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EMISSION FACTOR MODELLING FOR LIGHT VEHICLES WITHIN THE EUROPEAN *ARTEMIS* MODEL

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ABSTRACT

The emission models for atmospheric pollutants have been updated and strongly improved for the road light vehicles. This development is based on a wide and specific measurement campaign, with more than 150 vehicles and about 3500 tests for a large number of pollutants. The results of these measurements are included in a database especially designed, available and open to future European measurements data. The Artemis model for light vehicles contains a set of complementary sub-models. The base model calculates the hot emissions for each vehicle category according to the driving behaviour. It contains 5 alternative models: The main model considers traffic situations (discrete model), with emission factors for each of them; A simplified model, built on the same data, takes into account the driving behaviour through the average speed (continuous model); A continuous model, so-called kinematic, considers a limited number of aggregated kinematic parameters; 2 instantaneous models consider some instantaneous parameters as instantaneous speed. These models are associated to models taking into account the influence of several parameters, as cold start, using of auxiliaries like air conditioning, vehicle mileage, ambient air temperature and humidity, road slope and vehicle load.

Keywords: *Passenger car, inventory, Europe, regulated and unregulated pollutant, cold start, auxiliary, mileage, temperature, humidity, slope, load, traffic situation, kinematic.*

1. INTRODUCTION

In order to assess the present and future state of the emissions from transport and to evaluate different policies for reducing the emissions, it is necessary to have reliable knowledge about the sources and causes of the pollution, the technological and behavioural parameters of influence and the potentials of different strategies to reduce the pollution. The quantitative effects in general are calculated by emission models, which are also the basis for inventory systems at different levels of spatial resolution (local, regional, national, international). The *Artemis* project "*Assessment and reliability of transport emission models and inventory systems*" proposes to combine the experience from different emission calculation models and ongoing research in order to arrive at a harmonised methodology for emission estimates at the national and international level. It is the following step after two inventorying model developments in Europe: The European MEET (Methodologies for Estimating air pollutant Emissions from Transport) project [5] and the COST 319 action [6], which are the basis of the Copert 3 software [11] used in many countries; The German and Swiss emission model Handbook of emission factors HBEFA [10]. The main shape difference between the

MEET/Copert and HBEFA approaches is the taking into account of the kinematics: through the trip average speed in a continuous model for MEET/Copert, but through discrete traffic situations in HBEFA based on instantaneous modelling.

A rigorous statistical evaluation should be made of the whole sequence of operation of the inventory model, including the basic data (emission measurements, traffic statistics etc.), the parameters and assumptions of the models. For that purpose a wide European emission data base has been designed and most of the emission measurements available in Europe have been collected, including measurements carried out within the project itself. Then a deep and comprehensive analysis of the ways to take into account the driving behaviour has been made, allowing us to design several emission models adapted to different purposes, more applied or research oriented. Several sub-models are then built for taking into account the hot emission, cold start, auxiliaries, ambient air temperature and humidity, road gradient and vehicle load, but also evaporations treated in [4]. The method and outputs of the study are detailed in [9].

2. EMISSION DATA BASE

The database used to derive the Artemis light vehicle emission models includes the existing European emission data, either already collected within the European MEET project or Copert exercise, from the Handbook data base [10] or later than them, and the results of the vehicle tests carried out specifically within the project by the different partners. Finally all these data were included in the so-called Artemis LVEM database, aiming at gathering all European emission measurements.

2.1. Specific measurements

About 3500 tests (1 vehicle, 1 driving cycle) were carried out within the project to improve the quality of the emission models. The pollutants considered differ from one test to another. The regulated pollutants are systematically measured for all the tests. In addition a large number of unregulated pollutants, especially hydrocarbon species, are measured by five laboratories. The compounds quantified and characterised depend on laboratory: See **Table 1**. On-line measurements are performed by EMPA by chemical ionization mass spectrometry (CI-MS) for methane, benzene, toluene, xylenes and ethyl benzene, and by VTT by Fourier transform infrared (FTIR) for N_2O, NO/NO_2, NH_3 and formaldehyde. The other measurements are off-line, with different methods used:

