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SUSTAINABLE TRANSPORT. AN ATTEMPT TO APPLY THE COPERT IV METHOD TO CALCULATE THE EMISSIONS FROM PASSENGER CARS IN POLAND

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ZRÓWNOWAŻONY TRANSPORT. PRÓBA ZASTOSOWANIA METODY COPERT IV DO OBLICZENIA EMISJI ZANIECZYSZCZEŃ Z SAMOCHODÓW OSOBOWYCH W POLSCE

STRESZCZENIE: Celem artykułu jest wykonanie obliczeń emisji wybranych zanieczyszczeń wynikających z eksploatacji środków transportu drogowego przy wykorzystaniu metody COPERT IV.W tym celu w artykule zaproponowano założenia pozwalające na przetworzenie dostępnych danych, w taki sposób, aby możliwe było zastosowanie tej metody. Wykorzystując te założenia przygotowano dane a następnie wykonano obliczenia emisji zanieczyszczeń. Następnie wyciągnięto wnioski dotyczące możliwości stosowania metody COPERT IV w zakresie inwentaryzacji emisji z transportu drogowego w Polsce.

SŁOWA KLUCZOWE: emisja zanieczyszczeń, transport drogowy, metoda COPERT IV

Introduction

The calculation of emissions from road vehicles including passenger cars is necessary in order to conduct reporting at both the Polish and European Union levels. Reporting in this area in Poland is currently based on data from the National Centre for Emissions Management (KOBiZE); these data are used in the calculation of emission factors specified by the Motor Transport Institute (ITS) in Warsaw. The method of calculation of these indicators has its origins in the 1980s1 and provides for the division of passenger cars into the following categories2:

- those powered by four-stroke engines (older generation);
- those powered by two-stroke engines (older generation);
- low-emission engines.

This division means that all cars that meet the standards of the EURO series (starting from EURO 1, in force since 1992) are eligible for one group: low-emission vehicles. Following this, the same rates of emissions were defined from units of a particular type of fuel for cars that meet the various EURO standards (EURO 1 to EURO 6), among which the amounts of pollution emitted per unit of fuel consumed differ significantly. The fact that no differences in emissions resulting from various EURO standards met by the vehicle's engine were taken into account is a critical flaw of this method, which justifies an attempt to adopt another method of assessing the emissions from motor transport in Poland.

In the article, the COPERT IV methodology was used. It has been adopted by 22 EU member states to investigate the emissions from road transport3. The difficulties in applying this method result from the fact that the essential data required to perform calculations on the number of vehicles in Poland that meet the specific EURO standards within a particular category are not available. To carry out the calculations using the introduced method it is necessary to apply certain assumptions that would allow the available data to be processed in such a way as to make them compatible with the COPERT IV method.

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1 *Inventory of Emissions of Selected Pollutants from Road Transport Sector in 2008,* Warszawa 2008, p. 5.

2 Ibidem, p. 6.

3 L. Ntziachristos, et al., COPERT: A European Road Transport Emission*, Proceedings of the 4th International ICSC Symposium*, Thessaloniki 2009, pp. 491–504.

Metodologia Methods of data processing

The calculations were carried out for 2014, as these are the most recent data on the number of vehicles in each category that have been published.

To enter data into the COPERT IV program, it is necessary to set the number of passenger cars in compliance with specific EURO standards for the type of fuel and the engine capacity. It has been assumed that the number of cars should be defined in line with the following categories:

1. **Petroleum-powered cars**

1.1. Engine displacement less than 1400 cm^3

1.1.1. Do not meet the standards of EURO 1 (PC gasoline 0.8–1.4 l open loop)
1.1.2. EURO 1 (EURO 1 PC)
1.1.3. EURO 2 (PC EURO 2)
1.1.4. EURO 3 (EURO 3 PC)
1.1.5. EURO 4 (PC EURO 4)
1.1.6. EURO 5 (PC EURO 5)

