ANALYSIS OF DIFFERENT METHODOLOGIES FOR THE CALCULATION OF POLLUTANT EMISSIONS FROM VEHICLES

ANALIZA DIFERITELOR METODOLOGII PENTRU CALCULUL EMISIILOR DE POLUANȚI DE LA VEHICULE

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***Abstract**: Emissions from road transport are a key category in the Energy module. Their values are large, and the transport sector has become a key category also in the total emissions in the country. In this regard, the methodology for calculating emissions from transport plays an important role in adequately assessing real emissions. European countries and a number of countries on other continents use COPERT and other special programs. For Moldova, the use of software is done for the first time. Ways to overcome a number of difficulties are described. The experience gained allows made to another quality level of calculations for this category.*

Keywords: Emissions, greenhouse gases, inventory, pollutants, road vehicles, COPERT, experience, speed, driving mode.

***Rezumat**: Emisiile din transportul rutier reprezintă o categorie cheie în modulul Energie. Valorile acestora sunt mari, iar sectorul transporturilor a devenit o categorie cheie și în totalul emisiilor din țară. În acest sens, metodologia de calcul a emisiilor din transport joacă un rol important în evaluarea adecvată a emisiilor reale. Țările europene și o serie de țări de pe alte continente utilizează COPERT și alte programe speciale. Pentru Moldova, utilizarea software-ului se face pentru prima dată. Sunt descrise modalități de a depăși o serie de dificultăți. Experiența acumulată permite efectuarea calculelor pentru această categorie la un alt nivel de calitate.*

Cuvinte cheie: Emisii, gaze cu efect de seră, inventar, poluanți, vehicule rutiere, COPERT, experiență, viteză, mod de conducere.

1. Introduction

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During the recent years, the road transport as the key source of greenhouse gases emissions and pollution seems to draw a great share of attention. This occurs at the background of ever-growing number of vehicles around the world. Incorporation of a number of ecological regulations (Euro standards) concerning brand new cars highlights the attempts to reduce the road transport emissions.

Overall, this move gives positive outcomes although there is still a lot to do in order to reduce emissions in this sector. Thereat, accurate and adequate assessment of emissions from road transport is of paramount importance.

Emissions can be estimated by direct measurements and by calculation. Measurements, undoubtedly, are the best way, but require significant funds and special equipment.

Calculation methods are available for use in all countries. Methods are divided according to the degree of detail. The basic input data for all methods are: the amount of fuels consumed the number of cars of different categories, information about the driving mode (speed, distance traveled and types of roads), emission control methods, fuel characteristics and fuel quality.

The methodology for calculating greenhouse gas emissions is set out in the Guidelines for Assessing Climate Change (IPCC-Intergovernmental Panel on Climate Change), in the EMEP Guidelines (European Monitoring and Evaluation Program) for assessing a range of pollutants under the CLRTAP Convention [1-2]. Motor transport is included as a separate category in the “Energy” module, and can be calculated using one of three methods, depending on the tasks and availability of primary data. Most preferred is the most detailed method of calculation.

It is implemented in a special computer soft COPERT [3]. The methodology and mathematical apparatus are described in the IPCC and EMEP Guidebooks, as well as in the publications of the soft developers [8,16].

The application of the program is carried out by research groups in many countries. The analysis of total emissions by country is reflected in the Informative Inventory Reports under the CLRTAP Convention [15].

Analysis of emissions from vehicles is carried out for separately large cities [6,8], and is compared with the results obtained for other programs [9,13]. Additional analysis approaches are described to overcome difficulties due to incompleteness of primary information [12], and which are individual for countries and cities.

In this regard, the experience in using the COPERT computer soft, and the preparation of a specific set of primary data, a description of ways to search for missing data on the vehicle fleet and data on the driving mode, is valuable [4,12,14]. There are works that analyze the impact on human health, [10], describe standards, control measures and measures to reduce emissions [11].

Moldova produces such estimates over the last 20 years as part of preparation of the National Communication and Greenhouse Gas Sources and Sinks National Inventory Report for the IPCC country assessment reports. Published over the past period were four National Informative and four Emissions Inventory Reports for the IPCC as well as a number of other books. Photo images of such appear in Fig. 1 below.

Figure 1- National Communications and National Greenhouse Gas Inventories and Inventory Informative Report of pollutants emissions published in 2000-2018

2. Methodology calculating greenhouse gas emissions

Cadaster compilers and experts tend to select the method of estimation stemming from the targets set and the availability of primary data. The estimates data obtained when using higher-level data are then compared with the results obtained using the simplest tier 1 methodology.

The Tier 1 method uses the simple formula (1), which includes two factors — the amount of fuel used and the emission factor.

$$Emissions\ i = \sum_a (Fuel_a * EF_a) \quad (1)$$

Where:

Fuel - consumed fuel (TJ or tone) (represented by fuel sold);

*EF*a is the emission factor for a specific pollutant *i* (kg / TJ or kg/tone);

A -the type of fuel;
i -the type of pollutant.

Default emission factors for greenhouse gases (CO_2, CH_4, N_2O,) are available in the IPCC Manual, version 2006 [1]. Emission factors for 13 pollutants (CO, NO_x, NMVOC, SO_x, NH_3, Pb. Se, Cd. Cr, Hg, PAH, HCB, PCB, and some others) are in the European versions of the EMEP Guidelines (European Monitornig and Evaluation Program) [2].

