ROAD TRANSPORT

SNAP CODE : **070100**
070200
070300
070400
070500

SOURCE ACTIVITY TITLE : **Passenger Cars**
Light Duty Vehicles < 3.5t
Heavy Duty Vehicles > 3.5t and buses
Mopeds and Motorcycles < 50cm^3
Motorcycles > 50cm^3

1 ACTIVITIES INCLUDED

The vehicle category split required for reporting in CORINAIR does not meet all aspects of vehicle emissions considered important. Thus, a more detailed vehicle category split has been developed, presented in Table 1.1. With this vehicle split it is attempted on the one hand to introduce the technological changes which took effect in vehicles (e.g. introduction of three way catalytic converters in gasoline light duty vehicles) and on the other to preserve the distinction between the three major driving classes (urban, rural and highway) for a more detailed spatial allocation of emissions.

Moreover, other important emission related parameters, in particular the age of vehicles (year of production) and the engine technology, are not sufficiently reflected in the CORINAIR split. Major differences occur in the category passenger cars, where the different steps of international legal conformity have to be taken into account (ECE classes), as well as national legislation with the classes "Improved Conventional" and "Open Loop". This report provides detailed emission factors for a number of technology classes, which are presented in Table 1.2 and which in a second step can be aggregated to match the CORINAIR split.

The methodology proposed in 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 previous version of 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 (Ahlvik et al. 1997); 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.

It has also to be stressed that national programmes (e.g. German/Swiss/Austrian collaboration) produced results, which greatly helped to close some of the gaps in knowledge which were identified in previous exercises. In particular, in the framework of the Swiss/German project a large data base containing instantaneous measurements of pollutant emissions over a variety of cycles for passenger cars, but - more important - for goods vehicles was developed (see for example Hassel et al.1993), together with a computerised Handbook of emission factors (Keller et al. 1995). Most of the results of this activity have been taken over in the current update of the Guidebook Chapter on Road Traffic Emissions.

Due to the differences in the proposed calculation schemes, this part of the Emission Inventory Guidebook referring to Road Transport emissions is organised into two parts: Exhaust emissions (SNAP codes 07 01 to 07 05) are presented in this chapter, while Gasoline Evaporation from Cars (SNAP code 07 06) is dealt with separately in chapter B760.

Table 1.1: Vehicle category split

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 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

Table 1.1: Continued

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

Table 1.2: Detailed vehicle category split used in this report

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 - 97/24/EC Stage I EC Proposal IV - 97/24/EC Stage II
Motorcycles	*2 stroke* *>50cm*^{3}	Conventional EC Proposal V - 97/24/EC
	4 stroke *50 - 250cm*^{3}	Conventional EC Proposal V - 97/24/EC
	4 stroke *250 - 750cm*^{3}	Conventional EC Proposal V - 97/24/EC
	4 stroke *>750cm*^{3}	Conventional EC Proposal V - 97/24/EC

2 CONTRIBUTIONS TO TOTAL EMISSIONS

Road transport has been identified as a major source of air pollution, especially in urban areas. For example, the contribution of motor vehicles to total man-made NO_x emissions of the European Community in 1990 is estimated to be about 44% and to total man-made NMVOC about 34% (see Table 2.1). In addition, Table 2.2 presents the contribution to total traffic related emissions of the main vehicle sub-categories, for the pollutants CO, NO_x, VOC, CO_2, SO_2, Pb , particulates, N_2O and NH_3. It is of interest to note that gasoline passenger cars are the main traffic emitters of CO, VOC and Pb, while heavy duty trucks are responsible for major parts of traffic related NO_x, SO_2 and PM on average at EU level.

Table 2.1: Contribution of road transport to total man-made NO_x and NMVOC emissions in [kt] and [%]. Estimates of CORINAIR 90 (as of 10.4.1995)

	NO_x Emissions			**NMVOC Emissions**		
	Total	**Road Traffic**		**Total**	**Road Traffic**	
	kt	**kt**	**%**	**kt**	**kt**	**%**
B	343	190	55	394	189	48
DK	273	102	37	178	99	55
D	2425	1493	62	2484	810	33
F	1590	1038	65	2866	1170	41
GR	544	114	21	718	137	19
IRL	116	44	38	197	62	32
I	2053	946	46	2546	954	37
L	23	9	40	20	10	50
NL	576	272	47	460	184	40
P	221	107	48	644	81	13
E	1257	512	41	1894	449	24
UK	2773	1383	50	2682	982	37
EU 12	17759	7746	44	15084	5127	34

Table 2.2: 1990 Emissions of different vehicle categories as percentage of the EU Totals for road transport. In parentheses the range of dispersion of the countries (Estimates of CORINAIR 90)

	CO	**NO_x**	**NMVOC**	**CH_4**	**CO_2**	**SO_2**	**Pb**	**PM**	**N_2O**	**NH_3**
Gasoline Passenger Cars	80.0 (62-94)	49.8 (29-90)	62.4 (45-85)	70.3 (13-84)	47.7 (32-65)	19.4 (8-43)	80.4 (63-87)		49.3 (22-70)	87.6 (56-
Diesel Passenger Cars	0.9 (0-2)	3.3 (0-8)	1.8 (0-5)	1.5 (0-15)	10.0 (0-25)	16.4 (0-37)		26.2 (11-43)	11.8 (7-30)	2.0 (2-17)
LPG Passenger Cars	0.6 (0-3)	0.9 (0-5)	1.0 (0-5)	1.1 (0-5)	0.8 (0-4)					
Light Duty Vehicles	9.3 (1-24)	8.0 (2-17)	8.4 (2-20)	6.5 (2-17)	12.4 (1-23)	17.2 (5-27)	12.7 (6-32)	16.6 (0-31)	13.6 (6-26)	4.5 (3-15)
Heavy Duty Vehicles	5.4 (2-14)	37.8 (0-59)	13.5 (4-20)	10.7 (3-32)	27.9 (18-60)	46.4 (27-76)	2.1 (0-7)	57.2 (44-89)	24.8 (12-63	4.9 (4-31)
Motorcycles	3.8 (0-10)	0.2 (0-1)	13.0 (1-25)	9.9 (1-37)	1.2 (0-3)	0.6 (0-1)	4.8 (1-8)		0.4 (0-2)	1.1 (0-24)

3 GENERAL

3.1 Description

In order to help identifying the vehicle categories, Table 3.1 gives the classification of vehicles according to the UN-ECE. The main CORINAIR categories can be allocated to the UN-ECE classification as follows:

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

3.2 Definitions

The report contains emission factors for NO_x, N_2O, SO_x, VOC, CH_4, CO, CO_2, NH_3, diesel particulates and lead and other heavy metals. 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
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
NMVOC:	produced by deducting CH_4 from total VOC emissions

3.3 Controls

3.3.1 Gasoline passenger cars

Emissions from passenger cars differ significantly according to the age of the vehicle. This is due to the fact that since the early 70s the legislation tried to improve air quality by setting emission standards for those vehicles. As a result, and in order to conform with the more stringent standards, vehicle manufacturers developed new technologies for improved emission performance.

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:

Table 3.1: 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.

pre ECE :	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 12 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, F.R.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 F.R.Germany carried out after 1.7.1985), where compliance with US 83 limits is required. Today, this category mainly consists of 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, F.R.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, F.R.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 where compliance with US 83 limits is required. Today, this category mainly consists of 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, F.R.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, F.R.Germany, Greece, The Netherlands). Effective date: Denmark 1.1.1987, F.R.Germany 1.7.1985, Greece 1.1.1989, The Netherlands 1.1.1987. It is assumed that the required emission standards can be met by applying closed loop three way catalysts. Today, this category mainly consists of the passenger cars complying with the 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 after 1.1.1997 (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).

3.3.2 Other vehicle categories

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, or in general complying with the more stringent 91/441/EEC emission standards. 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 other parameters, the emission factors, in particular for particulates can vary substantially, depending on fuel quality and state of maintenance.

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. Moreover, speed depended emission factors are proposed for LPG cars complying the 91/441/EEC Directive. As far as the future legislation is concerned (i.e. 94/12/EEC and EC Proposal I) appropriate reduction percentages are introduced. 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.

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 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.

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/EEC Directive introduces stricter emission standards to light duty trucks by 1998/99 and is referred as EC Proposal II in this report. Sets of speed depended emission factors for gasoline light duty vehicles are given. As far as the future legislation is concerned (i.e. EC Proposal II - 96/69/EEC) appropriate reduction percentages are introduced.

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. The speed depended emission factors proposed for conventional and improved (93/59/EEC) light duty vehicles are presented. As far as the future legislation is concerned (i.e. EC Proposal II - 96/69/EEC) appropriate reduction percentages are introduced.

Gasoline Heavy Duty Vehicles

Heavy duty gasoline vehicles >3.5 tonnes play a negligible role in European emissions from road traffic due to their small number. Emission factors derived from an extrapolation of results from smaller vehicles are though presented.

Diesel Heavy Duty Vehicles

In the EC, emission standards for the gaseous pollutants CO, HC and NO_x 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 NO_x 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 applied so far has been made, as far as the classification of the heavy duty vehicles is concerned. As Table 1.2 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). As far as the latest and future legislation are concerned (i.e. 91/542/EEC Stages I and II) appropriate reduction percentages are suggested. In order to comply to the latest and future standards, imposed by the 91/542/EEC Directive, special reduction percentages are also suggested.

Urban Buses and Coaches

The sub-category "urban buses" refers to buses, independent of vehicle weight, which serve as transportation vehicles in urban areas and their velocity seldom exceeds 50km/h. The sub-category "coaches" refers to buses which mainly travel in rural and highway conditions and their velocity can reach or exceed 120km/h. Both of those vehicle types are considered as diesel powered. As far as the technology level is of concern, the same as with diesel heavy duty vehicles apply.

Mopeds <50cm³ and Motorcycles >50cm³

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.

Until lately, 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 has adopted new legislation (97/24/EC), to be implemented as follows: Mopeds Stage I and motorcycles - 17 June 1999; Mopeds Stage II - 17 June 2000.

3.3.3 Future emission standards

In the case where new emission standards have been adopted, but no measured data exist (e.g. PC 94/12/EEC), special reduction factors are given which can be applied on the given equations. Those factors have been derived by estimating the emission reduction imposed by the new standards and trends in the evolution of emissions from vehicles. They do not depend on the speed of the vehicle and are given as a percentage ratio of the most recent technology, for which detailed emission factors exist (e.g. in the case of passenger cars: 91/441/EEC). They should not be considered though of the same validity as the emission factor equations. When new measurement results become available revised emission equations will also be proposed for the latest and future technologies.

4 SIMPLER METHODOLOGY

Several methods to calculate emissions can be foreseen. In all cases, emission estimates have to be based on a mixture of (some) hard facts and a (large) number of assumptions. It is, therefore, important to define a method to be used for the estimation work which builds upon as many hard facts as possible, reducing at the same time the number of assumptions. However, when searching for such a compromise method, one always has to keep in mind the objective of the work, i.e. the final data usage which, determines to a large extent the source category split requirements.

In principle the detailed methodology proposed in the following section is easily applicable. A simple methodology for estimating emissions is based on total fuel consumption or total mileage or energy consumption data which then have to be multiplied by appropriate bulk emission factors.

Therefore, the formula to be applied in this case is

$$E_i = FC \cdot EF_i$$

with

E_i	=	mass of emissions of pollutant i during inventory period
FC	=	fuel consumption or mileage or energy consumption
EF_i	=	average emissions of pollutant i per unit of fuel used or mileage or energy

Since the simple methodology outlined above averages over different types of engines, using different types of fuels, it can provide only broad estimates at best.

Tables 4.1 to 4.8 present bulk emission factors for the application of the simple methodology. These tables have been produced by averaging the data submitted by the different European countries to the CORINAIR90 inventory. In addition an attempt was made to classify the emissions factors to different technology classes (especially as regards gasoline passenger cars) following the IPCC nomenclature.

Table 4.1: Estimated Emission Factors for Gasoline Passenger Cars

	NOx	**CH_4**	**VOC**	**CO**	**N_2O**	**CO_2**
Uncontrolled: Fuel Economy 11.2 l/100 km						
Total g/km	2.24	0.07	5.40	46.5	0.005	269
Exhaust	2.24	0.07	4.03	46.5	0.005	269
Evaporative (*)			1.37			
g/kg fuel	26.6	0.83	64.0	551	0.059	3183
g/MJ	0.610	0.019	1.47	12.7	0.001	73.2
Early non-catalyst controls: Fuel Economy 9.4 l/100 km						
Total g/km	2.05	0.08	5.31	28.6	0.005	225
Exhaust	2.05	0.08	3.94	28.6	0.005	225
Evaporative (*)			1.37			
g/kg fuel	29.0	1.13	75.2	405	0.071	3183
g/MJ	0.668	0.026	1.73	9.30	0.002	73.2
Non-catalyst controls: Fuel Economy 8.3 l/100 km						
Total g/km	2.30	0.07	4.58	18.7	0.005	199
Exhaust	2.30	0.07	3.32	18.7	0.005	199
Evaporative (*)			1.26			
g/kg fuel	36.7	1.12	73.2	298	0.080	3183
g/MJ	0.845	0.026	1.68	6.86	0.002	73.2
Oxidation catalyst: Fuel Economy 8.1 l/100 km						
Total g/km	1.35	0.07	1.51	7.52	0.005	193
Exhaust	1.35	0.07	1.07	7.52	0.005	193
Evaporative (*)			0.44			
g/kg fuel	22.3	1.15	24.9	124	0.082	3183
g/MJ	0.512	0.027	0.572	2.85	0.002	73.2

Three-way catalyst: Fuel Economy 8.5 l/100 km						
Total g/km	0.520	0.02	0.47	2.86	0.050	203
Exhaust	0.520	0.02	0.41	2.86	0.050	203
Evaporative (*)			0.06			
g/kg fuel	8.16	0.314	7.37	44.9	0.784	3183
g/MJ	0.187	0.007	0.169	1.03	0.018	73.2
2 - stroke: Fuel Economy 10.9 l/100 km						
Total g/km	0.76	0.08	13.3	12.0	0.005	259
Exhaust	0.76	0.08	11,6	12.0	0.005	259
Evaporative (*)			1.69			
g/kg fuel	9.34	0.983	164	148	0.061	3183
g/MJ	0.215	0.023	3.76	3.40	0.001	73.2