1.2. Engine displacement in the range of 1400–1999 cm^3

1.2.1. Do not meet the standards of EURO 1 (PC gasoline 1.4–2.0 l open loop)
1.2.2. EURO 1 (EURO 1 PC)
1.2.3. EURO 2 (PC EURO 2)
1.2.4. EURO 3 (EURO 3 PC)
1.2.5. EURO 4 (PC EURO 4)
1.2.6. EURO 5 (PC EURO 5)

1.3. Engine displacement equal to 2000 cm3 or more

1.3.1. Do not meet the standards of EURO 1 (ECE 15/04)
1.3.2. EURO 1 (EURO 1 PC)
1.3.3. EURO 2 (PC EURO 2)
1.3.4. EURO 3 (EURO 3 PC)
1.3.5. EURO 4 (PC EURO 4)
1.3.6. EURO 5 (PC EURO 5)

2. **Diesel-fuel powered cars**

2.1. Engine displacement below 1400 cm^3

2.1.1. EURO 4 (PC EURO 4)
2.1.2. EURO 5 (PC EURO 5)

2.2. Engine displacement in the range of 1400–1999 cm^3

2.2.1. Do not meet the EURO 1 standards (conventional)
2.2.2. EURO 1 (EURO 1 PC)
2.2.3. EURO 2 (PC EURO 2)

2.2.4. EURO 3 (EURO 3 PC)
2.2.5. EURO 4 (PC EURO 4)
2.2.6. EURO 5 (PC EURO 5)
2.3. Engine displacement equal to 2000 cm^3 or more
2.3.1. Do not meet the EURO 1 standards (conventional)
2.3.2. EURO 1 (EURO 1 PC)
2.3.3. EURO 2 (PC EURO 2)
2.3.4. EURO 3 (EURO 3 PC)
2.3.5. EURO 4 (PC EURO 4)
2.3.6. EURO 5 (PC EURO 5)
3. Fuelled by Liquefied Petroleum Gas (LPG)
3.1. Do not meet the EURO 1 standards (conventional)
3.2. EURO 1 (EURO 1 PC)
3.3. EURO 2 (PC EURO 2)
3.4. EURO 3 (EURO 3 PC)
3.5. EURO 4 (PC EURO 4)
3.6. EURO 5 (PC EURO 5)

There is no distinction in capacity for LPG-powered vehicles because COPERT IV methodology does not account for such a division. In the case of diesel-powered vehicles with an engine displacement below 1400 cm^3, the COPERT IV methodology assumes that such engines came into use after the application of the EURO 4 standard.

The literature usually states the date on which vehicles do not meet the technical standards required to obtain a homologation as the real date of introduction of the new standard. In the article, we use the date when the vehicles could not be legally registered because they could not meet the requirements of the new standards.

Table 1. The dates that indicate the moment when the cars registered for the first time should already be compliant with a particular EURO standard of emission.

EURO standard	Date when the standard became applicable
EURO 1	1 January 1993
EURO 2	1 January 1997
EURO 3	1 January 2001
EURO 4	1 January 2006
EURO 5	1 January 2011

The EURO 6 standard has not been included, because in the case of the first vehicle registration it became applicable from 1 September 2015; in this regard, it was assumed that in 2014 no car met the standard.

It is assumed that the actual structure of the share of individual types of fuels for a given engine displacement in the age category of vehicles is a reflection of the used-vehicles market presented at the biggest Polish car-trade online service: otomoto.pl. It is assumed that the current situation (analysis carried out in May 2016) reflects the situation in 2014.

Central Statistical Office data (Transport, report from 2014) present the number of passenger cars divided into the following age categories: up to 1, 2, 3, 4–5, 6–7, 8–9, 10–11, 12–15, 16–20, 21–25, 26–30, and 31 years and older. Advertisements published at the Otomoto car-sales online service have been analysed for each of these age categories, which helped to determine the percentages of different types of cars (fuel type and engine displacement) in a given age group. It was assumed that the product of the number of vehicles for this age group (Central Statistical Office) and the share of individual types of cars in a given age category (defined by www.otomoto.pl) determine the actual number of different kinds of cars found in Poland in 2014 in each age category. Then the number of cars in each group was summed to obtain the quantity of a given type of cars that met the different EURO standards. Figures were calculated with a condition, if a number of cars in a given age category recorded by the CSO concerned the time of two years or more, than the numbers of cars in any age fitting into the given range are even.

