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SAE_NA 2003-01-61

PROGRESS: A Computer Programme For Road Vehicles Emissions Evaluation

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ICE2003
6th International Conference on Engines for Automobile

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ABSTRACT

A computer PROGramme for Road vehicles EmiSSions evaluation (PROGRESS) was developed in order to assess the environmental impact from road traffic under real urban driving conditions. The procedure takes into account different aspects, i.e., the estimation of circulating fleet and the relevant urban driving statistics, the definition of typical urban trips and the evaluation of emission factors from road vehicles in urban environment. In the present release, PROGRESS allows to calculate the total mass of normalised pollutants at the exhaust of eight different vehicles categories, referring to the whole urban area (or part of it) and to different periods of time (ranging from one hour to one year).
In the paper the main characteristics of the PROGRESS code are presented, with reference to its structure, to the calculation procedure of hot, cold and total emissions and to the outputs. Finally an application is presented and discussed, referring to the city of Genoa.

INTRODUCTION

In recent years the continuous enforcement of legislation on air quality and exhaust emissions determined a significant progress to less polluting road vehicles. This was achieved through a substantial enhancement of vehicle powertrain systems (mostly internal combustion engines), the improvement of fuels quality and the widespread use of exhaust emissions aftertreatment devices.
In spite of this effort, the environmental impact of road transport remains still high, due to the considerable traffic growth and the consequent high share of energy used in this area [1].
The availability of flexible prediction models which allow to evaluate road vehicle emissions (with special reference to urban operation) highlighting the contribution of each vehicle category can help to better understand the situation and expected trends, supplying a powerful tool to plan structural or emergency actions aimed at the improvement of air quality in large urban areas.
Available procedures often used by research institutes and public administrations to predict the environmental impact of road vehicles are usually based on simplified models resulting from investigations referred to average European data [2, 3]. Moreover, emission factors are often related to a range of the vehicle average speed which doesn't allow to consider congested traffic situations and substantial approximations are adopted when evaluating the cold start effects on emissions or the contribution to air pollution of specific categories and classes whose importance is significant in many Italian urban areas (such as motorcycles and mopeds).

A dedicated procedure to assess road vehicles emissions has been developed within a joint research programme between the University of Genoa, the Provincial Administration and the Municipality of Genoa. A computer programme (PROGRESS) was set up which allows to calculate pollutant emissions (CO, HC, NO_X and PM) from different road vehicle categories and classes, taking into account basic input information, such as the composition of circulating fleet, the related urban mileage for each vehicle class and the definition of typical driving conditions. The code allows the evaluation of both cold and hot emissions from the considered vehicle categories and classes, referring to the whole urban area (or a specific portion of it) and to different time intervals.
The paper presents the main features of the calculation procedure, focusing on the selection of input information and the scheme adopted to evaluate exhaust emissions. A first application of the code is then presented, referring to the urban area of the city of Genoa: the relevant results for the year 2001 are presented and discussed, taking into account both circulating fleet composition and calculated road vehicles emissions.

DESCRIPTION OF PROGRESS STRUCTURE

The PROGRESS code was developed as a result of a two years technical–scientific co-operation between the Department of Thermal Machines, Energy Systems and Transportation (DIMSET) of the University of Genoa, the Environment Department of the Genoa Provincial Administration and the Mobility, Transport and Parking Sector of the Municipality of Genoa focused on the evaluation of pollutant emissions from road vehicles under real urban driving conditions in the city of Genoa.

As a first step, the identification of vehicle categories and classes was performed: on the basis of different sources (European Directives on exhaust emissions, UN-ECE classification, etc), eight different vehicle categories were defined (spark ignition and Diesel passenger cars and light duty vehicles, heavy duty commercial vehicles, buses, motorcycles and mopeds). They were further split in classes with reference to various parameters (i.e., engine displacement, combustion system, vehicle reference weight, year of production, 2 or 4 stroke engine, etc).

The wide investigation programme was then divided in different phases, respectively aiming at the assessment of the actual circulating fleet and the related urban mileage, the definition of typical driving conditions and the evaluation of road vehicle emission factors associated to urban travels [1]. As regards fleet composition and typical driving conditions, reference was made to the specific situation of the city of Genoa. The results of each task were then used in the development of PROGRESS, in order to evaluate the total mass of regulated pollutants (i.e., carbon monoxide, unburnt hydrocarbons, nitrogen oxides and particulate matter) at the exhaust of considered road vehicles, referring to the whole urban area (or part of it) and to different periods of time (ranging from one hour to one year).

The programme was developed in Excel® and is based on ten different data sheet:

- general information;
- data input;
- vehicle categories and classes selection;
- fleet composition;
- mileage;
- hot emission factors;
- hot emissions evaluation;
- cold emission factors;
- cold emissions evaluation;
- total (hot + cold) emissions evaluation.

A further data sheet summarises the main results of programme calculations, i.e., the number of considered vehicles and their total mileage, the hot and total masses of pollutants and their distribution between the selected categories, expressed as percentage. Further outputs are mean hot and cold emission factors for each vehicle category, while the mass of pollutants emitted by a single vehicle class are also known, both in absolute and relative terms.
A short description of the main data sheet is reported below, while the application of PROGRESS to the evaluation of road transport emissions in Genoa urban area will be presented in the following section.

DATA INPUT – The calculation procedure is mainly based on the management of four groups of parameters for which input options are required:

1. registered or actual circulating fleet;
2. mileage related to the considered area and period of time;
3. hot emission factors;
4. cold emission factors.