(*) Including diurnal, soak and running losses

Table 4.2: Estimated Emission Factors for Diesel Passenger Cars

	NOx	CH_4	VOC	CO	N_2O	CO_2
Moderate Control: Fuel Economy 7.3 l/100 km						
Total g/km	0.66	0.005	0.19	0.71	0.010	190
g/kg fuel	10.9	0.083	3.14	11.7	0.165	3138
g/MJ	0.257	0.002	0.074	0.276	0.004	73.8

Table 4.3: Estimated Emission Factors for LPG Passenger Cars

	NOx	CH_4	VOC	CO	N_2O	CO_2
Moderate Control: Fuel Economy 11.2 l/100 km(*)						
Total g/km	2.16	0.06	1.55	7.10	-	178
g/kg fuel	36.8	1.02	26.4	121	-	3030
g/MJ	0.798	0.022	0.573	2.62	-	65.7

(*) under 5 bar pressure

Table 4.4: Estimated Emission Factors for Gasoline Light Duty Vehicles

	NOx	CH_4	VOC	CO	N_2O	CO_2
Moderate Control: Fuel Economy 13.6 l/100 km						
Total g/km	2.94	0.08	6.17	36.8	0.006	325
Exhaust	2.94	0.08	4.89	36.8	0.006	325
Evaporative *			1.28			
g/kg fuel	28.8	0.783	60.4	361	0.059	3183
g/MJ	0.662	0.018	1.39	8.29	0.001	73.2

Table 4.5: Estimated Emission Factors for Diesel Light Duty Vehicles

	NOx	CH_4	VOC	CO	N_2O	CO_2
Moderate Control: Fuel Economy 10.9 l/100 km						
Total g/km	1.43	0.005	0.42	1.58	0.017	283
g/kg fuel	15.8	0.055	4.65	17.5	0.188	3138
g/MJ	0.373	0.001	0.109	0.412	0.004	73.8

Table 4.6: Estimated Emission Factors for Gasoline Heavy Duty Vehicles

	NOx	CH_4	VOC	CO	N_2O	CO_2
Moderate Control: Fuel Economy 22.5 l/100 km						
Total g/km	6.85	0.110	5.54	58.2	0.006	536
Exhaust	6.85	0.110	5.54	58.2	0.006	536
g/kg fuel	40.7	0.653	32.9	346	0.036	3183
g/MJ	0.935	0.015	0.756	7.94	0.001	73.2

Table 4.7: Estimated Emission Factors for Diesel Heavy Duty Vehicles

	NOx	CH_4	VOC	CO	N_2O	CO_2
Moderate Control: Fuel Economy 29.9 l/100 km						
Total g/km	10.4	0.060	2.01	8.98	0.030	774
g/kg fuel	42.3	0.243	8.16	36.4	0.122	3138
g/MJ	0.995	0.006	0.192	0.857	0.003	73.8

Table 4.8: Estimated Emission Factors for Motorcycles

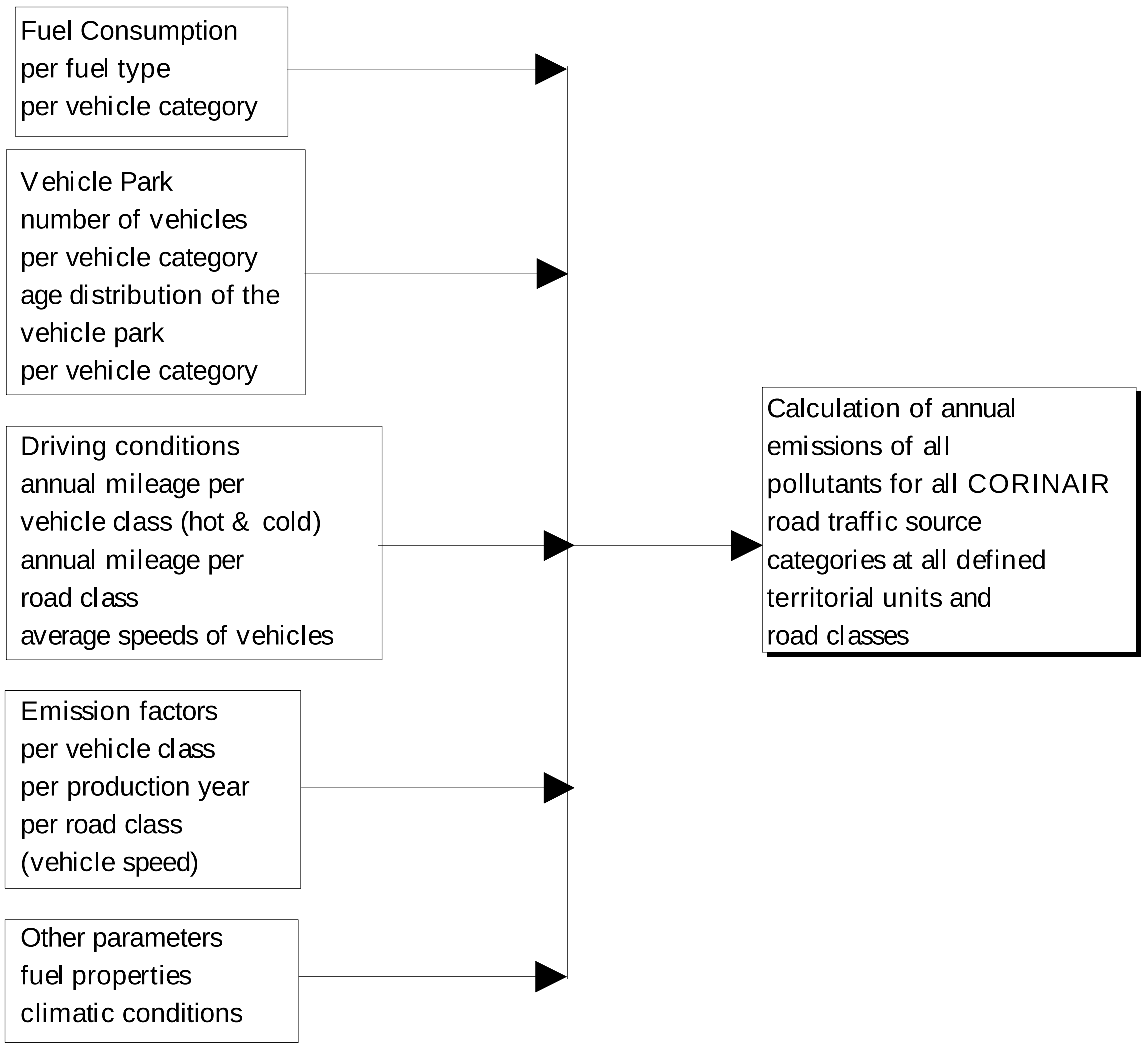
	NOx	CH_4	VOC	CO	N_2O	CO_2
MOTORCYCLES < 50 cc						
Uncontrolled: Fuel Economy 2.4 l/100 km						
Total g/km	0.05	0.10	6.60	10.0	0.001	57.3
Exhaust	0.05	0.10	6.30	10.0	0.001	57.3
Evaporative (*)			0.30			
g/kg fuel	2.78	5.55	366	554	0.056	3183
g/MJ	0.064	0.128	8.41	12.7	0.001	73.2
MOTORCYCLES > 50 cc 2 stroke						
Uncontrolled: Fuel Economy 4.0 l/100 km						
Total g/km	0.08	0.15	16.1	22.0	0.002	95.7
Exhaust	0.08	0.15	15.5	22.0	0.002	95.7
Evaporative (*)			0.6			
g/kg fuel	2.66	5.00	534	731	0.067	3183
g/MJ	0.061	0.115	12.3	16.8	0.002	73.2
MOTORCYCLES > 50 cc 4 stroke						
Uncontrolled: Fuel Economy 5.1 l/100 km						
Total g/km	0.30	0.20	4.10	20.0	0.002	121
Exhaust	0.30	0.20	3.55	20.0	0.002	121
Evaporative (*)			0.55			
g/kg fuel	7.89	5.26	108	526	0.053	3183
g/MJ	0.181	0.121	2.47	12.1	0.001	73.2

(*) Including diurnal, soak and running losses

5 DETAILED METHODOLOGY

The aim of the calculations described below is to estimate the emissions of NO_x (sum of NO and NO_2), N_2O, NMVOC (total VOC minus methane), CH_4, CO, CO_2, SO_x, NH_3, diesel particulates and lead from road traffic for the reference year, differentiated into six different major categories and 83 sub-categories, each of them separated into three types of roads (urban, rural, highway), for each area, or territorial unit (NUTS III). The basic data is therefore the reference year emission of pollutant i, caused by vehicle category j at local area level (NUTS III) on roads of type k. In the ideal case, such information must be available for all pollutants, all categories at all territorial units and for all types of roads.

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 such things as composition of vehicle park, vehicle age, driving patterns, some fuel parameters and a few climatic parameters. Other variations which may exist, for example, 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 above shows the calculation scheme.

This information in principle should be available for the smallest territorial unit (NUTS level III). However, this is not the case in most countries, so that it seems to be more appropriate for these countries to start at NUTS level 0 (national level) and to allocate emissions to other NUTS levels with the help of available surrogate data. This implies that local particularities within a certain country, which might have an influence on the results, e.g. mountains or climatic differences, cannot be fully described. An effort to simulate driving in positive or negative inclined roads, led to correction factors applied to the emissions of heavy duty vehicles. The effects of other parameters, as the altitude where the roads are found or state of maintenance of the vehicle park have not yet been incorporated in the methodology.

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. However, the model should not be used for NUTS much smaller than NUTS III because vehicle speeds and driving modes are average values themselves and may not fit to particular local circumstances

Exhaust emissions from road transport are divided into two 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 extra emissions" which are the emissions from vehicles while they are warming up.

5.1 Hot Emissions

These emissions depend on a variety of factors including the distance that each vehicle travels, its speed, its age and engine size. As explained later, many countries do not have solid estimates of these data. Therefore a method to estimate the emissions from available solid data has been proposed. However, it is important that each country uses the best data they have available. This is an issue to be resolved by each individual country.

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

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

The emission factors and vehicle kilometres are in most cases split into certain classes of road types 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 kilometres. 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:

$$E_{hot;i,j,k} = g_{j,k,1} \, . \, b_{j,1} \, . \, e_{*,hot,year,i,j,k} \qquad (1)$$

where:

$E_{hot,i,j,k}$ = emissions of the pollutant i in [g], caused 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)	=	1-10 for the pollutants covered
j (vehicle category)	=	1-83 for the on-road categories defined in the vehicle category split (Table 1.2)
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

$$m_j = h_j \,.\, v_j \qquad (2)$$

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:

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

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:

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

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.

$$O_l = \sum_j b_{j,l} \tag{5}$$

where:

O_l	=	total annual consumption of fuel type l

As a rule, the calculated O_l 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.

[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

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 , and/or , are those to which most attention should be given.

The factor $g_{j,k}$ can be calculated as follows:

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

$$g_{j,rural} = c_{j,rural} \cdot m_{j,rural} / \sum_{k=1}^{3} c_{j,k} \cdot m_{j,k} \qquad \text{for k = rural} \qquad (6)$$

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

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:

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

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

5.1.1 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:

fuel sold in a country and therefore have to be corrected if there are clear indications for a substantial import or export of fuel.

- to select one single average speed, representative of each of the road types "urban", "rural" and "highway" (e.g. 20 km/h, 60 km/h and 100 km/h, respectively) and to apply the emission factors taken from the graphs or calculated with the help of the equations, or
- to define mean speed distribution curves $f_k(z)$ and to integrate over the emission curves, i.e.:

$$e_{hot,i,j,k,g} = \int e(z) f_k(z) \qquad (8)$$

where:

$e_{hot,i,j,k,g}$	=	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 <2.5 tonnes on road classes "rural", "urban", "highway"
$e(z)$	=	mathematical expression (e.g. "best fit") of the speed-dependency of $e_{hot,i,j,g,z}$
$f_k(z)$	=	equation (e.g. formula of "best fit" curve) of the frequency distribution of the mean speeds which corresponds to the driving patterns of gasoline vehicles <2.5 tonnes on road classes "rural", "urban" and "highway", $f_k(z)$ depends on road type k and also, possibly, on engine size.

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.

5.1.2 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:

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

with:

$$s_{j,g} = \frac{a_{i,g}}{\sum_g a_{i,g}} \qquad (10)$$

for periods of legal or of technological conformity g with:

$á_{j,g}$	=	number of vehicles of category j produced within the period of legal or technological conformity g (only passenger cars)

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. The emission factors of passenger cars and light duty vehicles have been produced during two different time periods. In the first period (1989), the emission factors of non closed loop and conventional diesel passenger cars were derived. Lately (1995 - 1998) the emission factors of all other vehicle categories were proposed. In total, about 1 500 vehicles test data were evaluated during the first period of the investigation. 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. In the second time period, some 9 000 measurements in real-world and legislated cycles were available for passenger cars and light duty vehicles. Of those, emissions in real-world representative cycles were used to produce representative emission factors.

5.2 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 kilometres driven with cold engines. These factors may vary from country to country. Different driving behaviour (varying trip lengths), as well as climate with varying time (and hence distance) required to warm up the engine and/or the catalyst affect the fraction of distance driven with cold engines. These factors can be taken into account, but again information may not be available to do this thoroughly in all countries, so that estimates have to close identified gaps.

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

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

with:

$E_{cold,i,j}$ = 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)

b_j	=	fraction of mileage driven with cold engines[1] 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.

5.3 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 only the gradient effect on the emissions of heavy duty vehicles. The method adopted is the one developed in MEET (Samaras et al. 1998), 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

(1) "cold" engines are defined as those with a water temperature below 70°C

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 5.1. Positive road gradient corresponds to uphill driving and vice versa.