A necessary addition to data on the number of vehicles in each category is the values of the average mileage of vehicles belonging to the given category. The values are based on the INFO-EXPERT directory presenting the market values and mileages of standard passenger cars (September 2014 edition).

Data from the Central Statistical Office on the number of vehicles, based on records contained in the Central Register of Vehicles, are incoherent. In fact, in Poland, the number of cars on the roads is significantly smaller than that recorded by the statistics. The Automotive Market Research Institute SAMAR estimates that, in reality, approximately 15 million cars are moving on Polish roads. This estimation was based on data from the Central Register of Vehicles, assuming that a vehicle in regular use had been insured at least once in the last seven years. The difference is so significant (about 5 million vehicles) mainly because some of the registered vehicles have been dismantled into parts and sold or scrapped outside the administrative system or sold and exported abroad illegally. This situation primarily applies to the oldest vehicles. Therefore, it was assumed that the number of 5 million vehicles would reduce the number of vehicles in each age category of 16 years and

above in proportion to the share of a given age group in the total number of vehicles aged 16 years and older.

With the assumptions mentioned above, it was possible to compile data concerning the number of cars meeting each EURO standard including the average annual mileage, as shown in Table 2.

Table 2. Number of cars in the given category compliant with EURO standards and the average mileage of cars in that category in Poland in 2014.

	Number of vehicles [pcs.]	Average annual mileage [km]
1. Petroleum-powered cars		
1.1. Engine displacement below 1400 cm^3		
1.1.1. Non-compliant with EURO 1 standards (PC Gasoline 0,8-1,4 l Open Loop)	415451	4100
1.1.2. EURO 1 (PC EURO 1)	229103	6200
1.1.3. EURO 2 (PC EURO 2)	381520	8100
1.1.4. EURO 3 (PC EURO 3)	590934	9600
1.1.5. EURO 4 (PC EURO 4)	315000	12000
1.1.6. EURO 5 (PC EURO 5)	315049	13600
1.2. Engine displacement in the range of 1400-1999 cm^3		
1.2.1. Non-compliant with EURO 1 standards (PC Gasoline 1,4-2,0 l Open Loop)	636514	7800
1.2.2. EURO 1 (PC EURO 1)	419062	9300
1.2.3. EURO 2 (PC EURO 2)	653324	10400
1.2.4. EURO 3 (PC EURO 3)	918830	12000
1.2.5. EURO 4 (PC EURO 4)	285172	13600
1.2.6. EURO 5 (PC EURO 5)	219358	14400
1.3. Engine displacement equal to 2000 cm^3 or more		
1.3.1. Non-compliant with EURO 1 standards (ECE 15/04)	923636	8300
1.3.2. EURO 1 (PC EURO 1)	210900	9900
1.3.3. EURO 2 (PC EURO 2)	244467	10900
1.3.4. EURO 3 (PC EURO 3)	367517	12000
1.3.5. EURO 4 (PC EURO 4)	145106	16800
1.3.6. EURO 5 (PC EURO 5)	107749	18000