- gas chromatography with flame ionization detection (GC-FID) for about 110 VOC species by EMPA, for 18 species by IM, for C_2-C_6 compounds by Inrets-ULCO
- gas chromatograph with a mass spectrometer (GC-MS) for PAHs by IM and KTI, for C_6-C_{15} compounds by Inrets-ULCO
- gas chromatography for 13 compounds up to C_8 by VTT
- high performance liquid chromatography (HPLC) for aldehydes and ketones by EMPA, Inrets-USTL, KTI and VTT, for PAHs by Inrets-US

154 vehicles were tested specifically in 8 different laboratories (EMPA, IM, INRETS, KTI, LAT, TNO, TUG and VTT) for designing the new emission models: 102 petrol passengers cars (PC), 2 CNG, 48 diesel PC and 2 diesel Light Duty Vehicles (LDV), or according to emission standard: resp. 9, 10, 60, 66 and 9 Euro 0, 1, 2, 3, and 4. 36 driving cycles were used, but some of them only with few cars. The 3 Artemis cycles were used by almost all the vehicles tested; Then the most used driving cycles are the Artemis low or high motorisation, the EMPA BAB 1000, the Handbook, and the Inrets urbain fluide court ones. The test sequence depends on each laboratory. The vehicles were tested as received on a chassis dynamometer. The emissions are sampled usually with a bag or a trap, giving an physical

average of emission along the sampling time, or sampled and analysed continuously. All together about 3500 bags or vehicle-tests were produced specifically for the light vehicles. About 2400 tests were carried out to design the basic hot emission model for regulated pollutants, 1600 tests for the emission factors of unregulated pollutants, 1200 tests to design the instantaneous models, 500 tests for the cold start model, and 800 tests for the other sub-models (LDV, influence of mileage, ambient temperature and humidity, gradient, load), but some tests are common to different tasks.

***Table 1**: Numbers of unregulated pollutants measured per laboratory and per pollutant group.*

Laboratory		*n*
Empa		98
IM		58
Inrets +	ULCO	96
	US	16
	USTL	16
KTI		9
VTT		13
total		169

Unregulated pollutant group	*n*
non VOC	2
alkanes (saturated)	50
alkenes and alkynes (unsaturated)	28
monoaromatic hydrocarbons	39
polyaromatic hydrocarbons (light)	8
polyaromatic hydrocarbons (heavy)	22
carbonyl compounds (aldehydes and ketones)	20
total	169

2.2. Artemis light vehicle emission measurement database (Artemis LVEM DB)

Beside the emission measurement campaign carried out within the project, a database was developed to collect these data and all emission measurements made in Europe for passenger cars (PC) and light duty vehicles (LDV) for a driving cycle. Such data can be derived from measurements on a vehicle bench or on the road, but always after integration on a driving cycle or sub-cycle. It allowed the project partners to use the same internal and external data for designing the different PC and LDV emission factors, as presented in section 3.

The design of the database is linked to the emission parameters: the vehicle characteristics and the test characteristics, i.e. the driving cycle characteristics and the roller bench characteristics. The present version of Artemis LVEM database is formatted as an Access XP-Database. It database includes functions allowing to harmonise the emission data, to obtain comparable data. Four parameters found to have a quantifiable influence on the emission level [8] are taken into account: the gearshift strategy, the vehicle mileage, the ambient air temperature, and the ambient air humidity, standardised at the following values, resp.: Artemis strategy, 50 000 km, 23°C, 10.71 g H_2O/kg dry air. The harmonisation is an option and in any case the raw data, non harmonised, remain in the database. These corrections are quite important: when averaged per fuel type, emission standard and pollutant, they range from 0.83 to 1.48, but can be much higher for vehicle sub-classes or individual tests.

The present version of the Artemis LVEM database contains data of 2847 passenger cars and light duty vehicles, measured from 1980 to 2004, originated from laboratories from 10 European countries (Austria, Finland, France, Germany, Greece, Hungary, Italy, Sweden, Switzerland, The Netherlands, and United Kingdom). **Table 2** shows how the tested vehicles are distributed between different European emission standards and fuel types. With these vehicles, 12 685 tests were conducted when splitting up into the cycle level, and 18 824 tests respectively when analysing the sub-cycle level. Regarding pollutants per vehicle and sub-cycle, 177 861 emission factors (g km^{-1}) have been derived, for 404 pollutants. 25 430 among these emission factors concern unregulated pollutants.