Table 5.1: Road gradient classes

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

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:

$$as_{i,j,k}=A6_{i,j,k}V^6 + A5_{i,j,k}V^5 + A4_{i,j,k}V^4 + A3_{i,j,k}V^3 + A2_{i,j,k}V^2 + A1_{i,j,k}V + A0_{i,j,k} \qquad (12)$$

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:

$$ec_{hot,i,j,k} = as_{i,j,k} \cdot e_{hot,i,j,k} \qquad (13)$$

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.

5.4 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:

$$ec(l)_{i,j} = e_{i,j}\,(50\%) \times \left[1 + 2cf_i \times (lp - 50) / 100\right] \qquad (14)$$

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 totally laden one)

cf_i = load correction factor of the pollutant i.

The load correction factors cf_i for heavy duty vehicles are given in Table 5.2.

Table 5.2: Load correction factors applied to heavy duty vehicles

Pollutant	Load Factor
CO	0.21
NO_x	0.18
VOC	0.00
PM	0.08
Fuel Consumption	0.18

5.5 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, as Table 5.3 presents.

Table 5.3: Summary of Calculation Methods applied for the different Vehicle Categories and Pollutants

Method A: Hot emissions are calculated based on
the total annual kilometres driven per vehicle;
the share of kilometres 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.

Method B: The total annual emissions per vehicle are calculated based on
the total annual kilometres driven per vehicle;
the share of kilometres 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.

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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 kilometres driven per vehicles; the share of kilometres driven under the driving modes 'urban', 'rural', 'highway'; driving mode dependent emissions factors. ________________________ **remark**: For gasoline and diesel light duty vehicle cold start extra emissions for CO, NOx and NMVOC as well as fuel consumption are added using the method described under A.
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 kilometres driven by the vehicle category; fuel consumption and/or kilometre related emission factors.

These methods are applied to the different vehicle categories and the different pollutants as shown in Table 5.4.

Table 5.4: Summary of calculation methods applied for the different vehicle categories and pollutants

Vehicle Category	NOx	CO	NMVOC	CH_4	PM	N_2O	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 <50cm³	C	C	C	D	-	-	-	D	D	D	D	C
Motorcycles 2-st >50cm³	B	B	B	D	-	-	-	D	D	D	D	B
Motorcycles 4-st 50-250 cm³	B	B	B	D	-	-	-	D	D	D	D	B
Motorcycles 4-st 250-750cm³	B	B	B	D	-	-	-	D	D	D	D	B
Motorcycles 4-st >750cm³	B	B	B	D	-	-	-	D	D	D	D	B

6 RELEVANT ACTIVITY STATISTICS

In principle, vehicle statistics are readily available in the national statistical offices of all countries and in international statistical organisations and institutes (e.g. EUROSTAT, International Road Federation - IRF). However, it must be stressed that these statistics are almost exclusively vehicle oriented (i.e. comprising fleet data), with information about general aggregate categories only (e.g. passenger cars, trucks, buses, motorcycles). In addition, only little information referring to age and technology distribution can be found in a consistent form, while very little information is available (and only for some countries, e.g. Kraftfahrtbundesamt 1993) as regards activity data (with the exception of fuel statistics). In addition more detailed traffic data required for the calculations (such as average trip length for cold start emissions and evaporative losses) are available only in a few countries. As an example for the EC member states, Tables 6.1 to 6.3 give relevant statistics as submitted by the national experts to the CORINAIR 1985 exercise. For a more detailed analysis of the availability of relevant statistical data in the EC member states see Eggleston et al. 1989.

Table 6.1: 1985 Vehicle fleet in the EC

Country	GAS PC	DSL PC	LPG PC	LDV	HDV	TW
B	2670945	590960	81072	189000	122620	492264
DK	1414392	63656	22903	219000	55402	185995
D	23503765	2341000	-	635000	1305000	2881000
F	19628999	1464800	5000	-	496700	4031000
GR	1727408	15000	4058	505000	113700	347882
IRL	644450	66280	4590	-	28180	26025
I	19306126	2303110	885394	1862000	445972	5342353
L	135432	14214	1402	20000	8137	4585
NL	3881600	347000	543000	283000	131400	637000
P	1313589	388861	-	563000	105632	750000
E	8454371	719110	100000	1434000	269140	2236230
UK	15973197	1764446	-	1470000	663243	1128000
EC 12	98654274	10078437	1647419	7180000	3745126	18062334

Despite the lack of direct data in the national and international statistics as regards transport activity, and age and technology distribution of the vehicles, such data can be produced in an indirect way. The following hints may be helpful:

- *Age and technology distribution*: The (generally available) time series on fleet evolution and annual new registrations can be used in order to come up with estimates of appropriate scrappage rates. By combining the above with implementation dates of certain technologies, a relatively good picture of the fleet composition at specific years can be reached.
- *Mileage driven and mileage split*: Calculated fuel consumption on the basis of appropriate assumptions for annual mileage of the different vehicle categories can be balanced with available fuel statistics, following the methodology presented in chapter 5.1, using

representative fuel consumption factors. By applying a trial-and-error approach, it is possible to reach acceptable estimates of mileage activity data.

Table 6.2: 1990 total vehicle-kilometres (in 10^6) in the EC as reported to CORINAIR90

Country	GAS PC	DSL PC	LPG PC	LDV	HDV	TW
B	37687.4	22339.1	980.4	6881.6	7848.7	413.9
DK	26300.9	3104.5	170.1	4205.5	3244.6	691.5
D	380340.0	83243.0	-	16984.0	31427.0	9186.0
F	212157.0	80628.3	-	83117.4	30497.3	16468.0
GR	22125.8	2853.7	500.0	7972.7	6649.8	4412.6
IRL	13761.0	2271.4	84.9	3241.7	1286.0	341.2
I	163783.6	52101.0	22718.1	31672.2	40766.1	35861.7
L	2268.8	504.9	7.8	493.3	231.0	41.6
NL	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
P	17378.1	1929.5	-	1520.9	8304.2	958.6
E	111488.6	28158.4	892.5	32370.6	22357.3	10278.4
UK	318220.0	12510.0	-	36030.0	33320.0	6400.0
EC 12	1305511.3	289643.7	25353.8	224489.8	185932.0	85053.4

n.a.: not available

Table 6.3: Examples of Values for Average Estimated Trip Length l_{trip} as taken by EC Member States in COPERT 85

COUNTRY	TRIP LENGTH [km]
B	12
DK	9
D	14
F	12
GR	12
IRL	14
I	12
L	15
NL	13.1
P	12
E	6.31
UK	10

7 POINT SOURCE CRITERIA

There are no relevant point sources, which fall under the source activities dealt within this chapter.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

Emission factors corresponding to non-catalyst gasoline passenger cars were jointly worked out by the members of the CORINAIR Working Group (Eggleston et al. 1993), taking into account the results of comprehensive studies carried out in France, F.R.Germany, Greece, Italy, the Netherlands and the United Kingdom. In addition, some data measured in Austria, Sweden and Switzerland were incorporated. For catalyst equipped and improved diesel passenger cars (91/441/EEC and on), light duty vehicles, diesel heavy duty vehicles and 2 wheelers, the emission factors incorporated are the outcome of the MEET project. Emission and consumption factors for passenger cars and light duty vehicles originate from a large number of measurements conducted in several European countries (Samaras et al., 1998). For diesel heavy duty vehicles and two-wheelers the emission factors proposed in a joint German - Swiss research project (Keller et al., 1995) were adopted.

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

- 10 pollutants (CO, NO_x, N_2O, SO_2, VOC, CH_4, CO_2, NH_3, diesel particulates and lead
- 6 vehicle categories
- 3 road types

In practice, the picture looks somewhat different because:

- for some pollutants (e.g. CO_2, SO_2, lead, NH_3, 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 smaller than theoretically necessary.

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 NO_x together with fuel consumption factors fall under the first category, while SO_2, NH_3, Pb, CO_2, N_2O and partly CH_4 fall under the second one. Therefore this chapter is organised as follows:

- First the exhaust emission factors of CO, VOC and NO_x as well as fuel consumption factors of the individual SNAP activities are presented and discussed.
- Secondly the "bulk" emission factors for SO_2, NH_3, Pb, CO_2, N_2O and CH_4 follow.

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.

8.1 SNAP codes 070101 and 070102: Gasoline Passenger Cars

8.1.1 Hot Start Emission Factors

Gasoline passenger cars <2.5 tonnes certainly contribute to the largest part of emissions of road traffic. 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 8.1 - 8.4. They may be used, if necessary, for extrapolation purposes. 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 and below 5 (for catalyst cars) or 10 km/h (for non-catalyst passenger cars). 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 where 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 l/>2 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 six periods of legal conformity, that means: pre-ECE state and periods of application of ECE 15-00/01, 15-02, 15-03, 15-04 and three post 15-04 technologies: improved conventional, open loop (for vehicles with less than 2.0 l engine capacity) and closed loop.

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[1].

() 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.

Table 8.1: Speed Dependency of CO Emission Factors for Gasoline Passenger Cars

Vehicle Class	**Engine Capacity**	**Speed Range (km/h)**	**CO Emission Factor (g/km)**	**R^2**
PRE ECE	All capacities	10-100	$281V^{-0.630}$	0.924
	All capacities	100-130	$0.112V + 4.32$	-
ECE 15-00/01	All capacities	10-50	$313V^{-0.760}$	0.898
	All capacities	50-130	$27.22 - 0.406V + 0.0032V^2$	0.158
ECE 15-02	All capacities	10-60	$300V^{-0.797}$	0.747
	All capacities	60-130	$26.260 - 0.440V + 0.0026V^2$	0.102
ECE 15-03	All capacities	10-20	$161.36 - 45.62\ln(V)$	0.790
	All capacities	20-130	$37.92 - 0.680V + 0.00377V^2$	0.247
ECE 15-04	All capacities	10-60	$260.788 \cdot V^{-0.910}$	0.825
	All capacities	60-130	$14.653 - 0.220V + 0.001163V^2$	0.613
Improved	CC < 1.4 l	10-130	$14.577 - 0.294V + 0.002478V^2$	0.781
Conventional	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 8.2: Speed Dependency of VOC Emission Factors for Gasoline Passenger Cars

Vehicle Class	Engine Capacity	Speed Range (km/h)	VOC Emission Factor (g/km)	R^2
PRE ECE	All capacities	10-100	$30.34V^{-0.693}$	0.980
	All capacities	100-130	1.247	-
ECE 15-00/01	All capacities	10-50	$24.99V^{-0.704}$	0.901
	All capacities	50-130	$4.85V^{-0.318}$	0.095
ECE 15-02/03	All capacities	10-60	$25.75V^{-0.714}$	0.895
	All capacities	60-130	$1.95 - 0.019V + 0.00009V^2$	0.198
ECE 15-04	All capacities	10-60	$19.079V^{-0.693}$	0.838
	All capacities	60-130	$2.608 - 0.037V + 0.000179V^2$	0.341
Improved	CC < 1.4 l	10-130	$2.189 - 0.034V + 0.000201V^2$	0.766
Conventional	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 8.3: Speed Dependency of NO_x Emission Factors for Gasoline Passenger Cars

Vehicle Class	**Engine Capacity**	**Speed Range (km/h)**	**NO_x Emission Factor (g/km)**	**R^2**
PRE ECE	CC < 1.4 l	10-130	$1.173 + 0.0225V - 0.00014V^2$	0.916
ECE 15-00/01	1.4 l < CC < 2.0 l	10-130	$1.360 + 0.0217V - 0.00004V^2$	0.960
	CC > 2.0 l	10-130	$1.5 + 0.03V + 0.0001V^2$	0.972
ECE 15-02	CC < 1.4 l	10-130	$1.479 - 0.0037V + 0.00018V^2$	0.711
	1.4 l < CC < 2.0 l	10-130	$1.663 - 0.0038V + 0.00020V^2$	0.839
	CC > 2.0 l	10-130	$1.87 - 0.0039V + 0.00022V^2$	-
ECE 15-03	CC < 1.4 l	10-130	$1.616 - 0.0084V + 0.00025V^2$	0.844
	1.4 l < CC < 2.0 l	10-130	$1.29e^{0.0099V}$	0.798
	CC > 2.0 l	10-130	$2.784 - 0.0112V + 0.000294V^2$	0.577
ECE 15-04	CC < 1.4 l	10-130	$1.432 + 0.003V + 0.000097V^2$	0.669
	1.4 l < CC < 2.0 l	10-130	$1.484+0.013 \cdot V+0.000074V^2$	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 8.4: Speed Dependency of Fuel Consumption Factors for Gasoline Passenger Cars

Vehicle Class	**Cylinder Capacity**	**Speed Range (km/h)**	**Fuel Consumption Factor (g/km)**	**R^2**
PRE ECE	CC < 1.4 l	10-60	$521V^{-0.554}$	0.941
		60-80	55	-
		80-130	$0.386V + 24.143$	-
	1.4 l < CC < 2.0 l	10-60	$681V^{-0.583}$	0.936
		60-80	67	-
		80-130	$0.471V + 29.286$	-
	CC > 2.0 l	10-60	$979V^{-0.628}$	0.918
		60-80	80	-
		80-130	$0.414V + 46.867$	-
ECE 15-00/01	CC < 1.4 l	10-60	$595V^{-0.63}$	0.951
		60-130	$95 - 1.324V + 0.0086V^2$	0.289
	1.4 l < CC < 2.0 l	10-60	$864V^{-0.69}$	0.974
		60-130	$59 - 0.407V + 0.0042V^2$	0.647
	CC > 2.0 l	10-60	$1236V^{-0.764}$	0.976
		60-130	$65 - 0.407V + 0.0042V^2$	-
ECE 15-02/03	CC < 1.4 l	10-50	$544V^{-0.63}$	0.929
		50-130	$85 - 1.108V + 0.0077V^2$	0.641
	1.4 l < CC < 2.0 l	10-50	$879V^{-0.72}$	0.950
		50-130	$71 - 0.7032V + 0.0059V^2$	0.830
	CC > 2.0 l	10-50	$1224V^{-0.756}$	0.961
		50-130	$111 - 1.333V + 0.0093V^2$	0.847
ECE 15-04	CC < 1.4 l	10-25	$296.7 - 80.21\ln(V)$	0.518
		25-130	$81.1 - 1.014V + 0.0068V^2$	0.760
	1.4 l < CC < 2.0 l	10-60	$606.1V^{-0.667}$	0.907
		60-130	$102.5 - 1.364V + 0.0086V^2$	0.927
	CC > 2.0 l	10-60	$819.9V^{-0.663}$	0.966
		60-130	$41.7 + 0.122V + 0.0016V^2$	0.650
Improved Conventional	CC < 1.4 l	10-130	$80.52 - 1.41V + 0.013V^2$	0.954
	1.4 l < CC < 2.0 l	10-130	$111.0 - 2.031V + 0.017V^2$	0.994
Open Loop	CC < 1.4 l	10-130	$85.55 - 1.383V + 0.0117V^2$	0.997
	1.4 l < CC < 2.0 l	10-130	$109.6 - 1.98V + 0.0168V^2$	0.997
91/441/EEC	CC < 1.4 l	10-130	$93.672 - 1.5100V + 0.01090V^2$	0.558
	1.4 l < CC < 2.0 l	10-130	$135.42 - 2.4558V + 0.01740V^2$	0.552
	CC > 2.0 l	10-130	$156.77 - 2.6974V + 0.01870V^2$	0.466

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

The reduction rates for improved and future technologies of passenger cars are given in Table 8.5.