The emission factors used for calculating emissions in the country are taken in the table 1.

Table 1 - *Emission factors used to estimate greenhouse gas emissions*

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_x (SO_2)
Fuel	kg/TJ	kg/TJ	kg/TJ	kg/tone	kg/tone	kg/tone	kg/TJ
Gasoline	69300	33,0	3,2	8,7	84,7	10,1	45,7
Diesel / Gas Oil	74100	3,9	3,9	13,0	3,3	0,7	141,0
Matural gas	56100	92,0	3,0	13,0	5,7	0,3	0,0
LPG	63100	62,0	0,2	15,2	84,7	13,6	130,3
Kerosine	71900	3,9	3,9	8,73	84,7	10,05	139,114
Other oils	74100	3,9	3,9	8,73	84,7	10,05	149,254
Source:	*IPCC-2006*			*EMEP-2016*			

Tier 2 methodology bears on the same formula although duly documented national emission factors are required.

Tier 3 methodology bears on a special software COPERT. This software allows for calculation of about 200 pollutants, of which 30 are basic [3].

Detailed description of the calculation methodology complete with the mathematical fundamentals appears in the 2016 EMEP Guidebook.

Estimation of emissions when carrying out greenhouse gas inventory according to the vehicle category was bearing on tier 1 methodology. Likewise done were two attempts to make use of COPERT software (2012, 2018). The results of these were not included into the National Inventory Report. The purpose of this paper is to deliver a brief description of the experience in application of this soft. Also, a comparison of the results obtained by method 1 and method 3.

3. The results of calculations of emissions according to method 1 for road vehicles of the RM

a) Brief description of the motor transport sector

The vehicle fleet of the Right Bank region of the country is constantly growing (Fig. 2.) and includes:

1) Cars on gasoline and diesel fuel, and also equipped to use two types of fuel (including LPG and CNG); electric cars (category M1);

2) Light trucks up to 3.5 tons (N1) on gasoline, diesel fuel and on two types of additional types of fuel (liquefied petroleum gas LPG and compressed natural gas CNG);

3) Heavy trucks (N2-N3) on diesel fuel of different carrying capacity, including with trailers;

4) Buses urban and tourist on diesel fuel and compressed gas (M2-M3);

5) Motorcycles of different engine sizes (L1-L5), on gasoline.

The number of cars, according to the Statistical Yearbooks of the National Bureau of Statistics for 2014-2016 (Fig. 2), is slightly different (down) from the data on car registration (http://www.asp.gov.md) (Fig. 8). This highlights the system-wide problem of verifying data from different sources. The data on http://www.asp.gov.md are basic in the performed calculations.

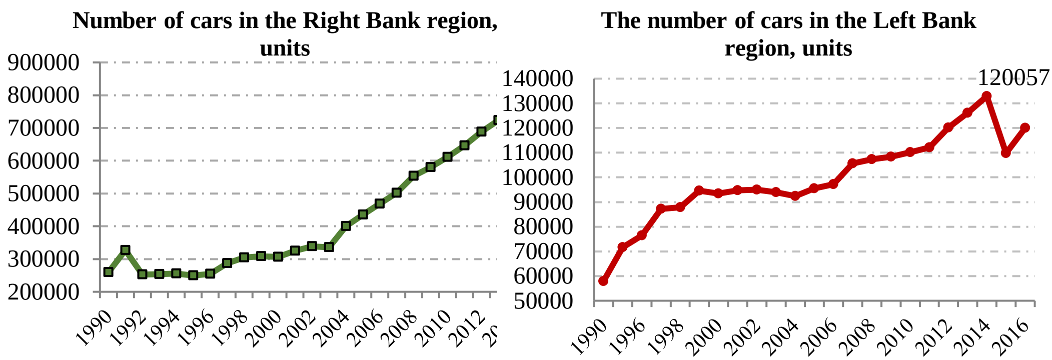

Figure 2 - The increase number of cars in the regions of the country for 1990-2016

b) Number of CO_2 emissions from motor vehicles

Emissions (CO_2, CH_4 and N_2O) are converted to CO_2-equivalent (CO_2-e) by multiplying the values of each gas by global warming coefficients (1.25.298), respectively, table 2.

Table 2 - *Greenhouse gas emissions in the category "Road Transport", CO_2-e thousand tones*

	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO_2	3826,363	2875,256	1975,653	1408,067	1289,420	1318,588	1240,187	1340,369	1166,576

CH_4	32,414	24,396	17,002	11,413	10,421	10,666	10,278	11,442	9,788
N_2O	54,968	41,323	28,294	20,225	18,549	19,003	17,830	19,157	16,710
Total, CO_2-e	3913,745	2940,976	2020,949	1439,705	1318,390	1348,257	1268,295	1370,969	1193,075
	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO_2	771,734	857,580	944,658	1147,418	1409,914	1571,642	1607,263	1543,990	1652,970
CH_4	5,958	6,053	6,435	8,145	9,667	10,305	10,606	9,760	10,233
N_2O	11,088	12,418	13,793	16,681	20,537	23,033	23,539	22,689	24,311
Total, CO_2-e	788,780	876,051	964,886	1172,244	1440,117	1604,980	1641,407	1576,439	1687,514
	2008	2009	2010	2011	2012	2013	2014	2015	2016
CO_2	1751,153	1710,757	1954,269	2069,938	1808,352	1933,954	2030,075	2120,021	2271,255
CH_4	10,763	10,961	11,246	11,238	9,693	9,800	9,787	10,277	11,977
N_2O	25,651	25,030	28,795	30,675	26,703	28,724	30,251	31,597	34,039
Total, CO_2-e	1787,568	1746,748	1994,310	2111,850	1844,748	1972,478	2070,113	2161,896	2317,271