	Number of vehicles [pcs.]	Average annual mileage [km]
2. For diesel (ON)		
2.1. Engine displacement below 1400 cm^3		
2.1.1. EURO 4 (PC EURO 4)	215744	13600
2.1.2. EURO 5 (PC EURO 5)	83842	15600
2.2. Engine displacement in the range of 1400-1999 cm^3		
2.2.1. Non-compliant with EURO 1 standard (Conventional)	188139	8300
2.2.2. EURO 1 (PC EURO 1)	199748	9900
2.2.3. EURO 2 (PC EURO 2)	490816	10900
2.2.4. EURO 3 (PC EURO 3)	1330823	12000
2.2.5. EURO 4 (PC EURO 4)	1061597	16800
2.2.6. EURO 5 (PC EURO 5)	482400	21600
2.3. Engine displacement equal to 2000 cm^3 or more		
2.3.1. Non-compliant with EURO 1 standard (Conventional)	265964	9200
2.3.2. EURO 1 (PC EURO 1)	134475	10800
2.3.3. EURO 2 (PC EURO 2)	254659	12100
2.3.4. EURO 3 (PC EURO 3)	678665	13200
2.3.5. EURO 4 (PC EURO 4)	536819	18000
2.3.6. EURO 5 (PC EURO 5)	251439	24000
3. Fuelled by propane-butane (LPG)		
3.1. Non-compliant with EURO 1 standard (Conventional)	375209	7800
3.2. EURO 1 (PC EURO 1)	236418	9300
3.3. EURO 2 (PC EURO 2)	256106	10400
3.4. EURO 3 (PC EURO 3)	259371	12000
3.5. EURO 4 (PC EURO 4)	83115	15600
3.6. EURO 5 (PC EURO 5)	20917	16400

The calculation of emissions using COPERT IV

Using data presented in Table 2, calculations of emissions of the following pollutants were carried out:

- Nitrous oxides (NOx);
- Non-methane volatile organic compounds (NMVOC);
- Particulate matter emissions from the combustion process (PM).

The calculations were made with the following assumptions concerning the operational speed of vehicles and mileages in different conditions:

- Average speed in urban conditions = 30 km/h (the share of urban conditions in total mileage = 45%);
- Average speed in non-urban conditions = 70 km/h (share of non-urban conditions in total mileage = 40%);
- Average speed on a highway = 120 km/h (share of highway conditions in total mileage = 15%).

The calculation results are presented in Table 3.

Table 3. The emission of pollutants (NOx, NMVOC, and PM) from passenger cars used in Poland in 2014

Specification		NO_x	NMVOC	Particulates
Gasoline 0,8-1,4 l	Open Loop	266,991	240,008	0,421
Gasoline 0,8-1,4 l	PC Euro 1 – 91/441/EEC	675,176	1164,11	3,508
Gasoline 0,8-1,4 l	PC Euro 2 – 94/12/EEC	800,055	1253,659	7,633
Gasoline 0,8-1,4 l	PC Euro 3 – 98/69/EC Stage2000	630,118	1173,525	6,178
Gasoline 0,8-1,4 l	PC Euro 4 – 98/69/EC Stage2005	250,999	431,861	4,116
Gasoline 0,8-1,4 l	PC Euro 5 – EC 715/2007	197,567	459,931	6,746
Gasoline 1,4-2,0 l	Open Loop	6551,97	2171,12	12,263
Gasoline 1,4-2,0 l	PC Euro 1 – 91/441/EEC	1845,074	3949,11	9,626
Gasoline 1,4-2,0 l	PC Euro 2 – 94/12/EEC	1749,749	3493,619	16,782
Gasoline 1,4-2,0 l	PC Euro 3 – 98/69/EC Stage2000	1217,985	2964,495	12,006
Gasoline 1,4-2,0 l	PC Euro 4 – 98/69/EC Stage2005	256,2	578,359	4,223
Gasoline 1,4-2,0 l	PC Euro 5 – EC 715/2007	144,569	449,239	4,973
Gasoline >2,0 l	ECE 15/04	22271,841	17415,783	18,935
Gasoline >2,0 l	PC Euro 1 – 91/441/EEC	925,813	1589,466	5,157
Gasoline >2,0 l	PC Euro 2 – 94/12/EEC	628,639	994,043	6,581
Gasoline >2,0 l	PC Euro 3 – 98/69/EC Stage2000	444,821	830,071	4,802
Gasoline >2,0 l	PC Euro 4 – 98/69/EC Stage2005	147,869	252,944	2,654
Gasoline >2,0 l	PC Euro 5 – EC 715/2007	78,288	187,849	3,053
Diesel <1,4 l	PC Euro 4 – 98/69/EC Stage2005	1893,451	62,457	151,493
Diesel <1,4 l	PC Euro 5 – EC 715/2007	880,683	21,102	5,482
Diesel 1,4-2,0 l	Conventional	940,752	387,392	587,354