As regards groups 1 and 2, three different options are available: default values, input for each considered class, input of total vehicles number and/or mileage. In the last case a single value is given, which is divided between the selected categories and classes according to the distribution obtained through the default values. These three different input modes for fleet and mileage definition were included in order to enhance the code flexibility and its capability to interact with other models and simulators.

In order to calculate hot emission factors, a reference year is requested, since some of them are corrected according to the vehicles total mileage and to the fleet composition, which depends on this parameter. Moreover, the frequency distribution of urban trips related to three mean speed classes (≤10 km/h, 10÷40 km/h and ≥40 km/h) for which emission factors were defined has to be fixed: default values are available (10, 85 and 5%, respectively) [4], but they can easily be changed in order to evaluate more congested or fluent traffic conditions.

As regards cold emissions evaluation, a mean value for urban trips length is requested: again a default value is available (6.6 km), which was calculated on the basis of a statistical investigation on urban mobility in Genoa, which allowed to estimate the total number of trips and the related mileage in an average day for the morning and evening peak hours (6:30÷9:00 am and 5:00÷8.00 pm). Finally, the frequency distribution of urban trips related to five ambient temperature classes (≤5 °C, 5÷10 °C, 10÷15 °C, 15÷20 °C and ≥ 20 °C) has to be defined, to allow a proper estimation of cold emission factors by weighting the contribution due to the different seasons; default values are obtained by averaging historical series related to monthly maximum and minimum temperature levels in Genoa and considering a uniform distribution of trips within the year.

VEHICLES CATEGORIES AND CLASSES SELECTION – This data sheet allows to select the road vehicles categories and the related classes for which emissions evaluation is performed.

Tab.1 – Identification of vehicle categories

Road vehicles categories	**Classes**
Spark ignition passenger cars (SI PC)	10
Diesel passenger cars (Diesel PC)	5
Spark ignition light duty vehicles (SI LDV)	5
Diesel light duty vehicles (Diesel LDV)	5
Heavy duty commercial vehicles (HDV)	6
Buses	6
Motorcycles	6
Mopeds	3

It is worth to notice that within PROGREES code a total number of 46 classes can be considered (tab.1, including those already defined by EU regulations on exhaust emissions for future years), while in a preliminary phase this number was higher than 140: a proper reduction was performed by joining homogeneous classes on the basis of collected information on emissions factors, circulating fleet, etc.

FLEET COMPOSITION – As previously described, data related to registered or actual circulating fleet can be given in three different forms: default values, input for each considered class or input of the total number of vehicles. While the second and the third choice are related to users' specific information (for example outputs from traffic simulators), the first is based on a proper processing of data from the National Register Office [5]: it is well known that the registered fleet is different in size from the circulating one, due to several factors that affect the actual use of vehicles [1]. Moreover, it is quite difficult to estimate a general relationship between them: an attempt was performed during the investigation on which PROGRESS is based, by comparing data on registered fleet with measurements from experimental traffic surveys and data from statistical studies on mobility, but the results were not completely reliable or were limited only to passenger cars. Therefore, for a general application of the code (i.e., for annual emissions evaluations referred to the whole urban area), the fleet registered in the considered area is taken into account for the different vehicle categories, associated with the mean values of urban mileage, related to the same period of time. Passenger cars and motorcycles number is properly increased (respectively of 20 and 10%, values obtained on the basis of a statistical investigation on urban mobility in Genoa) in order to consider in the calculation the vehicles starting outside and coming to the selected urban area.

As regards mopeds, the National Vehicle Register doesn't quantify them, due to the fact that the registration number isn't associated to the vehicle, but to its owner: this means that information from different sources [6, 7, 8] has to be considered in order to perform a correct estimate of mopeds figures, which represent a significant share of the total number of road vehicles (fig.1).
This data sheet is completed by the total amount of road vehicles included in the calculation, together with the relevant distribution among the selected categories.

MILEAGE – The above considerations can be applied also to this data sheet: while information for each considered class or on the total vehicles mileage are related to specific studies aiming at the deepening of different aspects according to users' requirements, default values were chosen in order to allow a general application of the code.
Different sources were taken into account to complete this database: for passenger cars, data related to a statistical investigation on urban mobility in Genoa were processed, thus linking the total annual mileage to the year of registration and then to the legislation phase on exhaust emissions, taking into account the PC fleet composition. To evaluate the annual mileage in urban driving mode, the distribution reported in [2] with reference to Italy was then adopted. As regards buses, data supplied by the local transport company were considered, which proved to be very close to those presented in [2, 9, 10]. For the other vehicle categories (LDV, HDV, motorcycles and mopeds), only information related to national surveys was available [9, 10]. A further investigation on this aspect seems necessary to take into account the increasing use of motorcycles and mopeds in some urban areas and the importance of HDV traffic in Genoa, related to commercial shipping activities.
The data sheet also provides information on the total mileage of vehicles included in the calculation, together with the relevant distribution among the selected categories.