In a first step, the Artemis LVEM database was developed and used only by the Artemis partners. The main part of the database is now available for anybody. It is at the same time open for data submission from new emission measurements.

***Table 2**: Number of vehicles per emission standard and per fuel type in the Artemis LVEM database.*

emis. standard	petrol	LPG	CNG	diesel	biodiesel	*Total*
pre-Euro 1	901			231		*1132*
Euro 1	1227	7		68		*1302*
Euro 2	169	3		64		*236*
Euro 3	100	2	1	54	2	*159*
Euro 4	15		1	2		*18*
total	*2412*	*12*	*2*	*419*	*2*	*2847*

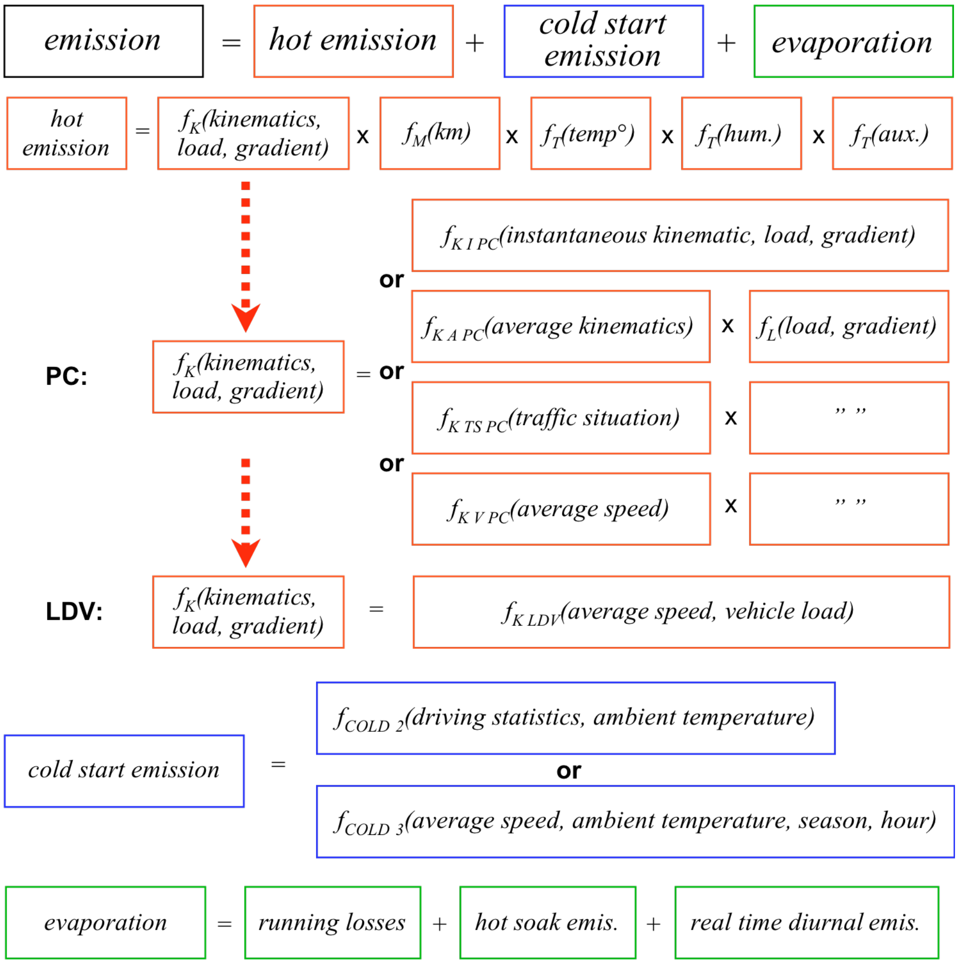

***Figure 1**: Shape of the Artemis emission model for light vehicles.*

3. EMISSION MODELLING

3.1. Shape of the emission model

The emission model, whose scheme is presented in **Figure 1**, is the sum of 3 sub-models, for hot emission, cold start extra emission, and evaporation. All the models and sub-models consider as an input parameter the technical characteristics of the vehicles, and especially the fuel used and the emission standard, and the driving behaviour and more generally the traffic characteristics presented in [1].

