,0
	> 2,0 l	1,0
I	< 1,4 l	5,0
	1,4 - 2,0 l	5,0
	> 2,0 l	5,0
IRL	< 1,4 l	0,0
	1,4 - 2,0 l	0,0
	> 2,0 l	0,0
L	< 1,4 l	5,0
	1,4 - 2,0 l	10,0
	> 2,0 l	15,0
NL	< 1,4 l	0,0
	1,4 - 2,0 l	0,0
	> 2,0 l	10,0
P	< 1,4 l	0,0
	1,4 - 2,0 l	10,0
	> 2,0 l	30,0
UK	< 1,4 l	0,0
	1,4 - 2,0 l	0,0
	> 2,0 l	0,0

Table V.4.1-1: Gradient factor functions for heavy duty vehicles <7,5 t

A6	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**	**case**	**slope** *[%]*	**vmin** *[km/h]*	**vmax** *[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	NOx	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	NOx	-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	NOx	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	NOx	-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

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

Table V.4.1-2: Gradient factor functions for heavy duty vehicles 7,5 - 16 t

A6	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**	**case**	**slope** *[%]*	**vmin** *[km/h]*	**vmax** *[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	NOx	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	NOx	-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	NOx	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	NOx	-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

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

Table V.4.1-3: Gradient factor functions for heavy duty vehicles 16 - 32 t

A6	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**	**case**	**slope** *[%]*	**vmin** *[km/h]*	**vmax** *[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	NOx	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	NOx	-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	NOx	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	NOx	-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

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

Table V.4.1-4: Gradient factor functions for heavy duty vehicles >32 t

A6	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**	**case**	**slope** *[%]*	**vmin** *[km/h]*	**vmax** *[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	NOx	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	NOx	-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	NOx	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	NOx	-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

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

Table V.4.1-5: Gradient factor functions for urban busses

A6	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**	**case**	**slope** *[%]*	**vmin** *[km/h]*	**vmax** *[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	NOx	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	NOx	-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	NOx	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	NOx	-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

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

Table V.4.1-6: Gradient factor functions for coaches

A6	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**	**case**	**slope** *[%]*	**vmin** *[km/h]*	**vmax** *[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	NOx	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	NOx	-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	NOx	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	NOx	-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 V.4.2-1: Load correction factors applied to heavy duty vehicles

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

Table V.5 - 1: Methane (CH_4) emission factors for all vehicle categories

CH_4 Emission Factors [g/km]	Urban	Rural	Highway
Passenger Cars			
Conventional	$0,268 - 0,00573V + 0,0000331V^2$		
Closed Loop	0,020	0,020	0,020
Diesel CC < 2,0 l	0,005	0,005	0,005
Diesel CC > 2,0 l	0,005	0,005	0,005
L P G	0,080	0,035	0,025
2-stroke	0,150	0,040	0,025
Light Duty Vehicles			
Gasoline	0,150	0,040	0,025
Diesel	0,005	0,005	0,005
Heavy Duty Vehicles			
Gasoline Veh. > 3,5 t	0,140	0,110	0,070
Diesel Veh. < 7,5 t	0,085	0,023	0,020
Diesel Veh. 7,5t< W <16 t	0,085	0,023	0,020
Diesel Veh. 16< W <32 t	0,175	0,800	0,070
Diesel Veh. > 32 t	0,175	0,800	0,070
Buses & Coaches	0,175	0,800	0,070
Motorcycles			
< 50 cm^3	0,100	0,100	0,100
> 50 cm^3 2 stroke	0,150	0,150	0,150
> 50 cm^3 4 stroke	0,200	0,200	0,200

V: average speed expressed in km / h

Table V.6 - 1: Nitrous Oxide (N_2O) emission factors for all vehicle categories

N_2O Emission Factors [g/km]	Urban	Rural	Highway
Passenger Cars			
Conventional	0,005	0,005	0,005
Closed Loop	0,050	0,050	0,050
Diesel CC < 2,0 l	0,010	0,010	0,010
Diesel CC > 2,0 l	0,010	0,010	0,010
L P G	n.a.	n.a.	n.a.
2-stroke	0,005	0,005	0,005
Light Duty Vehicles			
Gasoline	0,006	0,006	0,006
Diesel	0,017	0,017	0,017
Heavy Duty Vehicles			
Gasoline Veh. > 3,5 t	0,006	0,006	0,006
Diesel Veh. < 7,5 t	0,030	0,030	0,030
Diesel Veh. 7,5t< W <16 t	0,030	0,030	0,030
Diesel Veh. 16t< W <32 t	0,030	0,030	0,030
Diesel Veh. > 32 t	0,030	0,030	0,030
Buses & Coaches	0,030	0,030	0,030
Motorcycles			
< 50 cm^3	0,001	0,001	0,001
> 50 cm^3 2 stroke	0,002	0,002	0,002
> 50 cm^3 4 stroke	0,002	0,002	0,002