Table 8.5: Emission reduction percentage for improved and future gasoline 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

8.1.2 Emission Factors for Cold Starts

Since cold start emissions are quite sensitive to ambient temperatures, the estimates are made on a monthly basis (Joumard 1991).

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 8.6 provides estimates for β. It should be mentioned that this table applies to all vehicle categories considered. Table 8.7 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, Joumard et al. 1990, Rijkeboer et al. 1989). For application of Table 8.6, a value for the average trip length has to be determined (compare Table 6.3 showing values taken by EC Member States in the 1985 project).

Table 8.6: 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}	$0.698 - 0.051 \cdot l_{trip} - (0.01051 - 0.000770 \cdot l_{trip}) \cdot t_a$

Table 8.7: Relative Emission Factors e^{cold} / e^{hot} (Only Valid for Conventional Gasoline Powered Engines and temperature range of -10 ^oC to 30 ^oC)

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	$1.47 - 0.009 \cdot t_a$

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, Laurriko et al. 1987). The methodology as such, however, does not require modifications (at least as long as no further measurements are available). Table 8.8 provides an overview of the cold start emission factors.

Table 8.8: Relative Emission Factors e^{cold} / e^{hot} (Only valid for Closed Loop Gasoline Powered Engines and temperature range of -10^oC to 30^oC)

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	$1.47 - 0.009 \cdot t_a$

8.2 SNAP code 070103: Diesel Passenger Cars

8.2.1 Hot Emission Factors

Based on a relatively large number of measured data on emissions of conventional (before 91/441/EEC) diesel passenger cars <2.5 tonnes (CCMC 1989, Joumard 1990, Gorißen 1990, 1991, 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 (see Table 8.9). It should be mentioned that apart from other parameters, the emission factors, in particular those for VOC and particulates can vary substantially, depending on fuel quality and state of maintenance. Emission factors for recent passenger cars (91/441/EEC and on) are also given in Table 8.9 by the results of the MEET project (Samaras et al., 1997).

Table 8.9: Speed Dependency of Emission Factors for Diesel Vehicles <2.5 t

Pollutant	Vehicle Specifications	Speed Range (km/h)	Emission Factor (g/km)	R^2
CO	Conventional	10-130	$5.413V^{-0.574}$	0.745
	91/441/EEC	10-130	$0.9337 - 0.0170V + 0.0000961V^2$	0.674
NOx	Conventional CC < 2.0l	10-130	$0.918 - 0.014V + 0.000101V^2$	0.949
	Conventional CC > 2.0l	10-130	$1.331 - 0.018V + 0.000133V^2$	0.927
	All categories	10-130	$0.9037 - 0.01674V + 0.000127V^2$	0.424
VOC	Conventional	10-130	$4.61V^{-0.937}$	0.794
	All categories	10-130	$0.1354 - 0.0022V + 0.0000113V^2$	0.618
PM	Conventional	10-130	$0.45 - 0.0086V + 0.000058V^2$	0.439
	All categories	10-130	$0.1208- 0.00277V + 0.0000226V^2$	0.590
FC	Conventional	10-130	$118.489 - 2.084V + 0.014V^2$	0.583
	All categories	10-130	$83.660 - 1.3123V + 0.00790V^2$	0.610

Table 8.10: 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

8.2.2 Cold Start Emission Factors

The relative extra emissions of diesel passenger cars are shown in Table 8.11 (Joumard 1990, Gorißen 1990).

Table 8.11: Relative Emission Factors e^{cold} / e^{hot} (Only Valid for Diesel Passenger Cars and temperature range of -10 °C to 30 °C)

Diesel Passenger Cars	e^{cold}/e^{hot}
CO	$1.9 - 0.03 \cdot t_a$
NO_x	$1.3 - 0.013 \cdot t_a$
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 $e^{cold} / e^{hot} > 0.5$

8.3 SNAP code 070104: LPG Passenger Cars

8.3.1 Hot Emission Factors

As in the case of gasoline and diesel passenger cars <2.5 tonnes, emission factors are provided for LPG fuelled cars (Joumard 1990, TNO 1980), see Table 8.12. 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.

Table 8.12: Speed Dependency of Emission Factors for LPG Vehicles <2.5 t

Pollutant	Engine Capacity	Speed Range	Emission Factor [g/km]	R^2
CO	All categories	10-130	$12.523-0.418 \cdot V+0.0039 \cdot V^2$	0.893
NOx	All categories	10-130	$0.77 \cdot V^{0.285}$	0.598
VOC	All categories	10-130	$26.3 \cdot V^{-0.865}$	0.967
Fuel Consumption	All categories	Urban Rural Highway	59 45 54	- - -

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

Table 8.13: Emission reduction percentage for improved and future 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

8.3.2 Cold Start Emission Factors

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 8.14).

Table 8.14: Relative Emission Factors e^{cold} / e^{hot} (Only Valid for LPG Passenger Cars and temperature range of -10 °C to 30 °C)

LPG Passenger Cars	e^{cold} / e^{hot}
CO	$3.66 - 0.09 \cdot t_a$
NO_x	$0.98 - 0.006 \cdot t_a$
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

8.4 SNAP code 070105: Two Stroke Gasoline 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 8.15. They are relevant mainly for some Eastern European countries (and to some extent for the F.R. 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.

Table 8.15: Emission Factors for Gasoline Two-Stroke Vehicles <2.5 t

	CO [g/km]	NO_x [g/km]	VOC [g/km]	Fuel Consumption [g/km]
Urban	20.7	0.30	15.4	111.5
Rural	7.50	1.0	7.20	66.0
Highway	8.70	0.75	5.90	56.9

8.5 SNAP code 070200: Light Duty Vehicles

8.5.1 Hot Emission Factors

Gasoline Powered Light Duty Vehicles

The emission factors for gasoline light duty vehicles are given in Table 8.16. They are based on the results of the MEET project (Samaras et al., 1997).

Table 8.16: Emission Factors for Gasoline Light Duty Vehicles <3.5

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
NO_x	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	Conventional	10-130	$0.01870V^2 - 2.6974V + 156.77$	0.466
Consumption	93/59/EEC	10-130	$0.01870V^2 - 2.6974V + 156.77$	0.466

Table 8.17: 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

Diesel Powered Light Duty Vehicles

The emission factors for gasoline light duty vehicles are given in Table 8.18. They are also based on the results of the MEET project (Samaras et al., 1997).

Table 8.18: Emission 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

Table 8.19: 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

8.5.2 Cold Start Emission Factors

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.

8.6 SNAP code 070300: Heavy Duty Vehicles

8.6.1 Gasoline Powered 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 8.20.

Table 8.20: Emission Factors for Heavy Duty Gasoline Vehicles >3.5 t

	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

8.6.2 Diesel Powered Heavy Duty Vehicles

The data on emissions from heavy duty vehicles have been made available by a joint Swiss-German research project (Keller et al., 1995). Those results have also fully incorporated in the MEET project.

Table 8.21: Speed dependency of emission and consumption factors for conventional diesel heavy duty vehicles >3.5 t

Pollutant	Weight Class	Speed Range	Emission Factor [g/km]	R^2
CO	All Weight Categories	5-100	$37.280V^{-0.6945}$	0.880
NOx	Weight<7.5t	5 - 50	$50.305V^{-0.7708}$	0.902
		50 - 100	$0.0014V^2 - 0.1737V + 7.5506$	0.260
	7.5<Weight<16t	5 - 60	$92.584V^{-0.7393}$	0.940
		60 - 100	$0.0006V^2 - 0.0941V + 7.7785$	0.440
	16<Weight<32t	5 - 100	$108.36V^{-0.6061}$	0.650
	Weight>32t	5 - 100	$132.88V^{-0.5581}$	0.894
VOC	All Weight Categories	5-100	$40.120V^{-0.8774}$	0.976
PM	Weight<7.5t	5 - 100	$4.5563V^{-0.7070}$	0.944
	7.5<Weight<16t	5 - 100	$9.6037V^{-0.7259}$	0.974
	16<Weight<32t	5 - 100	$10.890V^{-0.7105}$	0.946
	Weight>32t	5 - 100	$11.028V^{-0.6960}$	0.961
Fuel Consumption	Weight<7.5t	5 - 60	$1425.2V^{-0.7593}$	0.990
		60 - 100	$0.0082V^2 - 0.0430V + 60.12$	0.798
	7.5<Weight<16t	5 - 60	$1068.4V^{-0.4905}$	0.628
		60 - 100	$0.0126V^2 - 0.6589V + 141.2$	0.037
	16<Weight<32t	5 - 60	$1595.1V^{-0.4744}$	0.628
		60 - 100	$0.0382V^2 - 5.1630V + 399.3$	0.037
	Weight>32t	5 - 60	$1855.7V^{-0.4367}$	0.914
		60 - 100	$0.0765V^2 - 11.414V + 720.9$	0.187

Table 8.22: 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 Stage I	Weight<7.5t	URBAN	50	30	25	35
		RURAL	40	30	25	35
		HIGHWAY	45	10	25	35
	7.5<Weight<16t	URBAN	50	30	25	35
		RURAL	40	30	25	35
		HIGHWAY	45	10	25	35
	16<Weight<32t	URBAN	45	45	50	35
		RURAL	40	40	35	35
		HIGHWAY	35	45	25	35
	Weight>32t	URBAN	45	45	50	35
		RURAL	40	40	35	35
		HIGHWAY	35	45	25	35
91/542/EEC Stage II	Weight<7.5t	URBAN	60	50	30	60
		RURAL	45	45	30	60
		HIGHWAY	50	35	30	60
	7.5<Weight<16t	URBAN	60	50	30	60
		RURAL	45	45	30	60
		HIGHWAY	50	35	30	60
	16<Weight<32t	URBAN	55	60	55	75
		RURAL	50	55	40	75
		HIGHWAY	35	55	35	75
	Weight>32t	URBAN	55	60	55	75
		RURAL	50	55	40	75
		HIGHWAY	35	55	35	75

The tables following present the coefficients of equation (12), used to correct the emission and consumption of heavy duty vehicles due to gradient effects. The correction factors depend on the gross weight class of the vehicle, the pollutant under consideration and the slope of the road. The columns v_{min} and v_{max} give respectively the minimum and maximum vehicle speeds for which the equations are applicable. Use of the equation outside that speed region might lead to significant overestimation of the slope effect and therefore should be avoided. The slope column consists of values as given in Table 5.1.

Table 8.23: Gradient factor functions for heavy duty vehicles <7.5 t

A6	A5	A4	A3	A2	A1	A0	case	slope *[%]*	v_{min} *[km/h]*	v_{max} *[km/h]*
0.00E+00	-4.33E-09	1.40E-06	-1.53E-04	6.22E-03	-1.01E-01	1.63E+00	VOC	4… 6	13.0	39.3
0.00E+00	-5.14E-08	9.90E-06	-7.17E-04	2.39E-02	-3.57E-01	2.95E+00	VOC	-6… -4	13.5	49.9
0.00E+00	-2.05E-08	4.25E-06	-3.30E-04	1.18E-02	-1.92E-01	2.16E+00	VOC	0… 4	15.1	69.9
0.00E+00	4.02E-09	-9.36E-07	8.39E-05	-3.66E-03	7.99E-02	3.98E-01	VOC	-4… 0	15.1	86.2
0.00E+00	1.51E-07	-1.93E-05	9.26E-04	-2.11E-02	2.57E-01	6.58E-02	CO	4… 6	13.0	39.3
0.00E+00	-7.00E-08	1.25E-05	-8.51E-04	2.71E-02	-3.96E-01	2.86E+00	CO	-6… -4	13.5	49.9
0.00E+00	-1.18E-08	2.49E-06	-1.95E-04	6.78E-03	-9.28E-02	1.52E+00	CO	0… 4	15.1	69.9
0.00E+00	-5.54E-10	1.80E-07	-1.82E-05	6.42E-04	-5.54E-03	8.14E-01	CO	-4… 0	15.1	86.2
0.00E+00	1.82E-08	-1.85E-06	3.32E-05	1.28E-03	-4.14E-03	1.43E+00	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 8.24: Gradient factor functions for heavy duty vehicles 7.5 - 16 t