The pollutants reported as emission factors are all the regulated pollutants, NO_2 and some non regulated ones. Although we produced data on a huge number of different unregulated compounds, VOCs and PAHs analyzed at different laboratories build up an inharmonic set of data. Clear differences were seen in the emission levels obtained at different laboratories for some pollutants. In addition, some suspected outliers were found. We select the species, which can be regarded as most important, most informative and most representative when limitations of our data are taken into account. These unregulated pollutants are as VOCs, acetaldehyde, acrolein, benzene, 1,3-butadiene, formaldehyde, ethylbenzene, n-hexane, and toluene, and as PAHs, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, dibenzo[a,h]anthracene, and indeno[1,2,3-c,d]pyrene. For particle properties, outputs of the Particulates project [12] were taken into account: Emission factors were developed for the particle number (size range >7 nm) and the integrated active surface area (7 nm – 1 µm) of the total particle population as well as the number of solid particles of three different size ranges: 7-50 nm, 50-100 nm and 100 nm-1 µm (aerodynamic diameter).

3.2. Instantaneous models

Instantaneous emission models for light-duty vehicles were already available [3, 7 for instance], but their accuracy was questionable [14]. Emission models based on mapping the emissions onto engine speed and brake mean effective pressure (or engine torque) were then developed at EMPA and TU-Graz. Both models give accurate results for the pre Euro 1 petrol and for diesel vehicles. However, the prediction quality using this static map is not satisfactory for three-ways catalysts vehicles. Since emissions of modern catalyst cars are very low in regular hot conditions, some short peaks, which mainly occur during transient loads, dominate the overall emission factor.

To predict such emission peaks, the models were extended by adding transient corrections. The EMPA model uses as dynamic variable the derivative of the manifold pressure. Using this dynamic map the engine-out emissions are very well predicted. A catalyst model is being furthermore considered which has as basic approach the modelling of the oxygen storage and release phenomena. The PHEM model developped at TU-Graz uses empirical transient correction functions based on several transient parameters, such as derivates of the engine power and engine speed over different time spans.

Considering fleets (groups) of vehicles, the quality of the models improves compared to the individual vehicle, even with a small number of vehicles. This proves that the errors in the individual vehicle models are random and not systematic. Thus, the two instantaneous emission models elaborated, although rather complex to develop, are able to predict contributory aspects like load, slope or different gear-shift scenarios, without introducing any ambiguous correction functions as it is usual for the bag based models.

3.3. Kinematic regression model

A second type of analytical model has been developed using emissions measured with 42 complete driving cycles and sub-cycles, a consistent set of kinematic parameters and a multivariate regression method based on principal components. The kinematic parameters belong to 2 blocks of variables: A first block of 7 variables (average running speed, average of the square speed, average of the cube speed, idling duration, duration at running speed, average product of instantaneous speed and acceleration, reciprocal of the trip length), and a second block of the two-dimensional distribution of the instantaneous speed (6 classes) and acceleration (7 classes). The final kinematic model is made, for each vehicle class, of a model for low emitters, a model for high emitters, and a model for all vehicles, and for each of the 3 cases, with a model 1 according to 7 kinematic parameters, a model 2 for 42 parameters, and a model 3 for 7+42 parameters.

The model 1 is the most understandable because the input parameters are average parameters, but it has the worst efficiency in terms of goodness of fit (R-square determination coefficient) as on overall for all emissions. The model 2 performs better and is in the most cases very close to the model 3, which is the most representative.

3.4. Traffic situations model

Following the Handbook approach [10], a “traffic situation approach” was developped. Compared to instantaneous or kinematic models, it is a non continuous or discrete model, which could be less accurate, but i) the kinematic input data are much simpler, as no speed profile neither complex kinematic parameters are necessary, ii) the kinematic input data are replaced by user oriented parameters, usually known by the traffic engineers.

The definition of traffic situations was elaborated after a large review of the European practices in order to be understandable across the different countries and users, and preferably close to the classifications usually implemented by traffic engineers. We adopted a road classification according to the function (access / distribution / through) and to the road network hierarchical organization, with 12 types of urban and rural roads. In addition, the road gradient and sinuosity were considered, with a qualitative approach (flat - sinuous / non-sinuous, hilly - ramps / sinuous, mountainous). Finally 4 levels of actual traffic conditions were also taken into account: free-flow traffic, heavy traffic, unsteady quite saturated traffic and the stop-and-go.