TOTAL (HOT + COLD) EMISSIONS EVALUATION – In general, for each vehicle of a specific class, the total emission e_{total} (g) on a trip of a fixed length d (km) is given by:

$$(e_{total})_{i,j} = (f_{hot})_{i,j} \cdot (f_{MC})_{i,j} \cdot d + (e_{cold})_{i,j}$$

for i = CO, HC, NO_x and PM
j = vehicle class

where:

- $(f_{hot})_{i,j}$ = hot emission factor (g/km, referred to a new vehicle), defined by comparing and processing data from different sources (experimental values from normalised cycles, European Directives limits, reports of the Cost319/Meet/Copert III projects, information from car makers, research institutes, universities, etc) [1].
- $(f_{MC})_{i,j}$ = mileage correction factor, estimated on the basis of data referred to measurements on the European driving cycle, properly processed in order to evaluate hot urban values for different mileage levels [1].
- $(e_{cold})_{i,j}$ = cold additional emission (g), calculated by integration of cold instantaneous emission factor $(f_{cold})_{i,j}$ on a trip of fixed length d, for proper values of mean speed and ambient temperature:

$$(e_{cold})_{i,j} = \int_0^d (f_{cold})_{i,j}\, dx$$

where

$$(f_{cold})_{i,j} = a_{i,j} \cdot \exp(-x / t_{i,j});$$

Cold instantaneous emission factor $(f_{cold})_{i,j}$ (g/km) is expressed as a decreasing exponential function of the travelled distance x (km), being $a_{i,j}$ = instantaneous emission factor at engine start and $t_{i,j}$ related to cold transient length; $a_{i,j}$ and $t_{i,j}$ levels were defined on the basis of experimental cold data on ECE15 cycle first repetition or part of it, with reference to two ambient temperature levels (0 and 20 °C) and three mean speed values (10, 20 and 40 km/h) [1].

On the basis of the above described calculation procedure, PROGRESS is therefore able to evaluate total emissions for a specific context: once hot emission factors are included in the related data sheet for the three considered mean speed classes (≤10 km/h, 10÷40 km/h and ≥40 km/h), average values are computed for each vehicle class taking into account the relevant urban mileage and the frequency distribution of urban trips referred to mean speed, thus allowing to define mean hot emission factors $(F_{hot\ mean})_{i,j}$. A similar calculation is performed for cold emissions, further complicated by the application of a mean value for urban trips length and of the frequency distribution of urban trips related to five ambient temperature classes: finally mean cold emission factors $(F_{cold\ mean})_{i,j}$ are obtained.

Hot and cold emissions ($(E_{hot})_{i,j}$ and $(E_{cold})_{i,j}$) in a given time interval for a selected vehicle class (j), which is characterised by the number of vehicles N_j and their travelled distance M_j (for example, a mean urban mileage in the fixed time interval), are therefore evaluated through the following products:

$$(E_{hot})_{i,j} = (F_{hot\ mean})_{i,j} \cdot N_j \cdot M_j;$$

$$(E_{cold})_{i,j} = (F_{cold\ mean})_{i,j} \cdot N_j \cdot M_j$$

for i = CO, HC, NO_x and PM.

It is then possible to obtain the class total emissions:

$$(E_{total})_{i,j} = (E_{hot})_{i,j} + (E_{cold})_{i,j}$$

which, added to the contributions of the other classes selected for the considered application, finally allows to evaluate total emissions:

$$(E_{total})_i = \sum_j (E_{total})_{i,j}$$

for i = CO, HC, NO_x and PM.

Hot, cold and total mass of pollutants and their distribution among the selected categories are reported in the related data sheet.

ROAD TRANSPORT EMISSIONS IN GENOA URBAN AREA

ROAD VEHICLES FLEET AND MILEAGE – A first application of the calculation procedure described in the previous section was performed referring to the whole urban area of the city of Genoa and to the year 2001, for which updated information on fleet composition was available.
Fig.1 presents the distribution (expressed as percentage of the total value) of road vehicles fleet and related urban mileage in Genoa for the year 2001. As regards fleet composition (fig.1a), reported data result from the integration of different sources in order to take into account the share of each vehicle category. It is apparent that typical private mobility (cars, motorcycles and mopeds) accounts for over 95% of the total number of circulating vehicles. Passenger cars (particularly those fitted with gasoline engine) represent the biggest figure according to the national trend [1, 5]; however, it is worth noticing the significant share of two-wheel vehicles (motorcycles and mopeds) in Genoa, which represent over 30% of total vehicles. The trend to a wider use of motorcycles and mopeds in central zones is typical of large urban areas in Italy, due to traffic congestion and parking difficulty. This tendency is even stronger in Genoa related to the territory characteristics and the climate conditions, which allow for an extensive use of two-wheelers all over the year.