CO_2 emissions decreased from 3862 (1990) to 2271 (2016), CH_4 from 32.414 to 11.19, N_2O- from 54.968 to 34.04 thousand tones. The total amount of CO_2-e emissions in the Republic of Moldova decreased from 3913.745 (1990) to 2317.271(2016) thousand tones (Fig. 3). The distribution of emissions by region (Left Bank and Right Bank) in 2016 was in the ratio of 12% and 88% (Fig. 4).

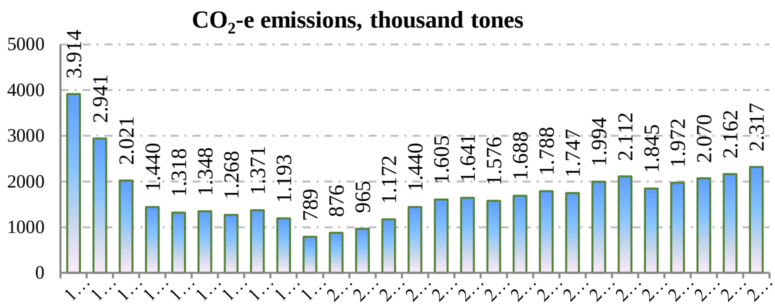

Figure 3 - Total CO2 emissions from motor vehicles, thousand tones

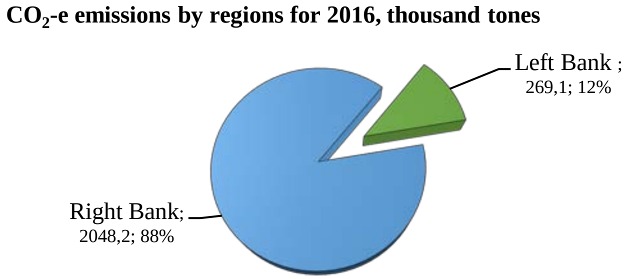

Figure 4 - The ratio of emissions by regions

c) Number of NO_x, CO, NMVOC, SO_2 emissions

Values emissions gases with indirect effects (unstable, short life) calculated by the method of level 1, table 3.

Table 3 - *Indirect gases emissions from the motor transport of the RM, thousand tones*

	1990	1991	1992	1993	1994	1995	1996	1997	1998
NOx	11,041	10,085	5,712	5,961	4,654	4,939	4,598	4,876	4,167
CO	67,563	61,837	29,770	23,606	21,949	22,996	21,855	24,819	21,107
NMVOC	8,154	7,460	3,623	2,907	2,677	2,799	2,657	3,002	2,554
SO_2	4,298	3,229	2,217	1,677	1,510	1,516	1,415	1,476	1,307
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
NOx	2,906	3,242	3,503	4,339	5,482	6,120	6,270	5,929	6,333
CO	12,434	12,241	13,133	16,919	20,389	21,791	22,451	20,528	21,154
NMVOC	1,515	1,496	1,604	2,065	2,512	2,688	2,768	2,544	2,629
SO_2	0,945	1,116	1,234	1,463	1,833	2,081	2,124	2,084	2,271
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
NOx	6,791	6,640	7,863	8,259	7,307	7,816	7,858	8,322	8,872
CO	22,055	22,011	21,587	22,284	18,671	18,220	18,022	18,456	18,890
NMVOC	2,755	2,742	2,736	2,820	2,387	2,345	2,323	2,381	2,433
SO_2	2,441	2,350	2,854	3,045	2,715	2,974	3,170	3,317	3,519