To characterize the speed characteristics of each traffic situation, a large collection of the existing European data recorded on-board vehicles, with 1500 speed - time curves, was compared with the traffic condition when available. It enabled a direct affectation of representative speed data for 69 traffic situations amongst more than 400. In addition 19 traffic situations correspond to each of the Artemis driving cycles or sub-cycles. For the other traffic situations, an affectation by similarity was done. However, this lack of data remains the main weakness of the approach and complementary data collection should be envisaged to improve it. 3 among the 19 traffic situations are macro situations, corresponding to urban, rural and motorway situations. In addition to all these traffic situations, we designed the most macroscopic traffic situation corresponding to the European situation, aggregating all other situations.

For the design of the corresponding emission factors, a large number of car emission data were considered, using more than 800 different driving cycles. In spite of its richness this heterogeneous dataset required a correction as regards the driving cycle. In that aim, we built-up a typology of test patterns to aggregate similar test cycles. Through Binary Correspondence Analysis and an automatic clustering, 15 classes or Reference Test Patterns (RTP) are defined, which can be combined together to compute emissions. For each RTP, one or several Reference Test Cycles are selected amongst the most significant in term of representativeness and number of associated emission data. To assess the emission factors of each RTP, the measured emission data were firstly corrected in order to process standardised data (see section 2.2); Then 2 models for deriving the emission factors for the RTP were developed.

For the model 1, the emission factors are computed on the base of a consistent sample of vehicles, i.e. the same vehicle sample for all RTPs as far as possible. For each of 14 RTPs out of 15, the emission data of 15 respective Reference test cycles (out of 21) were selected (14 Artemis sub-cycles plus one additional cycle); For the last RTP (urban stop and go), the emission data of another cycle were selected. With this restriction, the number of available measurements was significantly reduced to mostly Artemis subcycle measurements of Euro 2 and Euro 3 vehicles: The subset still consists of 1 500 vehicle.tests corresponding to 94 hours of measurements and 9 200 emission measurements. The emission factor per RTP is then derived from the average of measured emissions of the vehicle sample.

Model 2 considered the whole Artemis light vehicle emission measurement database (version 3 October 2005) described in section 2.2. The analyse of the variability and coherency of the emission data within each RTP and for each vehicle category shows some deviating cycles, generally far away from the Reference test cycles in term of kinematic, with however quasi-systematic under- or over-estimation: When they did not represent a high quantity of tests, the corresponding data were cancelled. From the 19 000 initial data, 10 000 coherent data (2672 diesel and 7381 petrol cars), corresponding to 1280 hours of emission measurements (of which 7350 vehicle.tests and 940 hours for Euro 2 and 3 vehicles), were retained. It enabled the computation of the emission for pre-Euro to Euro 4 passenger cars (see an examples on Figure 2). For Euro 2 - Euro 3 vehicles, the amount of data processed was thus 5 and 10 times larger than in for model 1 resp. when considering the number of data and the hours of measurements.

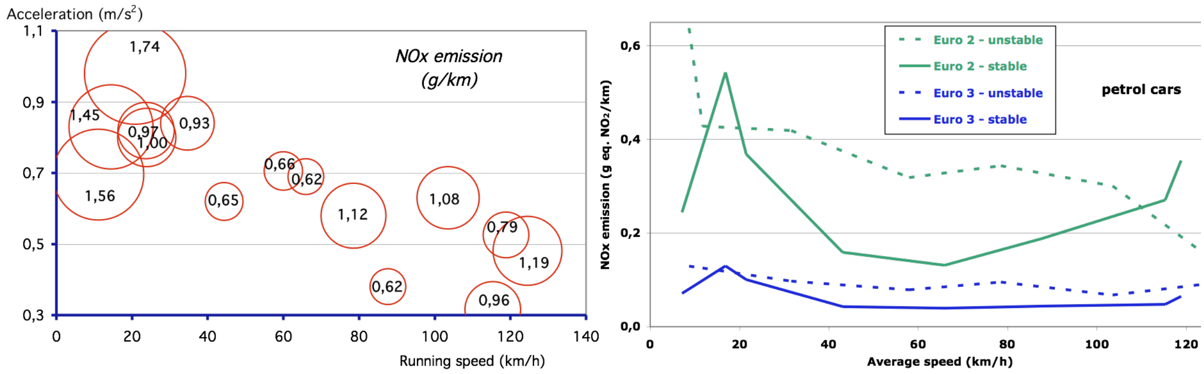

***Figure 2**: Variation of the NOx emission for the Traffic Situation model 2, for Euro 3 Diesel according to 15 RTPs (left), and for stable / unstable RTPs for petrol cars (right).*