A6	A5	A4	A3	A2	A1	A0	case	slope *[%]*	v_{min} *[km/h]*	v_{max} *[km/h]*
0.00E+00	1.28E-07	-1.65E-05	7.96E-04	-1.82E-02	2.04E-01	3.24E-01	VOC	4… 6	13.1	39.5
0.00E+00	-4.01E-08	8.12E-06	-6.01E-04	2.01E-02	-3.01E-01	2.76E+00	VOC	-6… -4	13.5	49.9
0.00E+00	-1.82E-08	3.70E-06	-2.78E-04	9.60E-03	-1.51E-01	1.94E+00	VOC	0… 4	15.1	70.3
0.00E+00	1.10E-09	-3.38E-07	3.94E-05	-2.13E-03	5.25E-02	6.52E-01	VOC	-4… 0	15.1	86.4
0.00E+00	3.28E-07	-4.35E-05	2.21E-03	-5.46E-02	6.73E-01	-1.88E+00	CO	4… 6	13.1	39.5
0.00E+00	-6.79E-08	1.21E-05	-8.24E-04	2.58E-02	-3.67E-01	2.89E+00	CO	-6… -4	13.5	49.9
0.00E+00	-1.09E-08	2.16E-06	-1.56E-04	4.85E-03	-5.79E-02	1.34E+00	CO	0… 4	15.1	70.3
0.00E+00	-1.11E-10	-3.21E-08	1.19E-05	-1.09E-03	3.34E-02	6.97E-01	CO	-4… 0	15.1	86.4
0.00E+00	-2.42E-07	3.49E-05	-1.96E-03	5.28E-02	-6.52E-01	4.60E+00	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

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

Table 8.25: Gradient factor functions for heavy duty vehicles 16 - 32 t

A6	A5	A4	A3	A2	A1	A0	case	slope *[%]*	v_{min} *[km/h]*	v_{max} *[km/h]*
0.00E+00	0.00E+00	6.18E-06	-6.51E-04	2.39E-02	-3.66E-01	3.24E+00	VOC	4… 6	12.5	36.5
0.00E+00	-4.96E-08	9.03E-06	-6.37E-04	2.11E-02	-3.22E-01	3.08E+00	VOC	-6… -4	13.5	49.9
0.00E+00	-2.11E-08	4.32E-06	-3.30E-04	1.17E-02	-1.91E-01	2.25E+00	VOC	0… 4	14.9	64.7
0.00E+00	3.21E-09	-7.41E-07	6.58E-05	-2.82E-03	5.69E-02	7.55E-01	VOC	-4… 0	15.1	86.1
0.00E+00	0.00E+00	-1.50E-05	1.43E-03	-4.92E-02	7.32E-01	-2.31E+00	CO	4… 6	12.5	36.5
0.00E+00	-7.70E-08	1.30E-05	-8.51E-04	2.62E-02	-3.80E-01	3.15E+00	CO	-6… -4	13.5	49.9
0.00E+00	-2.46E-08	4.79E-06	-3.44E-04	1.13E-02	-1.66E-01	2.12E+00	CO	0… 4	14.9	64.7
0.00E+00	1.44E-09	-3.32E-07	3.06E-05	-1.45E-03	2.91E-02	8.76E-01	CO	-4… 0	15.1	86.1
0.00E+00	0.00E+00	2.30E-06	-2.49E-04	9.39E-03	-1.26E-01	2.51E+00	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

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

Table 8.26: Gradient factor functions for heavy duty vehicles >32 t

A6	A5	A4	A3	A2	A1	A0	case	slope *[%]*	v_{min} *[km/h]*	v_{max} *[km/h]*
0.00E+00	5.68E-08	-5.40E-06	1.24E-04	1.11E-03	-6.09E-02	1.80E+00	VOC	4… 6	12.4	35.0
0.00E+00	-2.50E-08	5.91E-06	-4.88E-04	1.79E-02	-2.98E-01	3.08E+00	VOC	-6… -4	13.5	49.9
0.00E+00	-2.02E-08	4.10E-06	-3.11E-04	1.09E-02	-1.76E-01	2.18E+00	VOC	0… 4	14.8	66.3
0.00E+00	1.95E-09	-4.68E-07	4.26E-05	-1.84E-03	3.52E-02	9.32E-01	VOC	-4… 0	15.1	86.3
0.00E+00	1.43E-06	-1.75E-04	8.27E-03	-1.89E-01	2.09E+00	-7.12E+00	CO	4… 6	12.4	35.0
0.00E+00	-6.48E-08	1.17E-05	-7.95E-04	2.51E-02	-3.71E-01	3.10E+00	CO	-6… -4	13.5	49.9
0.00E+00	-8.63E-09	1.50E-06	-9.50E-05	2.65E-03	-2.44E-02	1.35E+00	CO	0… 4	14.8	66.3
0.00E+00	1.28E-09	-3.07E-07	2.99E-05	-1.48E-03	3.00E-02	8.54E-01	CO	-4… 0	15.1	86.3
0.00E+00	2.42E-08	3.11E-06	-4.50E-04	1.79E-02	-2.70E-01	3.56E+00	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

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

8.7 SNAP code 070300: Urban Buses and Coaches

Table 8.27 gives the emission factor equations for urban buses and coaches. One has to be aware of the fact that the equation for urban buses in only applicable in the range of 5 to 50 km/h since those vehicle only seldom exceed this speed.

Table 8.27: 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	5 - 50	$59.003V^{-0.7447}$	0.895
	Coaches	5 - 120	$63.791V^{-0.8393}$	0.978
NOx	Urban Buses	5 - 50	$89.174V^{-0.5185}$	0.534
	Coaches	5 - 60	$125.87V^{-0.6562}$	0.848
		60 - 120	$0.0010V^2 - 0.1608V + 14.308$	0.073
VOC	Urban Buses	5 - 50	$43.647V^{-1.0301}$	0.992
	Coaches	5 - 120	$44.217V^{-0.8870}$	0.993
PM	Urban Buses	5 - 50	$7.8609V^{-0.7360}$	0.920
	Coaches	5 - 120	$9.2934V^{-0.7373}$	0.975
Fuel Consumption	Urban Buses	5 - 50	$1371.6V^{-0.4318}$	0.502
	Coaches	5 -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 8.28: Emission reduction percentage for improved diesel urban buses and coaches applied to conventional vehicles

Diesel Heavy Duty Trucks > 3,5 t	**Weight Class**	**Road Classes**	**CO [%]**	**NOx [%]**	**VOC [%]**	**PM [%]**
91/542/EEC Stage I	URBAN BUSES	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 Stage II	URBAN BUSES	URBAN	60	50	30	60
		RURAL	-	-	-	-
		HIGHWAY	• -	-	-	-
	COACHES	URBAN	55	60	55	75
		RURAL	50	55	44	75
		HIGHWAY	35	55	35	75

Table 8.29: Gradient factor functions for urban buses

A6	A5	A4	A3	A2	A1	A0	case	slope [%]	v_{min} [km/h]	v_{max} [km/h]
0.00E+00	-2.12E-06	2.15E-04	-8.50E-03	1.62E-01	-1.49E+00	6.19E+00	VOC	4… 6	11.4	31.2
0.00E+00	-3.13E-07	3.32E-05	-1.37E-03	2.70E-02	-2.45E-01	1.72E+00	VOC	-6… -4	11.7	35.3
0.00E+00	1.75E-08	-4.51E-06	3.08E-04	-8.79E-03	1.11E-01	5.33E-01	VOC	0… 4	13.1	37.5
0.00E+00	4.15E-07	-5.26E-05	2.59E-03	-6.16E-02	7.06E-01	-2.13E+00	VOC	-4… 0	13.2	39.5
0.00E+00	-1.59E-06	1.57E-04	-6.04E-03	1.14E-01	-1.03E+00	4.91E+00	CO	4… 6	11.4	31.2
0.00E+00	-3.26E-07	3.80E-05	-1.71E-03	3.64E-02	-3.61E-01	2.05E+00	CO	-6… -4	11.7	35.3
0.00E+00	-3.21E-07	3.94E-05	-1.92E-03	4.65E-02	-5.57E-01	3.78E+00	CO	0… 4	13.1	37.5
0.00E+00	2.75E-07	-3.56E-05	1.79E-03	-4.36E-02	5.09E-01	-1.46E+00	CO	-4… 0	13.2	39.5
0.00E+00	7.96E-07	-9.09E-05	3.83E-03	-7.42E-02	6.63E-01	-2.96E-01	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

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

Table 8.30: Gradient factor functions for coaches

A6	A5	A4	A3	A2	A1	A0	case	slope [%]	v_{min} [km/h]	v_{max} [km/h]
0.00E+00	0.00E+00	4.15E-06	-5.14E-04	2.17E-02	-3.76E-01	3.43E+00	VOC	4… 6	9.7	34.8
0.00E+00	0.00E+00	3.03E-06	-4.09E-04	1.94E-02	-3.75E-01	3.98E+00	VOC	-6… -4	11.7	49.9
2.49E-10	-8.50E-08	1.14E-05	-7.66E-04	2.65E-02	-4.41E-01	3.80E+00	VOC	0… 4	13.1	95.3
1.42E-10	-5.47E-08	8.20E-06	-6.05E-04	2.27E-02	-4.01E-01	3.89E+00	VOC	-4… 0	13.1	102.9
0.00E+00	0.00E+00	5.20E-06	-6.07E-04	2.51E-02	-4.28E-01	3.56E+00	CO	4… 6	9.7	34.8
0.00E+00	0.00E+00	2.24E-06	-3.21E-04	1.61E-02	-3.30E-01	3.25E+00	CO	-6… -4	11.7	49.9
2.22E-10	-7.88E-08	1.10E-05	-7.63E-04	2.73E-02	-4.69E-01	3.99E+00	CO	0… 4	13.1	95.3
1.09E-10	-4.42E-08	6.93E-06	-5.33E-04	2.09E-02	-3.87E-01	3.60E+00	CO	-4… 0	13.1	102.9
0.00E+00	0.00E+00	-1.15E-05	9.84E-04	-3.02E-02	3.89E-01	7.29E-01	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

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

8.8 SNAP codes 070400: Mopeds & Motorcycles < 50cm³ and 070500 Motorcycles > 50cm³

Emissions of two-wheelers have had little attention in the past, certainly less than the emissions from passenger cars and trucks. Yet it was demonstrated already in the seventies that in countries with a large two-wheeler population the aggregated contribution can be rather significant. This is all the more true since the emissions of cars and trucks has been, or is going to be, severely restricted. Especially two-stroke engines can emit significant quantities of unburned hydrocarbons, but what measurement data there is, shows that four-stroke engines are not up to the same standards as e.g. passenger cars either. In the total national emission inventory two-wheelers may contribute a significant part. The emission factors according to the classification presented in Table 1.2 are given in Table 8.31 to 8.34.

Table 8.31: Emission and consumption factors for conventional mopeds

Conventional 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 8.32: Emission and consumption reduction percentage for improved mopeds applied to conventional ones

Mopeds <50cm³	Road Classes	CO [%]	NOx [%]	VOC [%]	FC [%]
EC Proposal III 97/24/EC Stage I	All Categories	50	0	55	40
EC Proposal IV 97/24/EC Stage II	All Categories	90	67	78	56

Table 8.33: Emission Factors for 2 stroke motorcycles >50 cm³

Pollutant	Vehicle Class	Speed Range	Emission Factor [g/km]
CO	Conventional	10 - 60	-0.00100V² + 0.1720V + 18.10
		60 - 110	0.00010V² + 0.0500V + 21.50
	EC proposal 97/24/EC	10 - 60	-0.00630V² + 0.7150V - 6.900
		60 - 110	0.00070V² + 0.1570V + 6.000
NOx	Conventional	10 - 60	0.00003V² - 0.0020V + 0.064
		60 - 110	-0.00002V² + 0.0049V - 0.157
	EC proposal 97/24/EC	10 - 60	0.00002V² - 0.0010V + 0.032-
		60 - 110	0.00002V² + 0.0041V - 0.152
VOC	Conventional	10 - 60	0.00350V² - 0.4090V + 20.10
		60 - 110	0.00030V² - 0.0524V + 10.60
	EC proposal 97/24/EC	10 - 60	-0.00100V² + 0.0970V + 3.900
		60 - 110	-0.00030V² + 0.0325V + 5.200
Fuel Consumption	Conventional	10 - 60	0.006300V² - 0.6028V + 44.40
		60 - 110	-0.00050V² + 0.2375V + 18.20
	EC proposal 97/24/EC	10 - 60	-0.00110V² + 0.2008V + 17.80
		60 - 110	-0.00100V² + 0.2425V + 14.60

Table 8.34: Emission Factors for 4 stroke motorcycles >50 cm³

Pollutant	Engine Capacity	Speed	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 - All Capacities	10 - 60	$0.00760V^2 - 0.7300V + 23.50$
		60 - 110	$0.00100V^2 + 0.0510V + 0.800$
NO_x	Conventional <250cm³	10 - 60	$0.00005V^2 - 0.0010V + 0.090$
		60 - 110	$0.00002V^2 + 0.0006V + 0.102$
	Conventional 250<cc<750cm³	10 - 60	$0.00005V^2 - 0.0009V + 0.092$
		60 - 110	$0.00002V^2 + 0.0007V + 0.104$
	Conventional >750cm³	10 - 60	$0.00005V^2 - 0.0008V + 0.100$
		60 - 110	$0.00002V^2 + 0.0008V + 0.112$
	EC Proposal - 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 - 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 - All Capacities	10 - 60	$0.02000V^2 - 2.0750V + 77.10$
		60 - 110	$0.00130V^2 - 0.0391V + 23.50$

8.9 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:

$$\textit{mass of } CO_2 = 44.011\ (\textit{mass of fuel}/(12.011 + 1.008 \cdot r_{H/C})) \qquad (14)$$

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:

$$\begin{aligned}\textit{mass of } CO_2 = 44.011\ (&\textit{mass of fuel}/(12.011 + 1.008 \cdot r_{H/C}))\\ &- \textit{mass of CO}/28.011 - \textit{mass of VOC}/13.85\\ &- \textit{mass of particulates}/12.011) \qquad (14a)\end{aligned}$$

8.10 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:

$$E_{SO2} = 2\sum_j \sum_l k_{S,l}\ b_{j,l} \qquad (15)$$

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.

8.11 Lead and other Heavy Metal 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:

$$E_{Pb} = 0.75\sum_j k_{Pb}\ b_j \qquad (16)$$

with

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 8.35 presents emission factors expressed in mg/kg fuel for Cadmium, Copper, Chromium, Nickel, Selenium and Zinc, as provided by the Panel on Heavy Metals and POPs. However, these emission factors have to be considered as preliminary estimates only. More measurements are needed in order to confirm these values.