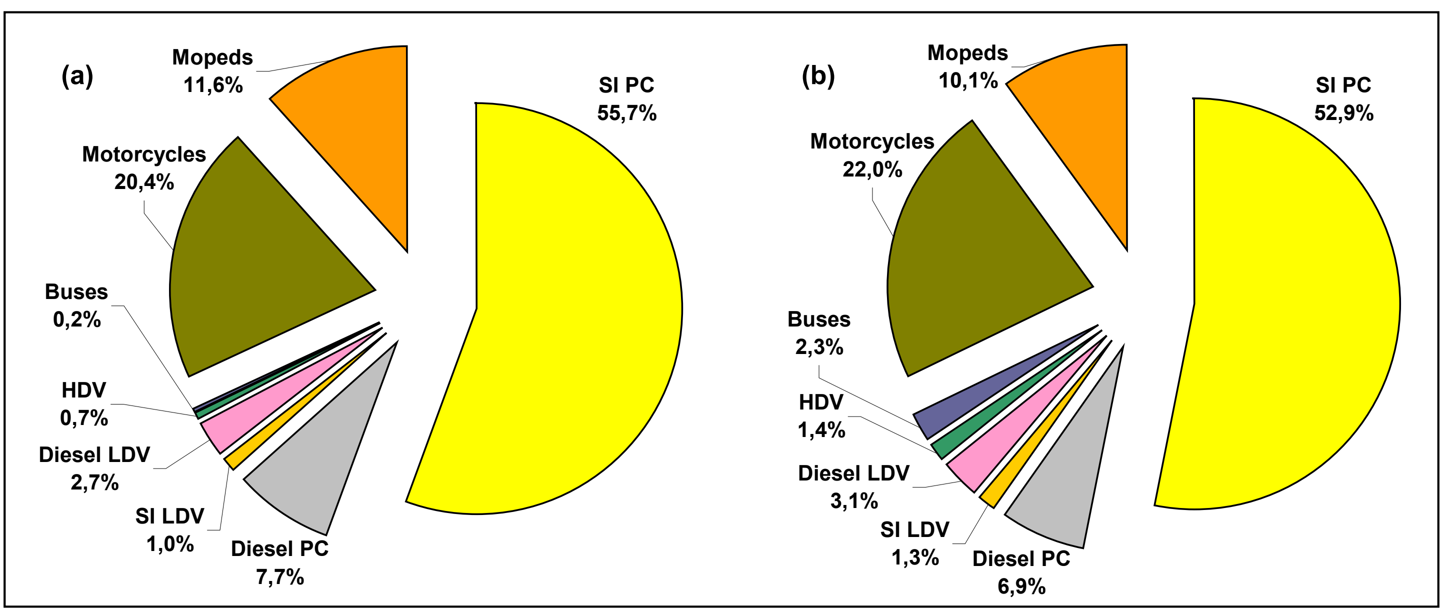

Fig.1 – Distribution of road vehicles fleet (a) and total urban mileage (b).

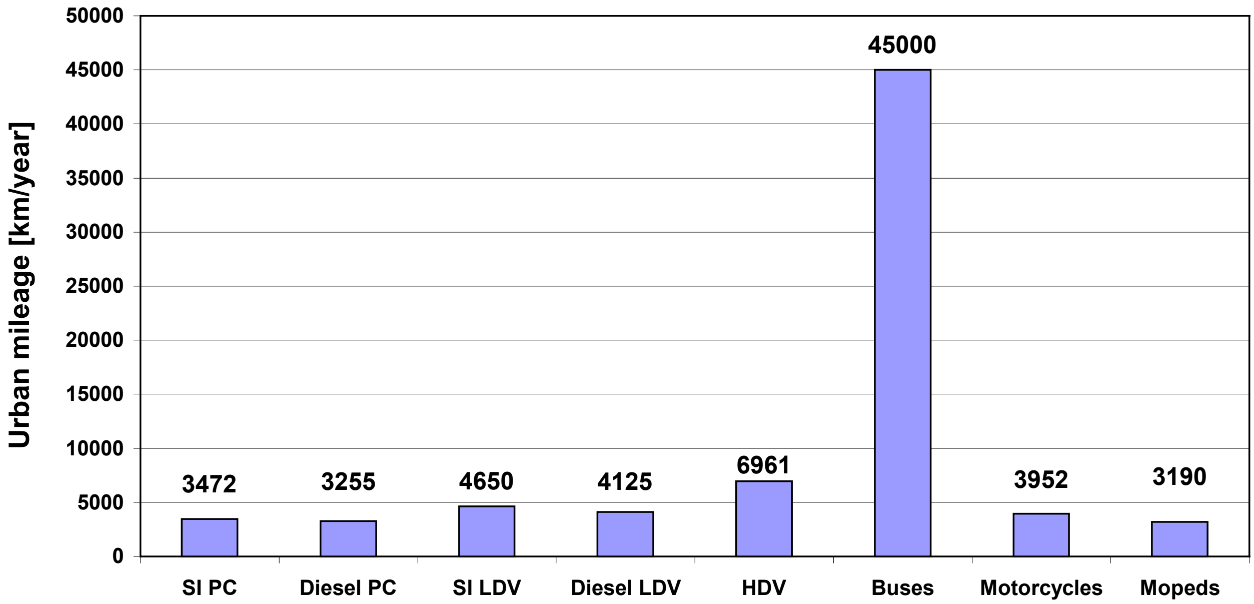

Fig.2 – Urban mileage per vehicle.

As regards heavy-duty vehicles (HDV), the share in fig.1a probably underestimates the real circulating fleet, being referred only to vehicles registered in Genoa. In order to evaluate the real circulating number of HDV, particularly in specific zones highly involved with industrial and shipping activities, a dedicated study seems suitable taking into account the number of vehicles entering and leaving the urban area and their typical driving schedules.

The distribution of road vehicles total urban mileage (fig.1b) is strictly related to the fleet composition, since urban mileage calculation for the different vehicle categories (calculated according to the above mentioned procedure based on different sources) provided quite similar results for the weightiest groups (fig.2). The only remarkable exception was found for buses which proved to have a mileage about ten times the average level of other vehicle categories. The consequent impact on the distribution of total mileage is not negligible, since buses, which account for only 0.2% of the circulating fleet, are responsible for 2.3% of total mileage in Genoa urban area.