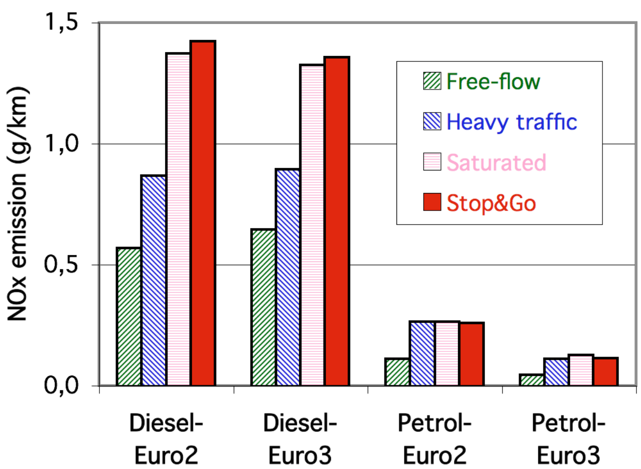

***Figure 3**: Traffic situation approach illustration: NOx emissions of cars estimated for an urban trunk road (speed limit: 50 km/h), at different traffic conditions.*

The emission cartography developed through the RTPs is particularly appropriated to compute emission for the different traffic situations. The distances between a traffic situation (represented by its speed curve) and the test cycles enabled thus identifying the closest test patterns and to consider each traffic situation as a linear combination of the RTPs, proportional to the proximity – in term of kinematic – to these test patterns. Therefore the emissions of hundreds traffic situations, including the 4 macro traffic situations, are computed by linear combination of the reference emissions of the closest RTPs, as defined in the model 2. These emission factors are illustrated in **Figure 3** for the 4 traffic conditions.

3.5. Average speed model

A fourth type of hot emission model was designed, similar to the MEET or Copert ones, i.e. taking into account kinematics through the average speed. Only hot emissions were used, but data were processed following two different statistical approaches, with different data clustering, leading to two alternative sets of speed dependent emission equations:

- A first model based on emission data clustering through 10 km h^{-1}speed range averaging in order to avoid overweighting of specific speed points with high number of data
- And a second model designed from the 15 RTP emission factors.

For the model 1, the emission data were corrected and homogenized against the ambient temperature and humidity, and gear choice strategy effects, but not according to vehicle mileage. An equation of the following general form was used for the emission factor *ef*, according to the average speed *v* (*a* to *f* being coefficients): $ef = \frac{a + c \cdot v + e \cdot v^2}{1 + b \cdot v + d \cdot v^2} + \frac{f}{v}$

The second model is derived from the RTP emission factors, as calculated within the development of the traffic situation model 2: The emission function is calculated by regression between these 15 RTP emission factors, expressed according to the average speed. The choice of the regression (power or 2nd to 5th order polynomial) is made for each data set with the following objectives: i)not to go outside the envelope of the measured points as far as possible, in order to avoid systematic over- or underestimation of emission for some speed ranges; ii)correspond to the apparent shape of the points according to the average speed; iii) avoid important oscillations; iv) never give negative figures; and v) be as simple as possible. This approach has the advantage to be fully coherent with the traffic situation model, based also on the RTP emission factors.