Table 8.35: Heavy Metal Emission Factors for all Vehicle Categories in mg/kg fuel

Vehicle Category Split (SNAP Code)	Cadmium	Copper	Chromium	Nickel	Selenium	Zinc
Passenger cars, gasoline (070101)	0.01	1.7	0.05	0.07	0.01	1
Passenger cars, catalyst - gasoline (070102)	0.01	1.7	0.05	0.07	0.01	1
Passenger cars, diesel (070103)	0.01	1.7	0.05	0.07	0.01	1
Passenger cars, LPG (070104)	0.0	0.0	0.0	0.0	0.0	0.0
Light duty vehicles, gasoline (070201)	0.01	1.7	0.05	0.07	0.01	1
Light duty vehicles, diesel (070202)	0.01	1.7	0.05	0.07	0.01	1
Heavy duty vehicles, gasoline (070301)	0.01	1.7	0.05	0.07	0.01	1
Heavy duty vehicles, diesel (070302)	0.01	1.7	0.05	0.07	0.01	1
Motorcycles < 50cc (070401)	0.01	1.7	0.05	0.07	0.01	1
Motorcycles > 50cc (070402)	0.01	1.7	0.05	0.07	0.01	1

In addition to the above heavy metals, noble metals used in the catalysts of vehicles (e.g. platinum, rhodium) should also be taken into account.

8.12 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 8.36 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.

Table 8.36: Methane (CH_4) Emission Factors for all Vehicle Categories

CH_4 Emission Factors [g/km]	**Urban**	**Rural**	**Highway**
Passenger Cars			
Conventional	$0.268 - 0.00573 \cdot V + 0.0000331 \cdot V^2$		
Closed Loop (91/441/EEC)	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. 3.5 - 16 t	0.085	0.023	0.020
Diesel Veh. > 16 t	0.175	0.080	0.070
Motorcycles			
< 50 cc	0.100	0.100	0.100
> 50 cc 2 stroke	0.150	0.150	0.150
> 50 cc 4 stroke	0.200	0.200	0.200

V: average speed expressed in km/h

8.13 Nitrous Oxide Emissions

Emission factors for N_2O are roughly estimated on the basis of literature review for all vehicle categories (Pringent et al. 1989, Perby 1990, de Reydellet 1990, Potter 1990, OECD 1991, Zajontz et al. 1991). 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 8.37.

Table 8.37: 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. 3.5 - 16 t	0.030	0.030	0.030
Diesel Veh. > 16 t	0.030	0.030	0.030
Motorcycles			
< 50 cc	0.001	0.001	0.001
> 50 cc 2 stroke	0.002	0.002	0.002
> 50 cc 4 stroke	0.002	0.002	0.002

n.a.: not available

8.14 Ammonia Emissions

For estimating ammonia emissions average emission factors are given for conventional and closed loop gasoline passenger cars and light duty vehicles and diesel passenger cars and light duty vehicles, related to the total annual kilometres driven.

These emission factors are based on literature review only and should be considered as broad estimates (de Reydellet 1990, Volkswagen 1989). Table 8.38 shows the emission factors proposed.

Table 8.38: 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. 3.5 - 16 t	0.003	0.003	0.003
Diesel Veh. > 16 t	0.003	0.003	0.003
Motorcycles			
< 50 cc	0.001	0.001	0.001
> 50 cc 2 stroke	0.002	0.002	0.002
> 50 cc 4 stroke	0.002	0.002	0.002

n.a.: not available

9 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, Tables 9.1, 9.2 and 9.3 provide information as used by Veldt, Derwent and Loibl et al. 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 this Guidebook.

Table 9.1: 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 4-stroke conventional	gas engine 3-way catalysts	Evaporation		
Ethane	1.4	1.8		1	3
Propane	0.1	1	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	25		
Hexane	7.1	6	15		
Heptane	4.6	5	2		
Octane	7.9	7			
Nonane	2.3	2			
Alkanes C>10	0.9	3		30 (1)	
Ethylene	7.2	7		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	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	1	1.5	
o-Xylene	2.5	2		0.5	
m,p-Xylene	5.6	4	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			
1,2,4-Trimethylbenzene	2.6	4			
1,3,5-Trimethylbenzene	0.8	2			
Other aromatic compounds C9	3.8	3			
Aromatic compounds C>10	4.5	6		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		1.5	
	100	100	100	100	100

(1) C13

Table 9.1 (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

Table 9.2: Composition of VOC Emissions of Motor Vehicles (Data as used by R. Derwent)

No.	Species	Percentage by mass speciation by source category, w/w %		
		petrol engines exhaust	diesel exhaust	petrol evaporation vehicles
0	methane	8.00	3.7	
1	ethane	1.30	0.5	
2	propane	1.20		
3	n-butane	1.95	2.5	19.990
4	i-butane	0.93	2.5	10.480
5	n-pentane	2.78	2.5	7.220
6	i-pentane	4.45	2.5	10.150
7	n-hexane	1.76	2.5	2.020
8	2-methylpentane	2.14	2.5	3.020
9	3-methylpentane	1.49	2.5	2.010
10	2,2-dimethylbutane	0.28	2.5	0.600
11	2,3-dimethylbutane	0.54	2.5	0.740
12	n-heptane	0.74	2.5	0.703
13	2-methylhexane	1.39	2.5	0.924
14	3-methylhexane	1.11	2.5	0.932
15	n-octane	0.37	2.5	0.270
16	methylheptanes	3.90	2.5	0.674
17	n-nonane	0.18	2.5	
18	methyloctanes	1.58	2.5	
19	n-decane	0.37	2.5	
20	methylnonanes	0.84	2.5	
21	n-undecane	2.75	2.5	
22	n-duodecane	2.75	2.5	
23	ethylene	7.90	11.0	
24	propylene	3.60	3.4	
25	1-butene	1.40	0.5	1.490
26	2-butene	0.50		2.550
27	2-pentene	0.90		2.350
28	1-pentene	0.70	0.7	0.490
29	2-methyl-1-butene	0.70		0.670
30	3-methyl-1-butene	0.70	0.5	0.670
31	2-methyl-2-butene	1.40	0.5	1.310
32	butylene	0.50		
33	acetylene	6.30	3.2	
34	benzene	3.20	2.6	2.340
35	toluene	7.20	0.8	5.660
36	o-xylene	1.58	0.8	1.590
37	a-xylene	2.06	0.8	1.880
38	p-xylene	2.06	0.8	1.880
39	ethylbenzene	1.20	0.8	1.320
40	n-propylbenzene	0.16	0.5	0.410
41	i-propylbenzene	0.13	0.5	0.120
42	1,2,3-trimethylbenzene	0.40	0.5	0.310
43	1,2,4-trimethylbenzene	1.60	0.5	1.600
44	1,3,5-trimethylbenzene	0.50	0.5	0.390
45	o-ethyltoluene	0.38	0.5	0.370
46	a-ethyltoluene	0.63	0.5	0.640
47	p-ethyltoluene	0.63	0.5	0.640
48	formaldehyde	1.60	5.9	
49	acetaldehyde	0.35	1.0	
50	proprionaldehyde	0.57	1.0	
51	butyraldehyde	0.07	1.0	
52	i-butyraldehyde		1.0	
53	valeraldehyde	0.03		
54	benzaldehyde	0.39		
55	acetone	0.14	2.0	

Table 9.3: Composition of VOC Emissions of Motor Vehicles (Loibl et al. 1993)

	Exhaust - Conventional Cars	Exhaust - Catalyst Cars	Exhaust - Cold Start (all cars)	2 stroke Engines	Diesel Engines	Evaporation losses
Non reactive						
Ethane	2	3	1	1	-	-
Acetylene	8	3	4	2	-	-
Paraffins						
Propane	-	-	-	1	-	2
Higher Paraffins	32	48	45	72	52	85
Olefins						
Ethene	11	7	6	3	6	-
Propene	5	4	2	1	3	-
Higher Olefins (C4+)	6	9	7	9	3	10
Aromatics						
Benzene	5	1	4	2	-	1
Toluene	10	11	140	3	-	1
Higher Aromatics (C8+)	21	6	21	6	12	1
Carbonyls						
Formaldehyde	-	8	-	-	13	-
Acetaldehyde	-	-	-	-	3	-
Higher Aldehydes (C3+)					4	
Cetones					1	
Other NMVOC						
Alcohols, esters, ethers						
Acids						
Halogenated Compounds						
Other/undefined					3	

10 UNCERTAINTY ESTIMATES

As in all cases of the application of estimation methodologies, the results obtained are subject to uncertainties. Since the true emissions are unknown, it is impossible to calculate the accuracy of the estimates. However, one can obtain an estimate of their precision. This estimate also provides an impression of the accuracy, if the methodology used for estimating road traffic emissions represents a reliable image of reality. These uncertainties are the results of errors which can be divided into random and systematic ones.

Random errors are those caused by:

- the inaccuracy of the measurement devices and techniques;

- the lack of a sufficient number of representative measurements, e.g., for heavy duty vehicles, cold starts, and evaporative emissions;
- erroneous data with regard to vehicle usage.

In principle systematic errors may be distinguished into two categories:

- Errors concerning emission factors and measurements:

  ⇒ Errors in the patterns used to simulate actual road traffic; this means that driving cycles may not be representative of real-life road traffic, e.g., typical speed and acceleration of real driving conditions may be considerably different from those used in off-road dynamometer tests, thus systematically underestimating vehicle emissions

  ⇒ Errors in the emission factors used for the calculations. Sufficient emission measurements are not available in all countries; therefore, average values derived from measurements in other countries have to be used. This can lead to significant variations because in some countries vehicles are undergoing periodic emission tests, so measured emission factors may not be representative of the vehicle fleets of other countries; this can bias the emission factor measurements and the evaluation of the effects of Inspection/Maintenance programmes and degradation of emission control equipment.

  ⇒ Errors in emission factor measurements. While, in principle and apart from the problems mentioned above, the data base for hot emission factors is quite rich and reliable, there is still much uncertainty associated with cold start and evaporative emission measurements, and possible systematic errors in these areas cannot be excluded.

- Errors concerning assessment of vehicle park and usage.

  ⇒ Erroneous assumptions of vehicle usage. In many countries the actual vehicle usage is not known, in some others, data from only a few statistical investigations are available. However, analysis presented elsewhere (Andrias et al. 1993b) shows that in most cases such errors are less important that errors in emission factors. Most important are errors in total kilometres travelled and in the average trip length. However, the fuel balance (i.e., the comparison of the calculated fuel consumption with the statistically known one), is a valuable means to check the validity of the various assumptions made and to avoid major errors. Nevertheless, it should be mentioned that assumptions which affect evaporative emissions are not always reflected in the calculated fuel consumption, which might lead to largely dispersed VOC estimates that do not violate the fuel balance. Although such a problem is rather unlikely to appear, this is a case where a systematic error in the assumption of one parameter can have a significant impact on the overall calculation.

⇒ Erroneous estimates of the vehicle park. Not all sub-categories of the methodology presented here appear in the statistics and, therefore, have to be estimated. To take an example, assessing the number of gasoline and diesel vehicles > 2.5 t which belong to the category "Light Duty Trucks" and those which belong to the category "Heavy Duty Vehicles" involves much uncertainty, since the exact numbers are not available. The same may hold true for splitting a certain category into different age and technology groups, as the real numbers are again not always known.

Table 10.1 provides qualitative indications of the "precision" which can be allocated to the calculation of the individual emissions. The table is based on subjective estimates of the working group members. It should be mentioned that only where the indicator 'A' is given the emission estimate is considered to be of satisfactory quantity (i.e. based on statistically significant number of measurements).

In order to illustrate this above evaluation, Table 10.2 presents as an example the estimate of the band of errors expressed as the coefficient of variation (CV = standard deviation / mean value) of the measured VOC emission factors and fuel consumption factors, using the data base which was constituted by the CORINAIR Working group. It is interesting to note that the mean CV for measured VOC emission factors is 33%, while the mean CV for fuel consumption factors is 11%. Moreover, measured data from older ECE classes (conventional cars) show lower variation than measurements of catalyst-equipped vehicles. This is partly due to the fact that there are fewer data from cars of recent model years compared to the data available for older classes; another reason for these variations is that, since the emission factors have been determined for on-road vehicles, the emission behaviour of recent vehicle classes differs according to the maintenance level of each vehicle, because the emission control systems of catalyst-equipped cars are sensitive to bad maintenance. Moreover, the category "Closed Loop Catalyst Cars" covers a number of different emissions standards and consecutively emission control techniques of different efficiency.

Table 10.1: Precision Indicators of the Emission Estimate for the Different Vehicle Categories and Pollutants

Legend: **A**: Statistically significant emission factors based on sufficiently large set of measured and evaluated data; **B**: Emission factors non statistically significant based on a small set of measured re-evaluated data; **C**: Emission factors estimated on the basis of available literature; **D**: Emission factors estimated applying similarity considerations and/or extrapolation.