Referring to the most important category of the circulating fleet in Genoa urban area, fig.3 shows a split of gasoline passenger cars by EU exhaust emissions regulations. Data related to fleet composition and total

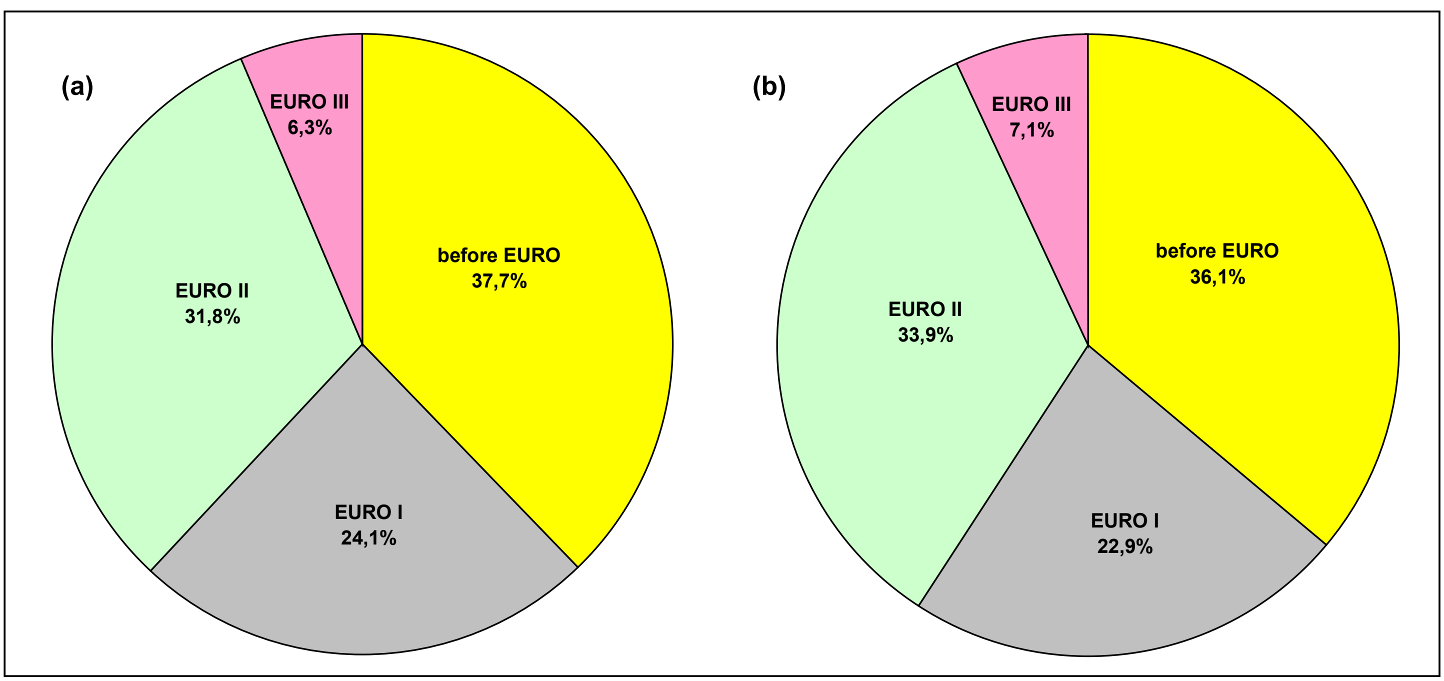

Fig.3 – Distribution of SI passenger cars (a) and related total urban mileage (b).

urban mileage are presented taking into account four classes, being all vehicles registered before 31/12/92 included in a single class (before-Euro).
It is interesting to note (fig.3a) that, despite national government incentives to old car wrecking and local restrictions to the circulation of more emitting vehicles in the central urban area, in the year 2001 the before-Euro class was still the largest, accounting for about 38% of the gasoline cars registered fleet in Genoa. This aspect is related to the slow renewal of spark ignition passenger car fleet, whose life cycle still approaches an average value of 15 years. This is also confirmed by the Euro III class share in the year 2001 (mostly vehicles registered starting 1/1/01), which was slightly over 6%. If passenger cars fitted with three-ways catalyst are considered, the Euro II class (registering period from 1/1/97 to 31/12/00) was the largest but the share of Euro I vehicles (registering period from 31/12/92 to 31/12/96) was also significant. SI cars aged over five years represented over 60% of the total fleet in Genoa at the end of the year 2001. It is interesting to note that in the case of Diesel cars a different fleet composition was found, with a share of Euro II and Euro III vehicles of about 70%.

The diagram of SI passenger cars urban mileage (fig.3b) confirms the distribution related to the fleet composition. Slightly increased shares can be observed for more recent vehicles but the shifts are quite low, generally between 1 and 2%. This result was not completely expected, since it is generally assessed that cars annual mileage is related to their age, increasing for more recent vehicles. This trend was also confirmed for SI passenger cars fleet in Genoa, but only referring to the vehicle total mileage (fig.4). When the urban mileage was calculated according to the procedure suggested in [2], taking into account different urban driving fractions for each legislation phase on exhaust emissions, the resulting data proved to be quite similar (fig.4) and the tendency to a lower mileage for the oldest vehicles was strongly reduced. The obtained distribution of total and urban SI cars mileage may suggest that aged vehicles are really less used than more recent ones, but their mission is mainly restricted to urban driving.