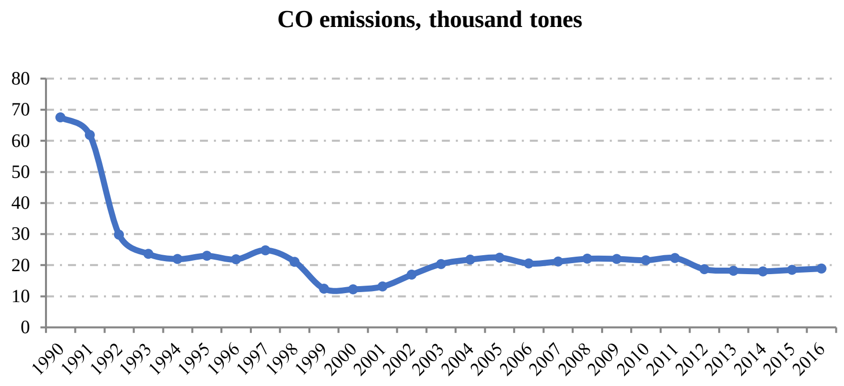

Figure 5 - Carbon monoxide emissions, thousand tones

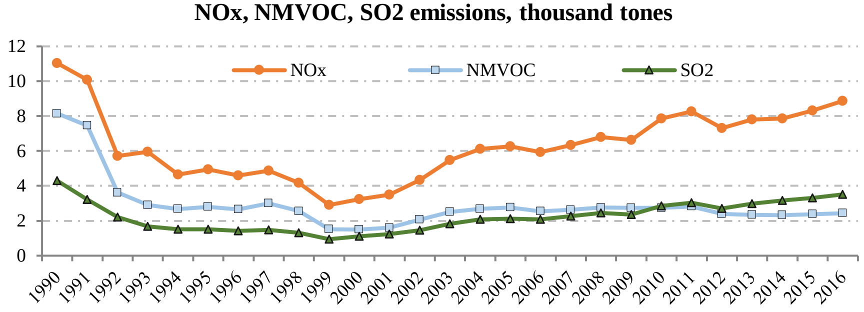

Figure 6 - NOx, NMVOC, SO2 emissions, thousand tones

The emissions of indirect gases also decreased in the period 1990-2016 (Fig. 5.6), namely (thousand tones):

- CO: from 67,563 to 18,890,
- NO_x: from 11.041 to 8.872;
- NMVOC: from 8,154 to 2,433;
- SO_2: from 4.298 to 3.519.

d) Activity data

The amounts of consumed fuels, presented in the Energy Balances of different years in the line "Road transport", were used to compile time series, table 4.

Table 4- *Fuel consumption Road Transport, 1990–2016, TJ*

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Gasoline	33752	25323	17375	11293	10739	11373	10750	12365	10482
Diesel/Gas Oil	18973	14275	9706	7832	6977	6897	6353	6236	5677
Natural gas	779	625	471	317	205	147	205	117	117
LPG	599	436	412	387	264	176	205	235	205
Kerosene				41					
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Gasoline	5998	5916	6457	8273	9793	10487	10761	9857	10062
Diesel/Gas Oil	4510	5721	6493	7475	9552	11134	11321	11369	12549
Natural gas	88	88	88	102	88	87	99	71	108
LPG	235	264	176	230	293	237	255	230	296
Kerosene	29	29					14		15
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Gasoline	10297	10322	9769	10272	8314	7973	7846	8047	8179
Diesel/Gas Oil	13527	12885	16509	17835	16005	17957	19390	20325	21795
Natural gas	92	207	281	139	153	242	223	297	982
LPG	476	461	600	455	595	590	587	629	545
Kerosene			3	1					
Other oils			1		2				

The general trends for 1990/2016 have the following dynamics, Fig.7:

- Gasoline consumption decreased from 33,752 to 8179 TJ, or more than 4 times;

- The use of diesel fuel increased 18,973 to 21,795 TJ or 1.15 times;
- There is an increase in the use of compressed natural gas 779 to 982 TJ, or 1.26 times;
- The dynamics of consumption of liquefied petroleum gas is maintained at about the same level: 599 (1990) to 545 (2016) TJ.

It should be noted that trends for all fuels have a decrease in the period 1994-2008, and then there is a steady increase.

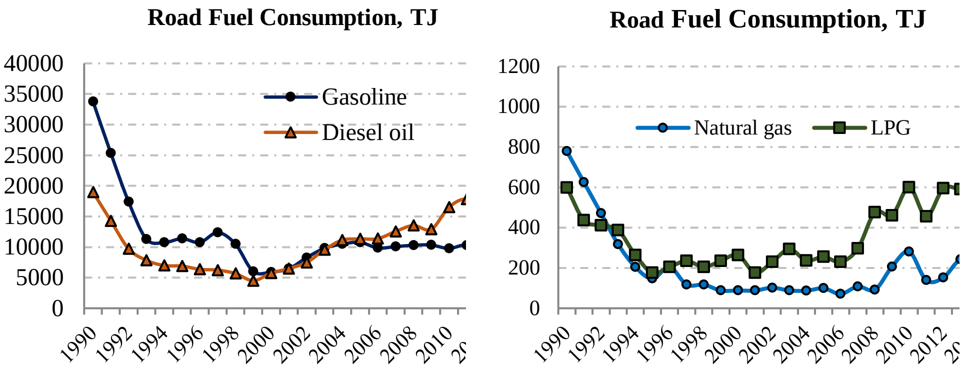

Figure 7 - Dynamics of fuel consumption for motor transport, TJ

The above emission values were estimated using the Tier 1 method. Also, the Tier 3 method was using the COPERT special soft.

The interface of version 4.9 software COPERT is a series of windows. It is necessary to enter (or import) the primary data showing the number of vehicles in each group as well as the driving modes.

4. Stages of work with COPERT

Working with the program involves several stages: preparing primary input data, working directly with the program, obtaining results of calculating emissions of each pollutant, analyzing and comparing the amounts of emissions of each pollutant with the quantities obtained by method 1.

Input data include information concerning vehicle fleet configuration; driving modes on different types of roads (rural and urban area, highway); vehicle compliance with the Euro-emission standards; consumption rate for each type of fuel; data on quality specifications of fuels and types of fuel used. These data have laid the foundation of basic input information.