Vehicle Category	**Pollutants**										
	NOx	CO	NMVOC	CH_4	PM	N_2O	NH_3	SO_2	CO_2	Pb	FC
Gasoline Passenger Cars											
Pre-ECE	A	A	A	A	-	C	C	A	A	B	A
ECE 15/00-01	A	A	A	A	-	C	C	A	A	B	A
ECE 15/02	A	A	A	A	-	C	C	A	A	B	A
ECE 15/03	A	A	A	A	-	C	C	A	A	B	A
ECE 15/04	A	A	A	A	-	C	C	A	A	B	A
Improved conventional	A	A	A	A	-	C	C	A	A	B	A
Open Loop	A	A	A	A	-	C	C	A	A	B	A
Closed Loop	A	A	A	B	-	C	C	A	A	B	A
Diesel Passenger Cars											
CC <2.0l	A	A	A	B	A	C	C	A	A	-	A
CC >2.0l	A	A	A	B	A	C	C	A	A	-	A
LPG Passenger Cars	A	A	A	-	-	--	-	-	A	-	A
2 Stroke Passenger Cars	B	B	B	D	-	D	D	A	B	B	B
Gasoline Light Duty	A	A	A	C	-	D	D	A	A	B	A
Diesel Light Duty	A	A	A	C	B	D	D	A	A	-	A
Gasoline Heavy Duty	D	D	D	D	-	D	D	D	D	D	D
Diesel Heavy Duty 3.5-16t	B	B	B	D	B	D	D	B	B	-	B
Diesel Heavy Duty >16t	B	B	B	D	B	D	D	B	B	-	B
Two Wheelers <50 cc	B	B	B	D	-	-	-	B	B	B	B
> 50 cc 2 stroke	B	B	B	D	-	-	-	B	B	B	B
> 50 cc 4 stroke	B	B	B	D	-	-	-	B	B	B	B
Cold Start Emissions											
Pass. Cars Conventional	B	B	B	-	-	-	-	-	B	B	B
Pass. Cars Closed Loop	C	C	C	-	-	-	-	-	C	B	C
Pass. Cars Diesel	C	C	C	-	C	-	-	-	C	-	C
Pass. Cars LPG	C	C	C	-	-	-	-	-	C	-	C
Gas Light Duty Vehicles	D	D	D	-	-	-	-	-	D	D	D
Diesel Light Duty Veh.	D	D	D	-	D	-	-	-	D	-	D

Table 10.2: Estimated error of emission factors, according to the variance of measured data for Passenger Cars < 3.5 t

Emission Factor	Legislation / Technology	Cylinder Capacity	Mean CV [%]
Gasoline Cars			
VOC	PRE ECE	All categories	16.5
	ECE 15-00/01	All categories	32.6
	ECE 15-02	All categories	32.7
	ECE 15-03	All categories	25.5
	ECE 15-04	All categories	32.8
	Improved Conventional	CC < 1.4 l	32.8
	Improved Conventional	1.4 l < CC < 2.0 l	39.9
	Open Loop	CC < 1.4 l	47.5
	Open Loop	1.4 l < CC < 2.0 l	49.2
	Closed Loop	All categories	44.2
FC	PRE ECE	CC < 1.4 l	3.2
	ECE 15-00/01		11.4
	ECE 15-02		9.5
	ECE 15-03		10.3
	ECE 15-04		10.3
	Improved Conventional		15.9
	Open Loop		15.0
	Closed Loop		17.2
	PRE ECE	1.4 l < CC < 2.0 l	3.1
	ECE 15-00/01		9.6
	ECE 15-02		10.7
	ECE 15-03		10.9
	ECE 15-04		25.8
	Improved Conventional		22.4
	Open Loop		20.7
	Closed Loop		21.2
	PRE ECE	CC > 2.0 l	6.3
	ECE 15-00/01		12.2
	ECE 15-02		6.7
	ECE 15-03		8.6
	ECE 15-04		11.0
	Closed Loop		23.8
Diesel Cars			
VOC		1.4 l < CC < 2.0 l	28.4
		CC > 2.0 l	54.5
FC		1.4 l < CC < 2.0 l	21.4
		CC > 2.0 l	21.6
LPG Cars			
VOC		All categories	9.2
FC		All categories	20.0

CV: coefficient of variation (= standard deviation / mean value)

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The work on emission factors for traffic revealed once more that knowledge of these emissions is far from complete. The points listed below are those for which the gaps in knowledge seem to be most striking and additional studies are required.

In particular the following points require further attention:

i) description of driving behaviour (statistical data), e.g. average mileage per vehicle, number of trips per day, average trip length and so on;

ii) cold start emissions for all vehicle categories; at this point it has to be stressed that an updated approach is already under development and evaluation in the framework of MEET (see Sérié and Joumard, 1997);

iii) correction factors for local particularities, e.g. mountain regions (altitude, air-conditioning maintenance effect), climatic particularities, local speed profiles;

iv) independent estimations, e.g. nation-wide surveys, of total annual mileage driven on the three road classes by each of the vehicle categories;

v) methodology and statistical input for estimating the spatial allocation of vehicle emissions;

vi) other unregulated pollutants (e.g. PAH, benzene)

Moreover, it should be mentioned that the estimation of emissions from road traffic might be, more than in the case of other source categories, a task which requires permanent updating. This is due to the relatively large and rapid changes in this sector over short time periods, e.g. the turnover of fleets is rather short, legislation changes quickly, the number of vehicles increases steadily and so on. These changes not only require the continuation of the work on emission factors, but also the adaptation of the methodology.

Above all, there are additional requirements of scientists, e.g. modellers, concerning the description of emissions in time, space and composition. The group got the impression that these tasks can only be accomplished if the work on emission estimates for road traffic is enlarged and becomes a permanent topic.

Finally, for many reasons, but in particular for the development of an efficient air pollution management policy, the work on estimation techniques for the prediction of future emissions is to a large extent based on the development of emission inventorying methodology (e.g. Samaras et al. 1991, Metz et al. 1993, Joumard et al. 1994).

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

This is a difficult task which should not be underestimated. In general one can distinguish two approaches for the spatial disaggregation of road transport emissions :

The top-down approach: Such an approach can be used in the absence of vehicle use data in smaller areas. In such cases the following guidelines apply:

i) Urban emissions should be allocated to urban areas only, e.g. by localising geographically all cities with more than 20 000 inhabitants and allocating the emissions via the population living in each of the cities. A list of these cities including their geographical co-ordinates can be provided by the statistical office of the EC (EUROSTAT) in Luxembourg.

ii) Rural emissions should be spread all over the country, but only outside urban areas, e.g. by taking the non-urban population density of a country

iii) Highway emissions should be allocated to highways only, that means: all roads on which vehicles are driven in accordance with the "highway driving pattern", not necessarily what is called "Autobahnen" in F.R.Germany, "autoroutes" in France, "autostrade" in Italy and so on. As a simple distribution key, the length of such roads in the territorial unit can be taken.

Some of the statistical data needed for carrying out the allocation of emissions can be found in EUROSTAT publications but in general national statistics are more detailed.

The bottom-up approach: A few countries may already have available the input data needed for the calculation scheme for a smaller NUTS than the whole of their country. These countries, of course, should directly apply the calculation scheme to the smaller units and subsequently build the national total by summing up emissions from the smaller units. However, in such cases it is recommended to cross-check the total obtained in this way with the total calculated by using the top-down approach in order to balance possible deviations in the statistics.

13 TEMPORAL DISAGGREGATION CRITERIA

The temporal resolution of road transport emissions is particularly important as input in mesoscale air quality models or for local air pollution assessment. In this case, the patterns of the traffic load, in conjunction with the variation over time of the average vehicle speed. should be used for the calculation of temporal variation of the emissions. This means that traffic counts and speed recordings (or estimates) should be available for the modelled area.

In principle, the two approaches (top down and bottom up) mentioned above for the spatial disaggregation apply here as well: In the top down approach total road traffic emissions are first spatially and then temporally disaggregated over the area, using traffic load and speed variation in a dimensionless form as the basic disaggregation pattern. In the bottom-up approach emissions are calculated on the basis of the available patterns and then summed up. Again, in such cases it is recommended to cross-check the total obtained in this way with the total calculated by using the top-down approach in order to balance possible deviations in the statistics.

According to the proposed methodology cold-start emissions are calculated on a monthly basis providing already a temporal resolution. However, special attention should be paid on the allocation of the cold-start extra emissions (and evaporative losses) in urban areas.. If solid data are lacking, then the following suggestion could be helpful: The urban area can be divided into three districts, a central business district, a residential district and an intermediate district. By coupling the districts with the trip patterns of the city, it is in principle possible to come up with a first approximation of temporal (and spatial) allocation of cold start emissions.

At this point it has to be recalled that spatial and temporal disaggregation of the emissions is coupled with a deterioration of the accuracy of the emission estimates. This is particularly true in the case of road transport emissions, because:

i) at high resolution the random character of transport activities dominates the emission estimates and
ii) the emission factors proposed are aggregated emission factors, averaged over a large number of driving cycles, therefore not necessarily representative of the instantaneous emissions of vehicles driven under actual conditions.

Emission Estimates for Urban areas

Spatially and temporally disaggregated emission inventories are necessary in order to make reliable air quality simulations and predict ambient concentration levels with reasonable accuracy. Several attempts to create a refined motor vehicle emission inventory have been made up to now, in particular for urban areas. These attempts can be distinguished in top-down (or macroscale) and bottom-up (or microscale) approaches. Evidently the bottom-up method attempts to simulate reality more accurately and requires more effort than the top-down method, although it is not yet clear whether such a degree of sophistication could bring more reliable emission estimates and consequently support better air quality simulations.

Figure 13.1 illustrates a methodological approach that can be followed in order to make maximum usage of both approaches in the creation of such an emission inventory. In the bottom-up approach motor vehicle emissions are calculated for each street or road of the area under simulation at an hourly basis; according to the top-down approach, the whole area is simulated on an annual basis. In principle, the top-down and bottom-up estimates of motor vehicle emissions are carried out independently. In each case the "hard facts", i.e. the most reliable information (such as traffic counts, statistics of vehicle registrations and measured emission factors) are the starting point; uncertain parameters are then assessed according to relevant knowledge and reasonable assumptions. In the top-down approach the fuel balance constitutes already an internal calibration point: calculated and statistical fuel consumption should not vary greatly.

After the independent estimates have been carried out, the estimated activity and emission data of the two approaches (in terms of calculated total annual vehicle kilometres, cold start annual vehicle kilometres and emission factors) are compared, and it is attempted to resolve the discrepancies that may be identified. This reconciliation procedure leads to a re-estimation of the most uncertain parameters of each approach. At this point, emission factors are evidently a crucial parameter; more analytical microscale estimates apply modal emission factors which are expressed as a function of instantaneous vehicle speed and acceleration (e.g. Wegerer 1990, Jost et al. 1992) and therefore differ from average speed dependent emission factors that are regularly used in macroscale models. In that case the harmonisation of the two different sets of emission factors is required as well. The activity and emission data having been reconciled, the next step is to calculate total fuel consumption and emissions with both approaches and compare their aggregate results.

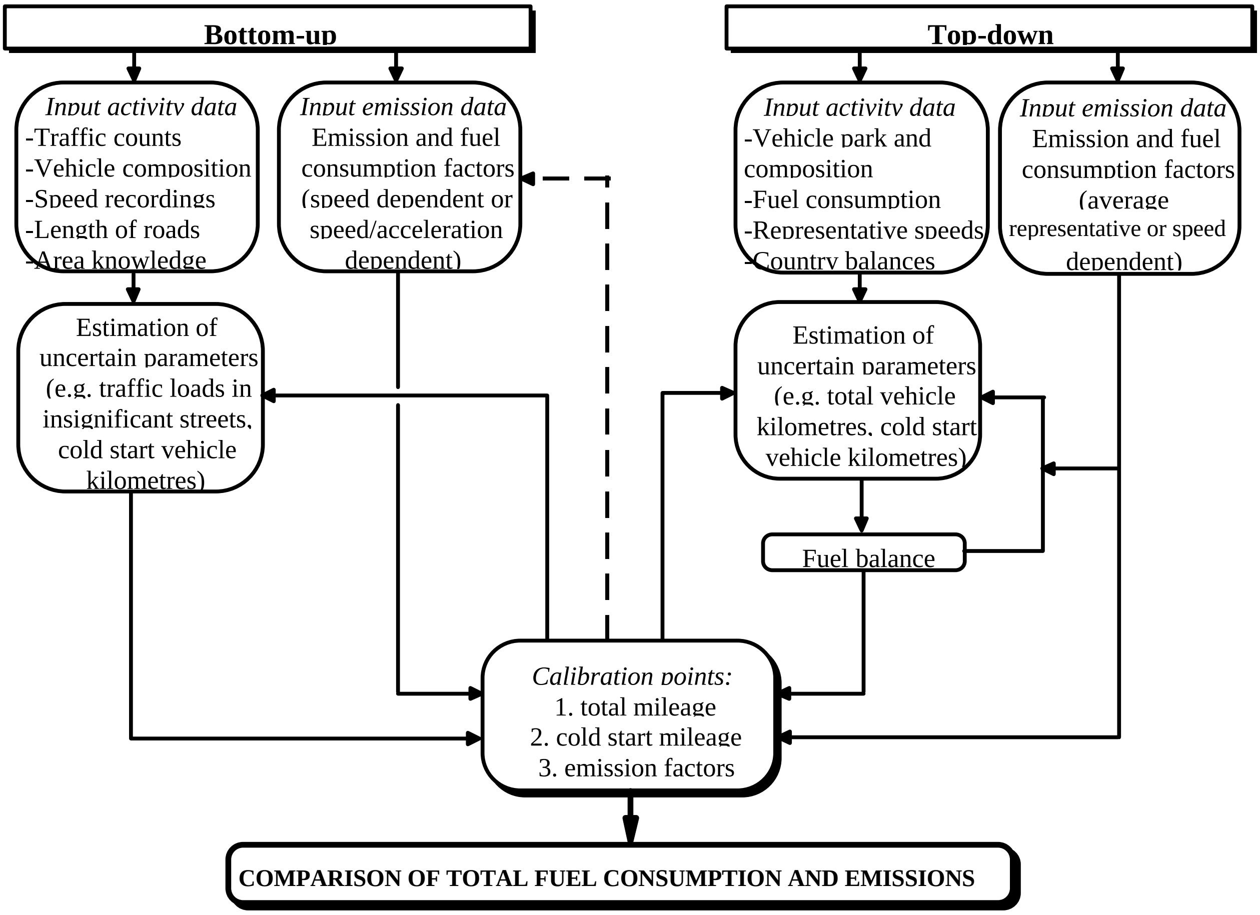

Figure 13.1: Flowchart of the proposed reconciliation method.

The scheme shown in Fig. 13.1 gives an overview of the required information for such an approach. Evidently most of these data are sufficiently available in most European cities. An aspect that should not be overlooked, however, is the knowledge of the area and its traffic patterns, so that appropriate assumptions can be conducted. It is therefore necessary to create inventories with the close co-operation of local experts.

14 ADDITIONAL COMMENTS

As mentioned above the results of this work have been translated into a computer programme, called COPERT II (**Co**mputer **P**rogramme to Calculate **E**missions from **R**oad **T**raffic), which substantially facilitates the practical application of the methodology (see Ntziachristos and Samaras, 1997). This program is the updated version of COPERT90 which was used by many European countries to produce emissions estimates from road traffic.