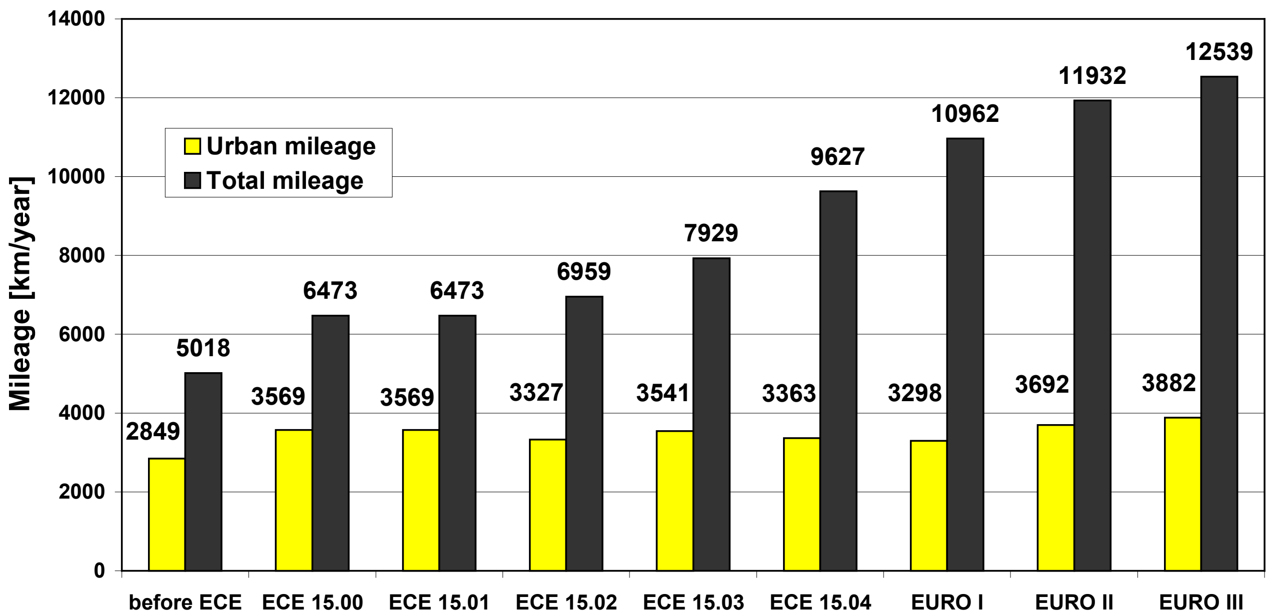

Fig.4 – SI passenger cars total and urban mileage.

As previously observed (fig.1), motorcycles represent an important category in many urban areas, referring both to the number of circulating vehicles and to the related urban mileage. Fig.5 shows the distribution of motorcycles in Genoa, referring to the year 2001, evaluated on the basis of different sources [6, 11]. In this case the before-Euro class (vehicles registered before 17/6/99) represents over 66% of the circulating fleet, with a prevailing share of motorcycles fitted with two-

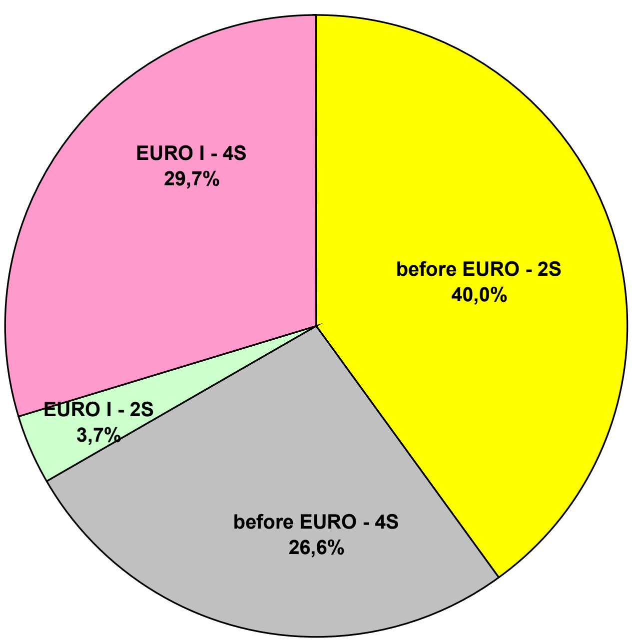

Fig.5 – Distribution of motorcycles.

stroke engine. However, it is worthy of note that at the end of the year 2001 Euro I vehicles was about one third of the total number of registered motorcycles in Genoa, with a significant share of four-stroke engines (about 90%) which more easily comply with stricter exhaust emission limits.
The relatively high number of recent motorcycles may be related to the mentioned parking difficulties in the central zone of the city of Genoa but also to an increasing use of two-wheel vehicles in the congested urban area. In any case, these aspects forced the renewal of the two-wheel fleet whose speed seems higher than that observed for passenger cars.

TOTAL EMISSIONS DISTRIBUTION – As described in the previous section, within the PROGRESS code total emissions are evaluated separately for the 46 considered classes (tab.1), since many parameters (hot and cold emission factors, vehicle number and mileage, etc) are function of each vehicle class. If the attention is focused only on larger groups, the relevant values referred to a specific vehicle category can be simply derived by adding the contributions from all the classes included in the category of interest (tab.1). Moreover, as a further intermediate result, the mean total emission factors, given by the ratios between total emissions and mileage can be evaluated. Tab.2 shows an example of it, referred to year 2001. Since mean emission factors depend on a great number of variables (vehicle fleet, mileage, reference year, frequency distribution of urban trips related to mean speed and ambient temperature levels, mean value of urban trips length, etc), their application to different urban environments should be carefully evaluated, even if it may be useful as a first approach. The presented values allow to identify the most polluting vehicles according to the different substances (SI passenger cars for CO, mopeds for HC, buses for NO_x and PM). Anyway, in order to properly compare private and public vehicles, a further step is necessary, taking into account the number of passengers: while average values for cars, motorcycles and mopeds approach the unit (1.2 passengers is the mean typical figure for cars in Genoa), buses present higher values, with an average level of 25 passengers per vehicle, balancing their substantial contribution to air pollution with the advantages of a public transport system.

Tab.2 – Mean total (hot + cold) emission factors for road vehicles.