Other data (such as road sloping, traffic/cargo load, etc.) were needed in order to estimate some minor additives in overall emissions. Output data were represented by the quantities of pollutant emissions for each group of vehicles in line with a preset configuration of vehicle fleet.There are two stages in software operation. Set at stage one was the operation mode of calculating the emission factors (derived from fuel specifications, driving speed on different types of road, etc.). The main parameter accounted for was the driving speed.Calculation of emission factors was done in the system of first- second- and third-order equations. Directly calculated at stage two were the emissions with the use of factors identified at stage one [7,8].

The primary data require some groundwork on distribution and systematization of data and should include as follows:

1) number of vehicles specifying engine cylinder capacity for different categories (such as: passenger cars M1, buses M2-M3, light commercial vehicles N1, heavy-duty vehicles N2-N3, motorcycles L1-L5); see Table 5;

2) vehicle year of manufacture or type of Euro standard;

3) n type of fuel (Gasoline, Diesel oil, LNG, LPG);

4) overall consumption of each type of fuel by Road transport (according to Energy Balances).

Table 5 - *Summary of all vehicle categories covered by the EMEP emission inventory guidebook 2016*

Category	Description
M1	Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat.
N1:	Vehicles used for the carriage of goods and having a maximum weight not exceeding 3.5 tonnes.
N2:	Vehicles used for the carriage of goods and having a maximum weight exceeding 3.5 tonnes but not exceeding 12 tonnes.
N3:	Vehicles used for the carriage of goods and having a maximum weight exceeding 12 tonnes.
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 tonnes.
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 tonnes.
L1:	Two-wheel powered vehicles with an engine cylinder capacity not exceeding 50 cm^3 , a maximum design speed not exceeding 40 km/h.
L2:	Three-wheel vehicles with an engine cylinder capacity not exceeding 50 см3, a maximum design speed not exceeding 40 km/h.
L3:	Two-wheel powered vehicles with an engine cylinder capacity exceeding 50 cm^3 or maximum design speed exceeding 40 km/h.

L4:	Three-wheel vehicles, symmetrically disposed with respect to the longitudinal central line with an engine cylinder capacity exceeding 50 см3 or maximum design speed exceeding 40 km/h (motorcycles with sidecar).
L5:	Three-wheel vehicles, asymmetrically disposed with respect to the longitudinal central line with an engine cylinder capacity exceeding 50 см3 or maximum design speed exceeding 40 km/h (motorcycles with sidecar), with maximum total mass not more than 1000 kg and either engine cylinder capacity exceeding 50 cm³ or maximum design speed exceeding 40 km/h (motorcycles with sidecar).

	2014	**%**	**2016**	**%**
M1	512 561	*66,5*	546 781	*66,9*
N1	114 784	*14,9*	120 582	*14,8*
N2-N3	95 784	*12,4*	100 180	*12,3*
L1+L5	25 941	*3,4*	28 642	*3,5*
M2-M3	21 377	*2,8*	20 995	*2,6*
Total	**770 447**		**817 180**	

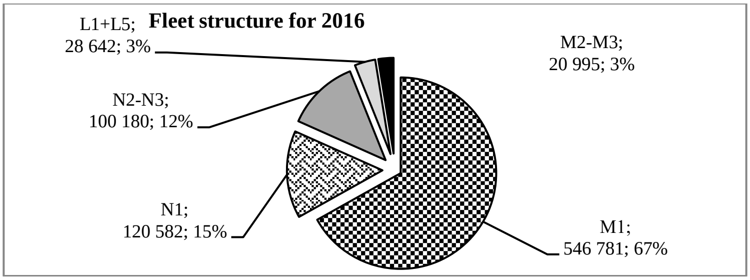

Figure 8 - Vehicle fleet structure for 2014 and 2016

5. Requirements for data formats and program interface

The COPERT 4.9 software includes several windows (Fig. 9 - the first window) for recording: the number of cars in each group, the driving mode parameters.The driving mode implies speed limits on different types of roads, including urban and rural area, highway as well as the share of vehicle driving on each type of roads.