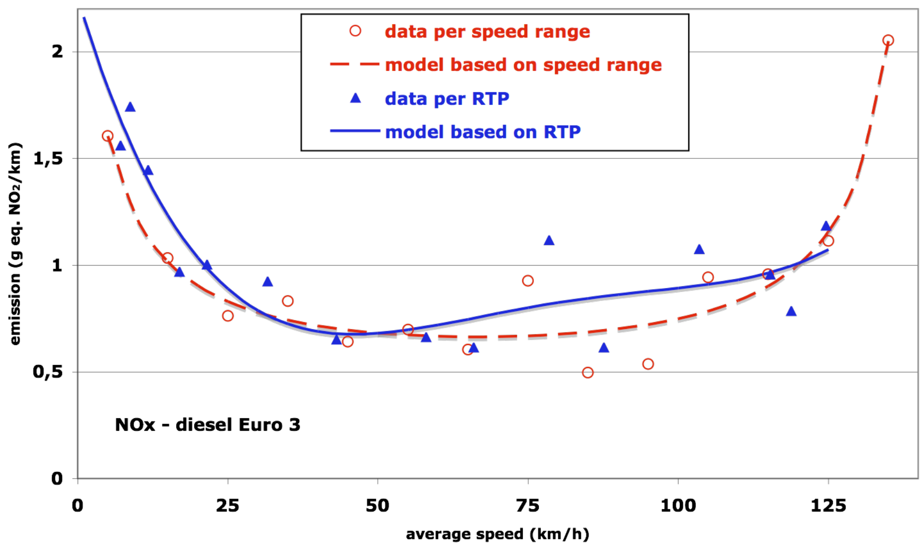

Figure 4: *Diesel Euro 3 NOx emission functions and data according to average speed, as designed through speed range averages or through RTPs.*

The comparison of the second approach based on RTPs with the first one based on speed range averages (see Figure 4) shows some differences in terms of curve shape and emission level, sometimes up to a factor 2. These differences may be attributed to the homogenization of the data as regard the vehicle mileage, done only in the second method, the way the emission data are clustered, the choice of the equation type. They show that such model depends a lot on the methodological assumptions.

Due to the lack of both measurement and literature data, it was decided to cover future vehicle technologies using reduction factors based on literature, limited available data and emission standard ratios.

3.6. Other sub-models

Due to the relative lack of data for Light Duty Vehicles, the LDV model is built as a function of the average speed and the vehicle loading rate. The influence of the mileage on hot emissions is a linear function of the mileage, with a maximum above 120 000 km for Euro 1 and 2 vehicles and 160 000 km for Euro 3 and 4 vehicles. The influence of the ambient temperature and humidity on the emissions are in most cases a linear function [8]. Road gradient and vehicle load are taking into account through a specific sub-model, together with auxiliaries. The modelling of cold start influence is based on the modelling of the cold excess emission in mass per start, depending on the ambient temperature, average speed and parking time. Then this extra emission is attributed to the trips, using statistics of trip length, start temperature and ambient temperature: Finally the cold extra emission model is a function of the season, the ambient temperature, the average speed and the hour of the day. It has to be added in parallel to the hot emission.

4. CONCLUSION

The aim of Artemis was to improve and update the European emission inventorying tools, but also to develop an harmonised approach, common to all European countries, by avoiding the former situation where several models were concurrent and gave different outputs for the same situation. This objective was only partially achieved. However, the Artemis model provides a series of models for distinct situations.

The model has been tested to calculate the road emissions for the period 1990-2004 in Sweden [13] for international reporting obligations on air emissions. There was in general a fairly good agreement with on-road emission data. The model for passenger cars and light commercial vehicles is implemented in the Artemis software [2], together with the models for 2 wheelers and heavy duty vehicles. In addition, separate models are provided for the non-road transport modes. All the light vehicle Artemis models (except the instantaneous and kinematic ones) and the software are publicly available and distributed free of charge.

The new vehicles, not tested in depth within the project, as Euro 4 and future Euro 5 ones, should be integrated on the basis of more extensive measurement campaign, including new or quite new concepts as for instance hybrid vehicles. For that the Artemis LVEM database could be used as far as this database includes all new emission measurements carried out in Europe on light vehicles.

The Artemis models were developed mainly for European users, although the model will be used, as Copert, by many users outside Europe. In some cases and especially for developing countries, the driving behaviour, the vehicles and the emission factors could be quite far from the European ones. The user's demand could also be different. It would be therefore very useful in the future to adapt the models to all the users, European or not.

5. ACKNOWLEDGEMENTS

We wish to thank the European Commission for its financial support as part of the contract n°1999-RD.10429 under the Competitive and sustainable growth programme of the 5th framework programme.