Category	CO	HC	NO_x	PM
	[g/km]			
SI PC	22.84	2.72	0.75	0.06
Diesel PC	1.21	0.35	0.81	0.36
SI LDV	33.33	3.39	1.28	0.07
Diesel LDV	1.98	0.39	2.44	0.83
HDV	4.55	3.18	9.82	0.91
Buses	18.34	2.32	23.15	1.57
Motorcycles	21.14	5.53	0.33	0.04
Mopeds	18.68	11.42	0.04	0.20

Moreover, mean factors reported in tab.2 help to analyse the results related to the distribution of total emissions (fig.6), while data referred to total pollution are presented in tab.3, together with the relevant contributions due to cold start effects.

Tab.3 – Total emissions and related cold contribution.

Total emissions [t]			
CO	**HC**	**NO_x**	**PM**
36570	7417	2387	299
Cold emissions [%]			
36.5	19.4	3.0	20.7

First of all, it should be noticed that, in the first release of PROGRESS, it wasn't possible to estimate cold emissions at the exhaust of motorcycles and mopeds, since data available in the open literature don't allow the definition of a reliable calculation procedure, as it was for passenger cars [1].
This approximation probably led to:

- underestimate two wheelers contribution to CO and HC emissions, since at engine start these vehicles either work with rich mixtures (before-Euro class) or present poor catalyst conversion efficiency (Euro I class). However, in this case the effects should be less significant of those outlined for passenger cars [1, 3], due to a lower catalyst global efficiency;
- a negligible effect on NO_x emissions, due to the low contribution of two wheelers to this pollutant, especially if fitted with 2S engines;
- underestimate PM emission, since experimental results show ratios between cold and hot PM emissions of 2S engine mopeds ranging from 1.3 (before-Euro) to 2.5 (Euro I, with catalyst) [12].

Considering the distribution of total CO emission among the eight considered vehicle categories (fig.6a), the most significant share is due to SI passenger cars, mainly related to their cold emissions: in fact, SI cars are responsible for 97% of calculated CO cold pollution (tab.3). Other significant contributions are due to motorcycles and mopeds, whose share is strictly related to the relevant urban mileage (fig.1b); in this case it should be taken into account that, in the considered year, a significant share of motorcycles (slightly over 40%, fig.5) and all the mopeds were equipped with 2S engines, whose operating conditions with rich mixtures for lubricating requirements lead to high CO exhaust levels. Despite their very high mean emission factor, SI light duty vehicles contribution is very low, due to the small fleet share (fig.1).

As regards total HC emission (fig.6b), two wheelers contribution confirms to be very high (about 60%). This is again related to 2S engines equipped vehicles, which present the well known short-circuiting phenomenon, with fresh charge exiting directly from the exhaust port during the scavenge process: the influence of fresh charge short circuiting is outlined by mopeds and motorcycles HC mean emission factors (tab.2),