n.a.: not available

Table V.9-1: Ammonia (NH_3) emission factors for all vehicle categories

NH_3 Emission Factors [g/km]	Urban	Rural	Highway
Passenger Cars			
Conventional	0,002	0,002	0,002
Closed Loop	0,070	0,100	0,100
Diesel CC < 2,0 l	0,001	0,001	0,001
Diesel CC > 2,0 l	0,001	0,001	0,001
L P G	n.a.	n.a.	n.a.
2-stroke	0,002	0,002	0,002
Light Duty Vehicles			
Gasoline	0,002	0,002	0,002
Diesel	0,001	0,001	0,001
Heavy Duty Vehicles			
Gasoline Veh. > 3,5 t	0,002	0,002	0,002
Diesel Veh. < 7,5 t	0,003	0,003	0,003
Diesel Veh. 7,5t< W <16 t	0,003	0,003	0,003
Diesel Veh. 16t< W <32 t	0,003	0,003	0,003
Diesel Veh. > 32 t	0,003	0,003	0,003
Buses & Coaches	0,003	0,003	0,003
Motorcycles			
< 50 cm³	0,001	0,001	0,001
> 50 cm³ 2 stroke	0,002	0,002	0,002
> 50 cm³ 4 stroke	0,002	0,002	0,002

n.a.: not available

Table V.10-1: 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 V.11-1: Composition of VOC Emissions of motor vehicles (Data as provided by C.Veldt) A) Non-methane VOC (composition in weight % of exhaust)

Species or group of species	Gasoline			Diesel	LPG
	Exhaust	gas	Evaporation		
	4-stroke	engine			
	conventional	3-way catalysts			
Ethane	1,4	1,8		1	3
Propane	0,1	1,0	1	1	44
n-Butane	3,1	5,5	20	2	
i-Butane	1,2	1,5	10		
n-Pentane	2,1	3,2	15	2	
i-Pentane	4,3	7,0	25		
Hexane	7,1	6,0	15		
Heptane	4,6	5,0	2		
Octane	7,9	7,0			
Nonane	2,3	2,0			
Alkanes C>10	0,9	3,0		30 (1)	
Ethylene	7,2	7,0		12	15
Acetylene	4,5	4,5		4	22
Propylene	3,8	2,5		3	10
Propadiene	0,2				
Methylacetylene	0,3	0,2			
1-Butene	1,7	1,5	1		
1,3 Butadiene	0,8	0,5		2	
2-Butene	0,6	0,5	2		
1-Pentene	0,7	0,5	2		
2-Pentene	1,1	1,0	3	1	
1-Hexene	0,6	0,4			
1,3 Hexene	0,6	0,4	1,5		
Alkanes C>7	0,3	0,2		2 (1)	
Benzene	4,5	3,5	1	2	
Toluene	12,0	7,0	1	1,5	
o-Xylene	2,5	2,0		0,5	
m,p-Xylene	5,6	4,0	0,5	1,5	
Ethylbenzene	2,1	1,5		0,5	
Styrene	0,7	0,5			0,1
1,2,3-Trimethylbenzene	0,5	1,0			
1,2,4-Trimethylbenzene	2,6	4,0			
1,3,5-Trimethylbenzene	0,8	2,0			
Other aromatic compounds C9	3,8	3,0			
Aromatic compounds C>10	4,5	6,0		20 (1)	
Formaldehyde	1,7	1,1		6	4
Acetaldehyde	0,3	0,5		2	2
Other Aldehydes C4	0,3	0,2		1,5	
Acrolein	0,2	0,2		1,5	
2-Butenal				1,0	
Benzaldehyde	0,4	0,3		0,5	
Acetone	0,1	1,0		1,5	
	100	100	100	100	100

(1) C13

Table V.11 - 1 (cont): Composition of VOC Emissions of motor vehicles (Data as provided by C.Veldt) B) Methane (composition in weight % of exhaust)

Gasoline	
- conventional	5
- 3-way catalyst equipped	12
Diesel	4
LPG	3

8. List of Abbreviations

CC	Cylinder Capacity of the Engine
CH_4	Methane
Cd	Cadmioum
CO	Carbon Monoxide
CO_2	Carbon Dioxide
Cr:	Chromium
Cu	Copper
FC	Fuel Consumption
GVW	Gross Vehicle Weight
NH_3	Ammonia
Ni	Nickel
NMVOC	Non-Methane Volatile Organic Compounds
N_2O	Nitrous Oxide
NOx	Nitrogen Oxides (sum of NO and NO_2)
NUTS	Nomenclature of Territorial Units for Statistics (0 to III). According to the EU definition, NUTS 0 is the territory of individual Member States
Pb	Lead
RVP	Reid Vapour Pressure (standardized vapour pressure measurement, conducted at 38°C, with a vapour : liquid ratio 4:1)
Se	Selenium
SOx	Sulphur Oxides
VOC	Volatile Organic Compounds
Zn	Zinc
	Countries
A	Austria
B	Belgium
D	Germany
DK	Denmark
E	Spain
EW	Estonia
F	France
SF	Finland
GR	Greece
H	Hungary
I	Italy
IRL	Ireland
L	Luxembourg
LT	Latvia
LR	Lithuania
M	Malta
NL	Netherlands
P	Portugal
PL	Poland
SL	Slovakia
GB	United Kingdom

9. List of Symbols and Indices

9.1. Symbols

a_j = number of gasoline vehicles of category j, operated in 1990

$a_{j,g}$ = number of vehicles of category j produced within the period of ECE legal conformity g or belonging to a distinct technology step (only vehicles passenger cars)

$as_{i,j,k}$ = the road gradient associated correction factor of the emission factor

$b_{j,l}$ = total annual consumption of fuel of type l in [kg] by vehicles of category j operated in 1990

$c_{j,k}$ = average fuel consumption in [g/km] of vehicle category j on road class k

cfi = load correction factor of the pollutant i.