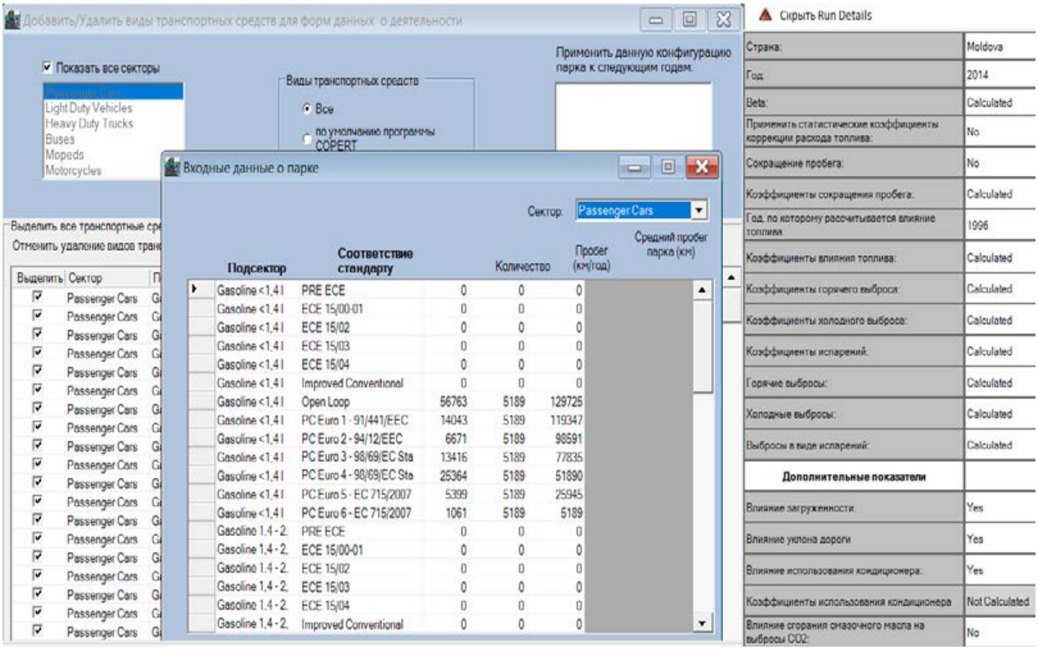

Figure 9 - A window for recording the configuration of the vehicle fleet for COPERT 4.9 software

The car fleet must be presented in great detail for each group of cars and for each European standard separately. To do this, follow these steps: Distribute the number of gasoline passenger cars by 4 types of engine volumes;

- the number of diesel passenger cars divided into groups according to 3 types of engine volumes;
- the number of light trucks should be divided into 3 groups by weight;
- the number of heavy trucks should be divided into 8 groups by weight (7.5-12 tons, 12-14 tons, 14-16 tons, 16-20 tons, 20-24 tons, 24-28 tons, 28-32 tons, more 32 tons);
- the number of buses must be presented in two types - urban and tourist;
- within each group of buses, additional weight separation is required.

As a result, the total number of cars is divided into 28 categories for 4 types of fuel and for 8 European standards (including 6 European standards and two "prewar" standards). This task needs to be solved at the beginning of work to fill a large table by car fleet configuration (step 1).

The program has the ability to take into account biofuels too, as well as specific characteristics of the fuel (according to the existing fuel quality standards).

For example, for the Republic of Moldova in the period 2014-2016 in the primary data there are many cars on two types of fuel (gasoline + liquefied gas, gasoline + compressed gas and other combinations). There are hybrid cars There are cars without specifying the type of fuel ("undefined"). A variety of fuels consumed requires a preliminary "convolution" of the number of cars to the types of fuels that are provided in the program (step 2). The type of European standard can be determined by the year of production of the machine, if it is not specified in advance (step 3).

Next, you must specify the speed of movement on different types of roads (step 4). There are no direct data on speed values. In this regard, we need either measurements of actual speeds or expert estimated values that need to be justified (*assumption 1*).

A separate indicator is the average annual mileage of cars. Statistical information on “ton-km” or “passenger-km” is not enough to calculate this indicator. Data on the average annual mileage of vehicles required for each individual category of vehicles and for each type of fuel. They can be calculated by the number of cars, the typical fuel consumption and the total fuel consumption of each type. The calculated average annual mileage will be estimated (*assumption 2*), but they can be refined and adjusted for the fuel balance in the calculations.

To clarify these values is necessary or to request transport companies, or recommend to the accounting statistics on a regular basis. As recommended indicators for such accounting, we note the average annual mileage of cars of each category and the number of cars of each category, indicating the weight and volume of engines.

6. Systematization of Data

For three years, there are detailed data obtained by the Office on Climate Change. They include the number of vehicles (TS) for the period 1990-2016, but divided into non-uniform intervals.

The number of cars is also distributed in most standard categories of vehicles (28). However, the primary data can not be used directly.

The difficulties are in the following points:

1) Many categories – 28, Euro standards 8 (6 + two previous "to the Euro");

2) Vehicle actually use not 4 types of fuel, but more than 10 types of combinations, which requires a "roll" to 4 types of fuel;

3) Some data on the vehicle is not in the form that is needed (for example, special cars). Such vehicles must first be attributed to the desired category of vehicle, based on the principles that the movement was carried out on a more economical fuel. The distribution of vehicles according to 3 conditions (Euro standards, fuel types and engine volumes (or grades by weight)) required the development of special intermediate files for switching to COPERT formats.

The result of the preliminary distribution is the tables, the form of which corresponds to COPERT (fig. 6).

Table 6 - *Distribution of vehicles by Euro standard*

	Units	**Total**
Passenger Cars Gasoline <1,4 l Conventional	56763	
Passenger Cars Gasoline <1,4 l PC Euro 1 - 91/441/EEC	14043	
Passenger Cars Gasoline <1,4 l PC Euro 2 - 94/12/EEC	6671	
Passenger Cars Gasoline <1,4 l PC Euro 3 - 98/69/EC Stage2000	13416	
Passenger Cars Gasoline <1,4 l PC Euro 4 - 98/69/EC Stage2005	25364	
Passenger Cars Gasoline <1,4 l Euro 5-2010	5399	
Passenger Cars Gasoline <1,4 l Euro 6-2014	1061	122718

The next step is to fill the tables with lists for each category for substitution into the program in the form (for example, for M1 on gasoline): These kits should be filled for each fuel type and for each vehicle category: for M1 - 7; for N1 - 4; for N2 - 2 for each type of fuel - total 8; for N3 - 6 for each type of fuel - total 24; for buses -16; for mopeds - 4; for motorcycles-12. The data prepared in a special file allows to start working with the program and fill in the largest table in it, according to the fleet structure, fig. 10.