Specification		NO_x	NMVOC	Particulates
Diesel 1,4-2,0 l	PC Euro 1 – 91/441/EEC	1429,871	162,933	244,346
Diesel 1,4-2,0 l	PC Euro 2 – 94/12/EEC	4155,387	304,559	473,612
Diesel 1,4-2,0 l	PC Euro 3 – 98/69/EC Stage2000	13508,108	491,929	944,752
Diesel 1,4-2,0 l	PC Euro 4 – 98/69/EC Stage2005	11509,2	379,645	920,84
Diesel 1,4-2,0 l	PC Euro 5 – EC 715/2007	7016,079	168,11	43,679
Diesel >2,0 l	Conventional	2337,403	607,022	920,351
Diesel >2,0 l	PC Euro 1 – 91/441/EEC	1050,133	181,775	179,454
Diesel >2,0 l	PC Euro 2 – 94/12/EEC	2393,374	513,972	272,786
Diesel >2,0 l	PC Euro 3 – 98/69/EC Stage2000	7577,437	586,099	529,964
Diesel >2,0 l	PC Euro 4 – 98/69/EC Stage2005	6235,576	205,688	498,903
Diesel >2,0 l	PC Euro 5 – EC 715/2007	4063,286	97,359	25,296
LPG	Conventional	6980,873	4356,298	7,229
LPG	PC Euro 1 – 91/441/EEC	1054,695	3251,298	5,431
LPG	PC Euro 2 – 94/12/EEC	599,705	2018,871	6,578
LPG	PC Euro 3 – 98/69/EC Stage2000	343,817	840,022	3,39
LPG	PC Euro 4 – 98/69/EC Stage2005	85,652	184,623	1,412
LPG	PC Euro 5 – EC 715/2007	18,85	48,846	0,374
Total		113158,056	54469,192	5952,383

Comparison of the results with Central Statistical Office data

The results have been compared with the data presented in the official statistics on the state of emissions from road transport, which are used to caryy out the ITS method (Table 4).

Table 4. Comparison of emissions from road transport calculated following the COPERT IV and ITS methods

Method	Emission size [Mg]		
	NO_x	NMVOC	PM
COPERT IV	113158	54469	5952
ITS	98270	43630	7430

Source: The author's own study based on Environmental Protection data for 2013, Warszawa 2015.

Because the data on emissions from road transport in 2014 in Poland have not yet been published, it was decided to compare data between different periods (COPERT IV: 2014; ITS: 2013). Over the period 2013–2014, no particularly significant changes were noticed in the used passenger car market in Poland. Therefore it can be assumed that the values estimated with the ITS method for 2014 will be comparable to data for 2013.

By analysing these data, it can be noticed that the emissions of NOx and NMVOC are 15 and 25% higher, respectively, when using the COPERT IV method, while the PM emission is 25% greater when estimated by the ITS method.

Conclusions

Comparison of emissions estimated by the two different methods was intended only to determine whether the method proposed in the article estimated the value at a level comparable to that currently reported in the emission inventories. There is no proof that the ITS or COPERT IV methods applied in this case give values with a smaller statistical error. The corresponding values are of comparable levels, indicating their relative reliability. However, it should be noted that the problem with the COPERT IV method is not the statistical error in the methodology but the lack of compatible data. Therefore the need to convert the data format necessitates the adoption of certain assumptions in the process, which ultimately diminishes the accuracy of the method. The flaw of the ITS method arises from the far-reaching simplification of the structure, namely the means of categorization of the vehicles and use of the average values of emission only. To improve the accuracy of this method, it was necessary to rebuild it. In conclusion, it seems that estimation of the road transport emissions in Poland can be more precise when using the COPERT IV method. Still, systematization of the data and increasing the precision of the records referring to the number of vehicles compliant with each EURO standard are critical. These tasks do not seem to be particularly difficult, especially when the records of the Central Register of Vehicles database are extensive enough to determine the particular EURO standard with which the car complies.

Literature

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