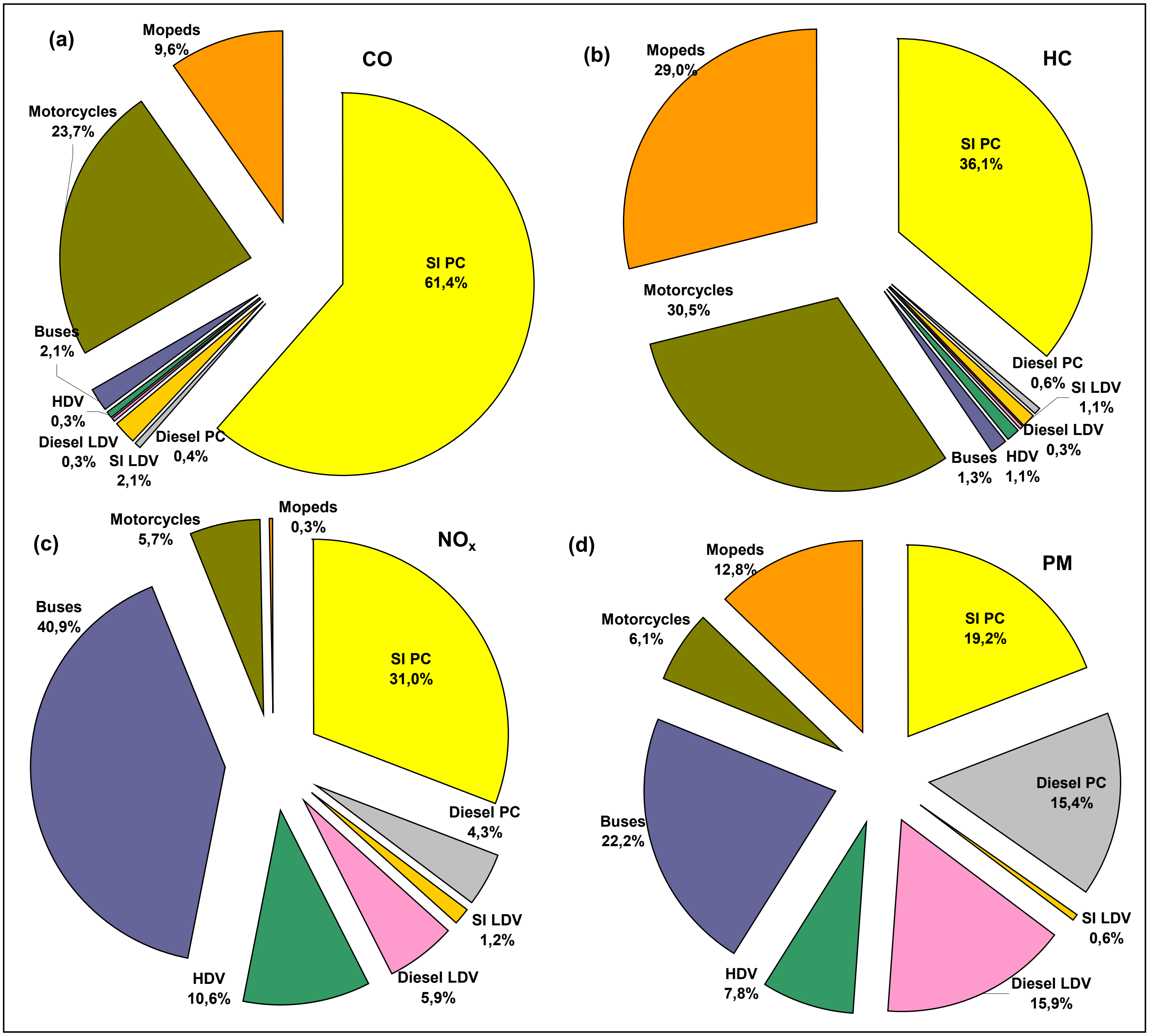

Fig.6 – Distribution of total CO, HC, NO_x and PM emissions.

respectively four and two times higher than that of SI cars, which, on its hand, includes cold start effects.

Total NO_x emission distribution shows a different situation (fig.6c), since buses are responsible for the most significant share. Their considerable average emission factor (tab.2) is mainly related to a 60% of vehicles belonging to the older class (before-Euro, registered before 1993), fitted with high NO_x emitting Diesel engines. In this case, cold emission contribution is negligible (tab.3).

The distribution of total PM emission is presented in fig.6d: this is probably the most interesting graph, both due to the great interest in PM pollution and its effect on human health and to the fact that, through the application of proper emission factors to all the categories fitted with SI engines (usually considered not affected by this pollutant), significant shares are also associated to SI cars and two wheelers.

Mopeds and motorcycles PM emission factors used in the calculations are based on three different experimental investigations [11, 12, 13], which achieved similar results, thus allowing for a reliable evaluation. The most polluting vehicles are respectively motorcycles belonging to before-Euro 2S engine class (86.9% of their category) and mopeds of before-Euro class (which contributes for 96.4% of mopeds PM emission). This is probably due to the strong correlation between particulate pollution and lubricant consumption [13].

On the other hand, data related to SI cars are based only on one reference [14]; in this case, additional experimental results are probably needed to define

suitable emission factors. However, it is worth remarking that cars registered before 1993 (before-Euro class) seem responsible for 93.4% of PM pollution, while a few percent is associated to catalysed cars. Different kinds of particulate can be emitted by gasoline engines, with organic particles including soot, soluble organic fractions (SOF), sulphates and lead [15]. The last source can be neglected, since measurements reported in [14] were performed with unleaded fuel. Soot emissions are mainly related to operation with very rich mixtures, therefore sulphates and SOF are probably the main components of measured particulate emissions in [14].
The analysis outlines that PM pollution due to SI vehicles should be substantially reduced in future thanks to the fleet renewal. However, in the present situation, emergency plans related to high PM10 concentrations in ambient air should also consider at least aged SI vehicles.
Finally, it must be noticed that PM cold emission is significant (about 21%, tab.3) and completely due to Diesel cars and light duty vehicles (99%). This distribution could be modified as an effect of PROGRESS future improvement related to specific aspects, such as heavy duty vehicles urban impact and cold start operation of two wheelers.

CONCLUSION

According to data reported in the emissions inventories [9, 10, 16], road transport is one of the main sources of air pollution. The knowledge of road vehicles emission factors in real use and the availability of models to calculate total emissions represent basic requirements to develop any project finalised to the enhancement of air quality in urban areas.

To this purpose, a computer PROGramme for Road vehicles EmiSSions evaluation (PROGRESS) was developed as a result of a joint investigation programme between the University of Genoa, the Provincial Administration and the Municipality of Genoa. In the paper, its flexible structure and calculation procedure, which allows the evaluation of CO, HC, NO_x and PM hot and cold emissions at the exhaust of different vehicle categories and classes referring to a selected urban area and time interval, was first described.
Then, an application of the code was presented with reference to total emissions in the whole urban area of the city of Genoa in year 2001. The main results of performed calculations can be summarised as follows:

- cars, motorcycles and mopeds accounts for over 90% of the total road vehicles fleet and urban mileage, with the highest share for SI cars, but with a significant contribution from two wheelers;
- CO and HC total emissions are mainly emitted by SI cars, motorcycles and mopeds, as a consequence of their fleet share, but also due to significant cold emissions of SI cars and to high emitting 2-stroke engines usually fitted on two wheelers;
- the most important contribution to NO_x emission is provided by buses, whose fleet includes about 60% of vehicles registered before 1993;
- PM emission distribution involves contributions from all the considered categories. Within the investigation it was possible to define proper emission factors also for vehicles fitted with SI engines. As a consequence, significant PM emission shares were evaluated for SI cars, motorcycles and mopeds, mainly due to older vehicles.

These results, together with more detailed analysis performed through the code, confirm PROGRESS to be a powerful and flexible tool for wide investigations on road vehicles pollution within urban environment.
Further improvements are scheduled, in order to deepen different aspects related both to the circulating fleet and to emission factors, with special reference to heavy duty vehicles, motorcycles and mopeds. Moreover, the integration with models for traffic and air quality prediction will be developed, in order to study the effects of operating mobility plans on emissions.

ACKNOWLEDGMENTS

This work was developed with the financial support of the Ministry for the Environment and the Territory Protection.
The authors would like to thank the Environment Department of the Genoa Provincial Administration and the Mobility, Transport and Parking Sector of the Municipality of Genoa for their permission to the publication of the paper.

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