				2014		
				Units	Суммарно	Comments
	Light Duty Vehicles	Gasoline <3,5t	Conventional	4897		IC+OP = <1990+ (199
N1	Light Duty Vehicles	Gasoline <3,5t	LD Euro 1 - 93/59/EEC	1798		
	Light Duty Vehicles	Gasoline <3,5t	LD Euro 2 - 96/69/EEC	2095		
	Light Duty Vehicles	Gasoline <3,5t	LD Euro 3 - 98/69/EC Stage2000	3422		
	Light Duty Vehicles	Gasoline <3,5t	LD Euro 4 - 98/69/EC Stage2005	567		
	Light Duty Vehicles	Gasoline <3,5t	Euro 5-2010	66		
	Light Duty Vehicles	Gasoline <3,5t	Euro 6-2014	11	12857	
	Light Duty Vehicles	Diesel <3,5 t	Conventional	18501		IC+OP = <1990+ (199
	Light Duty Vehicles	Diesel <3,5 t	LD Euro 1 - 93/59/EEC	15059		add differences "-1"
	Light Duty Vehicles	Diesel <3,5 t	LD Euro 2 - 96/69/EEC	22042		
	Light Duty Vehicles	Diesel <3,5 t	LD Euro 3 - 98/69/EC Stage2000	37564		
	Light Duty Vehicles	Diesel <3,5 t	LD Euro 4 - 98/69/EC Stage2005	7113		
	Light Duty Vehicles	Diesel <3,5 t	Euro 5-2010	788		
	Light Duty Vehicles	Diesel <3,5 t	Euro 6-2014	131	101198	
	Light Duty Vehicles	LPG <3,5 t	Conventional	70		IC+OP = <1990+ (199
	Light Duty Vehicles	LPG <3,5 t	LD Euro 1 - 93/59/EEC	82		
	Light Duty Vehicles	LPG <3,5 t	LD Euro 2 - 96/69/EEC	126		
	Light Duty Vehicles	LPG <3,5 t	LD Euro 3 - 98/69/EC Stage2000	217		
	Light Duty Vehicles	LPG <3,5 t	LD Euro 4 - 98/69/EC Stage2005	42		
	Light Duty Vehicles	LPG <3,5 t	Euro 5-2010	5		
	Light Duty Vehicles	LPG <3,5 t	Euro 6-2014	1	543	
	Light Duty Vehicles	Gas comprimat <3,5 t	Conventional	26		IC+OP = <1990+ (199
	Light Duty Vehicles	Gas comprimat <3,5 t	LD Euro 1 - 93/59/EEC	28		
	Light Duty Vehicles	Gas comprimat <3,5 t	LD Euro 2 - 96/69/EEC	43		
	Light Duty Vehicles	Gas comprimat <3,5 t	LD Euro 3 - 98/69/EC Stage2000	73		
	Light Duty Vehicles	Gas comprimat <3,5 t	LD Euro 4 - 98/69/EC Stage2005	14		
	Light Duty Vehicles	Gas comprimat <3,5 t	Euro 5-2010	2		
	Light Duty Vehicles	Gas comprimat <3,5 t	Euro 6-2014	0	186	

Figure 10 - Prepared data on the number of cars for category N1 for one year (fragment)

Filling the list of cars in COPERT can be done manually, but it is possible also to import from Excel. Special File - "bulb" to import in the program was developed and used to conduct a number of experiments. For each year, about 100 experimental calculations were carried out for different speeds and average annual runs. At the end of each calculation, the fuel balance is checked. This made it possible to make adjustments for driving modes.

7. Calculation of emissions

The main components of emissions are emissions from hot and cold engines. You can also calculate additional emissions: from consideration of the quality of the fuel, evaporation from gasoline, the influence of the air conditioner, and the burning of lubricating oil.

It is possible to take into account other supporting aspects: traffic congestion, the number of axles, the slope of the road, the use of selective catalytic reduction systems and other. But the main and biggest are emissions from hot and cold engine.

The kind of the final output information of emissions of each pollutant (for example, VOC) is given in table. 7.

Table 7- *Fragment of the page of the output file of the program (by pollutant emissions VOC)*

Sector	**Subsector**	**Technology**	**2016**
Passenger Cars	Gasoline <1,4 l	PRE ECE	0
Passenger Cars	Gasoline <1,4 l	ECE 15/00-01	0
Passenger Cars	Gasoline <1,4 l	ECE 15/02	0
Passenger Cars	Gasoline <1,4 l	ECE 15/03	0
Passenger Cars	Gasoline <1,4 l	ECE 15/04	0
Passenger Cars	Gasoline <1,4 l	Improved Conventional	0
Passenger Cars	Gasoline <1,4 l	Open Loop	54301
Passenger Cars	Gasoline <1,4 l	PC Euro 1 - 91/441/EEC	13432
Passenger Cars	Gasoline <1,4 l	PC Euro 2 - 94/12/EEC	6385
Passenger Cars	Gasoline <1,4 l	PC Euro 3 - 98/69/EC Stage2000	12998
Passenger Cars	Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	31704
Passenger Cars	Gasoline <1,4 l	PC Euro 5 - EC 715/2007	6274
Passenger Cars	Gasoline <1,4 l	PC Euro 6 - EC 715/2007	2792
Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	0
Passenger Cars	Gasoline 1,4 - 2,0 l	Improved Conventional	0
Passenger Cars	Gasoline 1,4 - 2,0 l	Open Loop	62564
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	30017
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	19285
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	32134

8. Calculation of fuel consumption

At the end of each experimental cycle, the fuel balance is calculated. This is necessary for the verification of the actual consumed fuels and the calculated quantities that are obtained with the given parameters of the movement of vehicles.