$d_{j,k}$ = share of annual mileage driven on road class k by vehicle category j

$e_{hot,year,i,j,k}$ = average fleet representative baseline emission factor in [g/km] for the pollutant i, for the vehicle category j, operated on roads of type k with hot engines.

$e*_{hot,year,i,j,k}$ = average fleet representative baseline emission factor in [g/kg fuel] for the pollutant i, relevant for the vehicle category j, operated on roads of type k with hot engines.

e^{cold}/e^{hot} = ratio of emissions of cold to hot engines

$e_{hot,i,j,k,g}$ = emission factor in [g/km] for pollutant i, for the vehicle category j, operated on roads of type k with hot engines, valid for regulatory step g

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)

$e^{s,hot}$ = mean emission factor for hot soak emissions

$e^{s,warm}$ = mean emission factor for cold and warm soak emissions

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

$e^{r,warm}$ = average emission factor for warm running losses of gasoline powered vehicles

echot,i,j,k = road gradient 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

ec(l)i,j = load corrected emission factor of the pollutant i in [g/km] of the vehicle of category j

ei,j(50%) =emission factor of the pollutant i in [g/km] of the vehicle of ategory j calculated for a load of 50%

e(z) = mathematical equation (e.g. formula of best fit curve) of the speed dependency of $e_{hot,z;i,j,g}$

$f_k(z)$ = equation (e.g. formula of 'best fit' curve) of the speed distribution which corresponds to the driving patterns of gasoline vehicles < 2,5 t on road classes 'rural', 'urban' and 'highway'

$g_{j,k,l}$ = share of annual consumption of fuel of type 1 used by vehicles of category j, driven on road type k

h_j = number of vehicles of category j

$k_{S,e}$ = weight related sulphur content of fuel of type l in [kg/kg]

k_{Pb} = weight related lead content of gasoline in [kg/kg]

ltrip = average trip length

lp = the actual load factor (Expressed as a percentage of the maximum load. That is, lp = 0 denotes an unladen vehicle and lp = 100 represents a totally laden one)

m_j = total annual mileage in [km] of vehicle category j

$m_{j,k}$ = total annual mileage in [km] of vehicle category j on road class k

p = fraction of trips, finished with hot engine (depending on the average monthly ambient temperature)

$r_{H/C}$ = ratio of hydrogen to carbon atoms in the fuel

q = fraction of gasoline powered vehicles equipped with fuel injection

$s_{j,g}$ = share of vehicles of category j of total national fleet, belonging to a period of legal conformity g (only applicable for gasoline vehicles < 2,5 t)

t_a = monthly mean ambient temperature in [^oC]

$t_{a,min}$ = monthly mean minimum ambient temperature in [^oC]

$t_{a,rise}$ = monthly mean of the daily ambient temperature rise in [^oC]

v_j = average annual mileage driven by each vehicle of category j

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

z = the speed of gasoline vehicles <2,5 t on road classes ‘rural’, ‘urban’ and ‘highway’

β_j = fraction of mileage driven with cold engines

$A_{i,j,k}0$-$A_{i,j,k}6$ = road gradient calculating constants for each pollutant, weight and gradient class

$E_{hot,i,j,k}$ = emissions of the pollutant i in [g] caused in the reference year 1990 by vehicles of category j driven on roads of type k with hot engines

$E_{cold,i,j}$ = emissions of the pollutant i due to cold-starts in urban areas, caused by vehicles of category j

$E_{eva,VOC,j}$ = VOC emissions due to evaporative losses, caused by vehicles of category j under urban driving conditions

O_l = total annual consumption of fuel [kg] of type l

R = hot and warm running losses

S^c = average hot and warm soak emission factor of gasoline powered vehicles equipped with carburetor

S^{fi} = average hot and warm soak emission factor of gasoline powered vehicles equipped with fuel injection

V = vehicle speed in [km / h]

9.2. List of Indices

g = indicator of regulatory situation applicable to vehicle ECE regulation steps 0 - 4 or earlier (1 - 6, only relevant for gasoline powered vehicles <2,5 t) or technology steps

i (pollutants) = 1 - 10 for the pollutants covered

j(vehicles category) = 1 - 39 (or 34 if only on-road vehicles are considered) for the vehicle categories defined in the COPERT 90 nomenclature

k (road classes) = 1 - 3 for ‘urban’, ‘rural’ and ‘highway’ driving pattern

l = fuel type (1 - 3 for gasoline, diesel, LPG)