6. REFERENCES

1. André M., M. Rapone, N. Adra, I. Pollak, M. Keller & I. McCrae (2006): Traffic characteristics for the estimation of pollutant emissions from road transport – Artemis deliverable 10. *Inrets report*, Bron, France, LTE 0606, 89 p.
2. Artemis: www.inrets.fr/ur/lte/publi-autresactions/fichesresultats/cadrefichesresuvert.html
3. Barth, M., An, F., Norbeck, J. and Ross, M., (1996): Modal emissions modeling: A physical approach. *Transportation Research Record*, Vol. 1520, p. 81-88.
4. Hausberger S., W. Tripolt, J. Brenner, J. Wiesmayr & E. Bukvarevic (2005): Evaporative emissions of vehicles. Artemis deliverable 6, *TUG report*, Graz, Austria, 70 p.
5. Hickman J., D. Hassel, R. Joumard, Z. Samaras & S. Sorenson (1999): MEET - Methodology for calculating transport emissions and energy consumption. *European Commission*, DG VII, ISBN 92-828-6785-4, Luxembourg, 362 p. www.inrets.fr/infos/cost319/M22.pdf
6. Joumard R. (ed.) (1999): COST 319 - Estimation of pollutant emissions from transport: Scientific state-of-the-art and network of European scientists. *European Commission*, DG Transport, n°EUR 18902, ISBN 92-828-6797-8, Luxembourg, 174 p. www.inrets.fr/infos/cost319/index.html
7. Joumard R., P. Jost, A.J. Hickman & D. Hassel (1995): Hot passenger car emissions modelling as a function of instantaneous speed and acceleration. 3rd Int. Symp. *Transport and Air Pollution*, Avignon, France, 6-10 June, 1994, and Sc. Total Environ., vol. 69, p. 167-174.
8. Joumard R., M. André, J. Laurikko, T. Le Anh, S. Geivanidis, Z. Samaras, Z. Oláh, P. Devaux, J.M. André, E. Cornelis, P. Rouveirolles, S. Lacour , M.V. Prati, R. Vermeulen & M. Zallinger (2006): Accuracy of exhaust emissions measurements on vehicle bench - Artemis deliverable 2. *Inrets report*, Bron, France, n°LTE 0522, 140 p.
9. Joumard R., J.M. André, M. Rapone, M. Zallinger, N. Kljun, M. André, S. Samaras, S. Roujol, J. Laurikko, M. Weilenmann, K. Markewitz, S. Geivanidis, D. Ajtay & L. Paturel (2007): Emission factor modelling and database for light vehicles - Artemis deliverable 3. Inrets report, Bron, France, n°LTE 0523, 237 p. www.inrets.fr/ur/lte/publi-autresactions/fichesresultats/cadrefichesresuvert.html
10. Keller M. (2004): Handbook emission factors for road traffic (HBEFA, version 2.1). Software, Infras, Bern. www.umwelt-schweiz.ch/buwal/eng/fachgebiete/fg_luft/quellen/verkehr/emission/
11. Ntziachristos L. & Z Samaras (2000): Copert III, Computer Program to Calculate Emissions from Road Transport. *European Environment Agency*, Copenhagen.
12. Samaras Z., L. Ntziachristos, N. Thompson, D. Hall, R. Westerholm & P. Boulter (2005): Characterisation of exhaust particulate emissions from road vehicles (Particulates). *LAT report*, Thessaloniki, Greece, 114 p. http://lat.eng.auth.gr/particulates/deliverables/Particulates_D16.pdf
13. Sjödin A., M. Ekström, U. Hammarström, M.-R. Yahya, E. Ericsson, H. Larsson, J. Almén, C. Sandström & H. Johansson (2006): Implementation and Evaluation of the ARTEMIS Road Model for Sweden's International Reporting Obligations on Air Emissions. 2nd conf. *Environment & Transport*, incl. 15th conf. *Transport and Air Pollution*, 12-14 June 2006, Reims, France. Proceedings, actes Inrets, n°107, vol. 1, Arcueil, France, p. 375-382.
14. Sturm P.J., P. Boulter, P. de Haan, R. Joumard, S. Hausberger, J. Hickmann, M. Keller, W. Niederle, L. Ntziachristos, C. Reiter, Z. Samaras, G. Schinagl, T. Schweizer & R. Pischinger (1998): Instantaneous emission data and their use in estimating passenger car emissions. *VKM-THD Report*, Vol. 74, Verlag der Techn. Univ. Graz, Graz, Austria, 42 p., ISBN 3-901351-24-8.