If there is a discrepancy of more than 10%, the COPERT instruction recommends [3]:

1) to adjust the mileage data on each drive mode (urban, rural, highway);

2) adjust the speed parameters, which depend on the emission factors calculated COPERT (speed included as a multiplier with different exponents, depending on the type of equations);
3) adjust the distribution of technology.

In the current works, recalculation cycles were performed until the convergence in the fuel balance was (-0.05) - (+ 0.05) %.

The variants with the best convergence in the fuel balance and the selected parameters of the driving mode were analyzed additionally to determine emission trends. These calculations are made for the speed range of 10 to 40 km in the urban environment, as there was no information about the actual speed. The calculated variants give nomograms of emission trends, with which you can find emissions at specific points for a given mode of movement.

This approach is compelled and can be useful until assumption 1 is replaced by the values of the measured speed.

9. Measurement of average daily speed

Measurements of the average speed of movement of one taxi-car were performed every day for ten days. The driver during the day of work applied the program of automatic monitoring of the speed mode of the car and the average distance of the trip. During experiments on measurements, not everything worked out right away. The professional driver experimented with different programs, trying to debug their regular work on different days.

The results were recorded automatically on the output images that are shown in fig. 11. At the moment, we received 14 points in 14 working days. It is advisable to continue this work and further.

Figure 11 - Photo images of the output windows of programs on measuring average speed and average travel distance per day

The obtained average speeds of movement per day in the urban environment will make it possible to refine the calculations of emissions in further work.

10. Comparison of the results of the calculation of GHG by COPERT and Method 1

The results of the calculation of greenhouse gas emissions, which are obtained using the COPERT program for three years 2014, 2015, 2016, are compared with emissions using method 1, table 8.

Table 8 - *Comparison of emission calculation results using Tier 1 and Tier 3 (COPERT),Gg*

		CO_2	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
2016	Method 1 (IPCC-2006)	2007,6	0,4218	0,1008	7,7130	16,7766	2,1627
	Method 3 (COPERT)	2024,5	0,4496	0,0519	13,1071	18,5013	3,2520
	Differences	*(+0,8%)*	*(+6,6%)*	*(-48,5 %)*	*(+69,9 %)*	*(+10,3 %)*	*(+50,4 %)*
2015	Method 1 (IPCC-2006)	1866,4	0,3545	0,0931	7,1485	16,3542	2,1120
	Method 3 (COPERT)	1874,4	0,2447	0,0565	12,5343	16,5374	3,4361
	Differences	*(+0,4%)*	*(-31,0%)*	*(-39,3 %)*	*(+75,3 %)*	*(+1,1 %)*	*(+62,7 %)*
2014	Method 1 (IPCC-2006)	1775,8	0,3350	0,0886	6,7050	15,8885	2,0509
	Method 3 (COPERT)	1791,1	0,2139	0,0448	11,4497	16,9546	3,1618
	Differences	*(+0,9%)*	*(-36,1%)*	*(-49,4 %)*	*(+70,8 %)*	*(+6,7 %)*	*(+54,2 %)*

A brief analysis of the quantities of emissions: CO_2- emissions by both methods show similar values; CH_4- emissions by both methods show values of the same order, but any emissions dynamics of findings can not be done; N_2O - emissions calculated by the program, a 2-fold lower than the emissions calculated by Method 1; NO_x - emissions calculated by the program, a 2-fold higher than the emissions calculated by Tier 1; CO - emissions by both methods show similar values, but it is difficult to make conclusions on the dynamics of emissions; NMVOC- emissions calculated by the program are 1.5 times higher than the emissions of the Tier 1.

11. Experience in using COPERT

The experience gained with the program can be useful, so you can summarize some of the approaches used: a) it is necessary to develop special calculation files for importing data into the program; b) variants of calculations with different parameters must be recorded in the journal of experiments; c) annual analysis of the vehicles structure from available sources is necessary; d) the resulting emissions can be adjusted for speed. Real-world speed measurements can be of great help.

Advantages of the program:
a) Application of the program opens wide opportunities for in-depth analysis;
b) Using the program represents a significant improvement in the quality of calculations.

12. Conclusions

The experience of using the program for calculating emissions from road vehicles has shown the feasibility of its using in view of the various aspects of driving mode and the coverage of a large number of pollutants. Preparation of primary data on the configuration of the fleet requires detailed statistics.

This is a difficult moment. The official statistics provides information on the number of vehicles, but not on the volume of engines and weight, used fuel, Euro-standards. In this regard, it is necessary to improve the reflection of such parameters of vehicles for the possibility of continuous use of the program. This sector is a key in the total emissions. Efforts to improve the statistical base of vehicles will be justified, and will allow obtaining a more accurate estimate of emissions from fuel combustion in road vehicles.

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