Finally it is worth to mention that it has already been decided that the technical work carried out in the framework of the COST action and the MEET project will be taken on board in the work carried out both in the framework of UN-ECE EMEP Task Force on emission inventories and for the activities of the European Environment Agency's - Topic Center on Air Emissions. Therefore the future update of this Chapter as well as of COPERT will fully incorporate the results of the above mentioned activities.

15 SUPPLEMENTARY DOCUMENTS

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Ahlvik P., S. Eggleston, N. Gorissen, D. Hassel, A.-J. Hickman, R. Joumard, L. Ntziachristos, R. Rijkeboer, Z. Samaras and K.-H. Zierock, (1997) COPERTII Methodology and Emission Factors, Draft Final Report, European Environment Agency, European Topic Center on Air Emissions.

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16 VERIFICATION PROCEDURES

In the following only some concepts for emissions inventory verification are outlined, that are applicable in the case of road transport emission inventories. For a more detailed discussion on these issues, refer to Mobley et al. 1994 (see Chapter on “Procedures for Verification of Emission Inventories” in this Guidebook). In general these approaches can be categorised into soft and ground truth verification approaches. Specifically:

i) The first category comprises:

- Comparison of alternate estimates: These estimates can be compared to each other to infer the validity of the data based on the degree of agreement among these estimates. Such a process can help to homogenise data developed through different approaches.

- Quality Attribute Ratings: This approach involves the development of a semi-quantitative procedure that could assign a value for a component of an emissions inventory or to the collective emissions inventory. An example of such a technique (called the Data Attribute Rating System) is in development in US E.P.A. A numerical scale is used to rank a list of attributes in a relative priority against the set of criteria selected to represent the reliability of each attribute estimate.

ii) The second category comprises:

- Survey Analyses: Some common methodologies for estimating emissions from area sources rely on a per capita or per area emission factor. The results of a statistical sampling based on these principles could be applied to develop regionally specific emission or allocation factors that depend on population density, economic demographics etc.

- Indirect Source Sampling: These approaches can use remote measurement techniques (FTIR, Ultra Violet Spectrometry, Gas Radiometer).Specifically the Gas Filter Radiometer Emission Test System has been used to measure in use motor vehicle emissions.

- Ambient Ratio Studies: Typically these measurement programmes include a rural measurement side, two or more sides in the downtown area and two or more sides in the downwind sector. Grid based and trajectory modelling approaches are used to simulate the urban area and model predictions are compared to the observed concentrations.

- Tunnel Studies: Concentrations can be measured at both the upwind and downwind portals of the tunnel and the emissions rate can be calculated by the air difference. The measured concentrations data may be used to estimate the mass emissions rate for the sampling period.

- Air Quality Modelling: This is a complex activity in which atmospheric processes are simulated through the solution of a series of mathematical expressions. All models involve simplifying assumptions to represent the process active in the atmosphere. The lack of understanding of all the atmospheric processes and the simplifying assumptions contribute to a significant uncertainty in model outputs.

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List of Abbreviations

CC:	Cylinder Capacity of the Engine
CH_4:	Methane
CO:	Carbon Monoxide
CO_2:	Carbon Dioxide
FC:	Fuel Consumption
GVW:	Gross Vehicle Weight
NH_3:	Ammonia
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
SOx:	Sulphur Oxides
VOC:	Volatile Organic Compounds

List of 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)
$b_{j,l}$	=	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
$d_{j,k}$	=	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(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]
l_{trip}	=	average trip length
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
$r_{H/C}$	=	ratio of hydrogen to carbon atoms in the fuel
$s_{j,g}$	=	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]
v_j	=	average annual mileage driven by each vehicle of category j
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
$E_{hot,i,j,k}$	=	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
O_l	=	total annual consumption of fuel [kg] of type l
V	=	vehicle speed in [km/h]

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)

19 RELEASE VERSION, DATE AND SOURCE

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SNAP CODE : **070600**

SOURCE ACTIVITY TITLE : **Gasoline Evaporation From Vehicles**

1 ACTIVITIES INCLUDED

Evaporative emissions occur in significant 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. It should be noted that also refuelling losses exist. These are not included in this chapter as they are emitted at petrol stations.

2 CONTRIBUTIONS TO TOTAL EMISSIONS

Evaporative losses contribute substantially to total road transport related VOC emissions. On the basis of the results of CORINAIR 90 exercise, evaporative losses account for about 25% of total VOC emissions from road transport in the EU, as Table 2.1 shows.

Table 2.1: 1990 Total Evaporative Emissions as Percentage of the National and EU Total VOC of Road Transport

B	34.2
DK	34.9
D	22.1
F	30.1
GR	28.2
IRL	44.8
I	23.9
L	41.9
NL	n.a.
P	33.0
E	27.1
UK	14.5
EU 12	23.7

n.a.: not available

3 GENERAL

3.1 Description

There are three primary sources of evaporative emissions from vehicles[(1)] :

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

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

3.1.1 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.

3.1.2 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.

3.1.3 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.

[(1)] In US literature there is a fourth source mentioned: "Resting Loss Emissions" which result from vapour permeating parts of the evaporative control system. However, they are not taken into account explicitly in this paper.

3.2 Emissions

Evaporative VOC emissions from gasoline fuelled vehicles add to total NMVOC emissions. For evaporating emissions tank breathing is reported as $CH_{2,33}$ and hot soak as $CH_{2,20}$. These are the units used to report test protocols.

3.3 Controls

Until 1993 evaporative losses of gasoline passenger cars were not controlled in Europe, with the exception of the EFTA countries which have adopted the US EPA SHED test procedure. Since 1993 the EC adopted equivalent emission standards as well (Directive 91/441/EEC). In order to comply with these requirements the application of an on board carbon canister is necessary, which adsorbs gasoline vapours and desorbs them to the engine under appropriate conditions. The overall efficiency of these canisters is of the order of 90%. Currently a step further is under consideration (namely introduction of the "large canister").

4 SIMPLER METHODOLOGY

No simple methodology is proposed here, because in principle all countries are in the position to apply the detailed methodology.

5 DETAILED METHODOLOGY

The main equation for estimating the evaporative emissions is (Gorißen 1988):

$$E_{eva,voc,j} = 365 \cdot a_j \, (e^d + S^c + S^{fi}) + R \qquad (1)$$

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

S^{c}	=	$(l\text{-}q)\,(p \cdot x \cdot e^{s,hot} + w \cdot x \cdot e^{s,warm})$	(2)
S^{fi}	=	$q \cdot e^{fi} \cdot x$	(3)
R	=	$m_j\,(p \cdot e^{r,\,hot} + w \cdot e^{r,\,warm})$	(4)

where:

q	=	fraction of gasoline powered vehicles equipped with fuel injection	
p	=	fraction of trips finished with hot engine (dependent on the average monthly ambient temperature)	
w	=	fraction of trips finished with cold or warm engine[1] (shorter trips) or with catalyst below its light-off temperature	
x	=	mean number of trips of a vehicle per day, average over the year	
		$x = v_j / (365 \cdot l_{trip})$	(5)
$e^{s,hot}$	=	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	

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.

With reference to the application of the baseline calculation scheme outlined in chapter B710 Table 5.1, Table 5.1 summarises the methods proposed for application for the calculation of evaporation losses.

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(1) Engines are defined as "cold" or "warm" if the water temperature is below 70^{o}C

Table 5.1: Summary of Calculation Methods applied for Calculation of Evaporation Losses (cf. chapter B710, Table 5.1)

Evaporation	NMVOC
Pass. Cars Conventional	A
Pass. Cars Closed Loop	A
Light Duty Vehicles	C
Two Wheelers <50 cm^3	D
Two Wheelers >50 cm^3	D

6 RELEVANT ACTIVITY STATISTICS

Apart from the emission factors, the proposed methodology requires, a number of statistical data which are most likely not available in many countries, e.g. the parameters p, i, w and x. Table 6.1 shows an example from the data base of CORINAIR85 exercise. These data can be found only in detailed national statistics, or can be produced via surveys.

Table 6.1: Examples of Statistical Input Data Relevant for Estimating Evaporative Emissions as used by EC Member States in COPERT 85

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

7 POINT SOURCE CRITERIA

There are no relevant point sources which fall under the source activities dealt with in this chapter.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

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 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.

8.1 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 8.1 for uncontrolled and controlled vehicles (based mainly on Concawe 1987, 1990, Eggleston 1991, 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.

Table 8.1: Summary of Emission Factors for Estimating Evaporative Emissions of Gasoline Powered 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

The application of the proposed methodology requires detailed knowledge of driving behaviour and vehicle park composition.

8.2 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.

8.3 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 <50 cc and 0.4 times those of passenger cars for motor cycles >50 cc. Again this approach has to be considered as a drastic simplification, which has been chosen only because the required data are not available.

9 SPECIES PROFILES

See the discussion in section 9 of Chapter B710 on road transport.

10 UNCERTAINTY ESTIMATES

Using the indicators introduced in Chapter B710 Table 8.24, Table 10.1 provides qualitative estimates of the precision which can be allocated to the calculation of evaporative losses.

Table 10.1: Summary of Precision Indicators of the Evaporative Emission Estimates (cf. Chapter B710 Table 8.24)

Evaporation	NMVOC
Pass. Cars Conventional	C
Pass. Cars Closed Loop	C
Light Duty Vehicles	D
Two Wheelers <50 cm^3	D
Two Wheelers >50 cm^3 2 str.	D
Two Wheelers >50 cm^3 4 str.	D

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

In general, the estimation of evaporative emissions from gasoline vehicles involves still a large number of uncertainties which can not be solved without carrying out further measurements. Therefore the methodology cannot overcome many of the problems, but can try only to improve on some specific aspects. It should be strongly underlined that the authors see a need to improve the proposed methodology further, in particular in order to take into account better the temperature and RVP dependencies of evaporative emissions for the different vehicle categories. In addition the following points require further attention:

i) evaporative emission factors for all vehicle categories, and
ii) quantitative determination of parameters relevant to evaporative emissions, e.g. fuel properties (Reid vapour pressure);

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Evidently the principles of the approaches outlined for exhaust emission spatial allocation apply equally to evaporative losses. In particular as regards the top down approach, the following hints may be useful:

- **Diurnal losses**: As diurnal losses occur at any time, their spatial allocation to urban/rural/highway conditions depends on the time spent by the vehicles on the different road classes. Therefore for those vehicles that are used by city inhabitants one can assume that 11/12 of their diurnal emissions occur in urban areas, the rest being split between rural and highway driving proportionally to the ratio of (rural mileage $\cdot$ highway speed) / (highway mileage $\cdot$ rural speed)

- **Soak losses**: The majority of these emissions occur in the area of residence of the car owner, as they are associated with short trips.

- **Running losses**: Running losses are proportional to the mileage driven by the vehicles. Therefore their allocation to urban areas - rural areas - highways has to follow the mileage split assumed for the calculation of the exhaust emissions.

13 TEMPORAL DISAGGREGATION CRITERIA

- **Diurnal losses and Soak losses**: The calculation scheme proposed can be applied for finer temporal resolution (e.g. during a diurnal cycle)

- **Running losses**: The temporal variation of these emissions depends (as outlined in Chapter B710 on road transport) on the availability of traffic data (e.g. traffic counts).

14 ADDITIONAL COMMENTS

The evaporation losses calculation scheme presented above, is fully integrated into COPERT II (**Co**mputer **P**rogramme to Calculate **E**missions from **R**oad **T**raffic), which substantially facilitates the practical application of the methodology (see Ntziachristos et al. 1997).

15 SUPPLEMENTARY DOCUMENTS

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

Andrias A., Z. Samaras, D. Zafiris and K.-H. Zierock (1993): CORINAIR Working Group on Emission Factors for Calculating 1990 Emissions from Road Traffic. Volume 2: COPERT - Computer Programme to Calculate Emissions from Road Traffic - User's Manual. Final Report, Document of the European Commission ISBN 92-826-5572-X

Ntziachristos L., Samaras Z., (1997), COPERT II - Computer Programme to Calculate Emissions from Road Transport, User's Manual - European Environmental Agency

16 VERIFICATION PROCEDURES

See the discussion in Chapter 16 of Chapter B710 on road transport.

17 REFERENCES

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

Eggleston S. (1991): Data on evaporative emissions of gasoline passenger cars submitted to the CORINAIR Working Group on Emission Factors for Calculating 1990 Emissions from Road Traffic. Brussels 7 and 8/10/1991

Gorißen N. (1988): Evaporative Emissions of Gasoline Powered Vehicles. Paper contributed to the CORINAIR working group on Emission from Road Traffic, unpublished. Umweltbundesamt, Berlin

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

Mobley J.D. and M. Saeger (1994): Concepts for Emissions Inventory Verification, US EPA Draft Final Report.

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

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U.S. Environmental Protection Agency; *Supplement A to Compilation of Air Pollutant Emission Factors (AP-42) - Volume II: Mobile Sources*, Test and Evaluation Branch, Office of Air and Radiation, January 1991.

U.S. Environmental Protection Agency; *User's Guide to MOBILE5*, Test and Evaluation Branch, Office of Air and Radiation, Draft 4a, December 3, 1992.

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.

List of Abbreviations

CH_4:	Methane
NMVOC:	Non-Methane Volatile Organic Compounds
RVP:	Reid Vapour Pressure (standardised vapour pressure measurement, conducted at 38 ^oC, with a vapour: liquid ratio 4:1)
VOC:	Volatile Organic Compounds

List of Symbols

a_j	=	number of gasoline vehicles of category j, operated in 1990
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
l_{trip}	=	average trip length
p	=	fraction of trips, finished with hot engine (depending on the average monthly ambient temperature)
q	=	fraction of gasoline powered vehicles equipped with fuel injection
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]
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

β_j = fraction of mileage driven with cold engines

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

R = hot and warm running losses

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

19 RELEASE VERSION, DATE AND SOURCE

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SNAP CODE : **070700**

SOURCE ACTIVITY TITLE : **Automobile Tyre and Brake Wear**

A specific methodology for these activities has not been prepared because the contribution to total national emissions is thought to be currently insignificant, i.e. less than 1% of national emissions of any pollutant.

If you have information contrary to this please contact the expert panel leaders.

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