

THE INFLUENCE OF THE VEHICLE AGE ON THE CALCULATED PROBABILITY OF EXCEEDING THE STANDARDISED EXHAUST EMISSION

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Abstract

The article presents the results of investigations of the influence of vehicle age on traffic exhaust emission. The measurements of the test group of 500 different vehicles have been made in accordance with ECE Regulations and the methodology of periodical car inspection. Those measurements provided information about the level of emission from each vehicle and allowed to identify high polluting vehicles. The percentage of faulty vehicles and the type of faults were estimated. Next, the percentage of high polluting vehicles has been estimated. The results of investigations were compared to the requirements of each model of a given year. The percentage of high polluting vehicles for each model of a given year has been presented. The vehicles have been divided into different exhaust emission legislation classes. The percentage of high polluting vehicles for each exhaust emission legislation class has been elaborated. Next, the relation between exhaust emission and the vehicle age has been made and presented. The probability of exceeding the standardized exhaust emission for each model of a given year of vehicles has been calculated. The calculations included the exhaust emission such as carbon monoxide and hydrocarbons. The likelihood of carbon monoxide and hydrocarbons emission violations have been estimated applying logit analysis. The calculations have been made in two cases, for manufactures and national emission standards. The results of investigations and analysis show that vehicle age plays a significant role in determining exhaust emission test results.

Keywords: *Traffic emission, vehicle age, logit analysis*

1. Introduction

The motor vehicle is one of the largest sources of air pollutants emission. The emission level depends on many factors such as the type of engine and its capacity, the fuel consumption, the type of vehicle and also the age structure of vehicles, the number of vehicles etc. The technical improvements and the more restrictive emission standards resulted in the reduction of emission level for newly produced vehicles. There are still a lot of older vehicles which do not meet the requirements of new emissions standards. In many urban areas a lot of aging vehicles are used which causes a serious problem of air pollution. The important problem is also the number of vehicles and the number of kilometres covered by vehicles and these two factors are still increasing. Nowadays, there are a lot of different methodologies to calculate emissions [1-5] in order to determine emission level from road transport thoroughly.

Some countries use vehicle inspection and maintenance (I/M) programs to identify high polluting vehicles [6-8]. These programs also safeguard whether the vehicles are operating in accordance with the standards. In many countries, a high-emitter profile model has been used to help identify more efficiently the failed and highly polluting vehicles [7]. The inspection and maintenance programs have been criticized. These programs were not as effective and cost-effective as previously expected. There are problems to identify the failed and highly polluting vehicles precisely and yet the methodologies to identify these vehicles have been elaborated and applied.

It is a very important problem to estimate the number of vehicles which are in poor technical conditions and their actual influence on motor vehicle emission level. Therefore, the way of

determining the effect of age and technical changes on motor vehicle emission has been developed.

Also the influence of the engine construction and the engine technical conditions on traffic emission level has been determined [9-11].

2. Methodology

This article presents the results of the investigations and the simulations of traffic emission. The measurements of exhaust emission for 500 different vehicles have been made in accordance with ECE Regulations and the methodology of periodical car inspection. These measurements provided information about the level of emission from each vehicle. The age structure of the test group of vehicles has been determined. The results of investigations concerning the level of exhaust emission were compared to the requirements of each model of a given year. Those investigations gave information about the percentage of high polluting vehicles for each year a car's production. Next, the vehicles have been divided into different exhaust emission legislation classes. The percentage of high polluting vehicles for each exhaust emission legislation class has been elaborated.

Then, the relation between exhaust emission (CO and HC) and the vehicle age has been defined.

The probability of exceeding the standardized exhaust emission for each model of a given year of vehicles has been calculated. The calculations included exhaust emission such as carbon monoxide and hydrocarbons. The likelihood of carbon monoxide and hydrocarbons emission violations have been estimated applying logit analysis.

3. Vehicle structure

For the test group of vehicles the age structure has been determined. The vehicles have been categorized into the appropriate groups of cars with European emission standards which are connected with the age of vehicle. The results have been shown in Fig. 1.

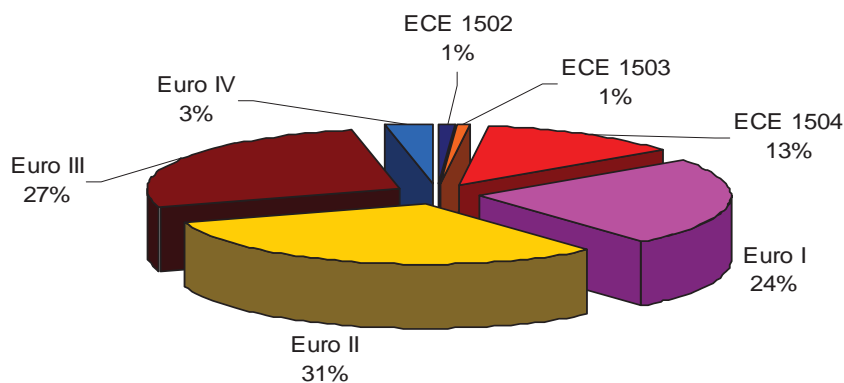


Fig. 1. The age structure of the test group

The Euro emission standards are connected with the age of vehicle. For passenger cars, Euro IV refers to the vehicles which were produced between 2005 and 2009. The Euro III refers to the vehicles which were produced between 2000 and 2005, Euro II to the vehicles between 1996 and 2000, Euro I between 1992 and 1996.

Approximately 31% of vehicles from the test group of vehicles should meet the requirements of Euro II. About 27 % of vehicles should meet the Euro III requirements. About 24 % of vehicles should meet the Euro I requirements and about 13 % should meet the Euro IV requirements. The rest of vehicles have met the requirements older then Euro I.

4. The results of the research

The measurements of exhaust emission have been made for the group of 500 different vehicles. These measurements have been made in accordance with ECE Regulations and the methodology of periodical car inspection and provided information about the level of emission for each vehicle.

4.1. Exceeding the standardized exhaust emission

Firstly, the information about the level of emission from each vehicle was compared with the emission standards determined by vehicle manufacturers. The percentages of vehicles, which have exceeded and those which have not exceeded the emission standards determined by the vehicle manufacturers, have been elaborated. The relationship between the percentage of vehicles which have exceeded and those which have not exceeded the CO (carbon monoxide) and HC (hydrocarbons) emission standards as well as vehicle age, have been presented in the Fig. 2.

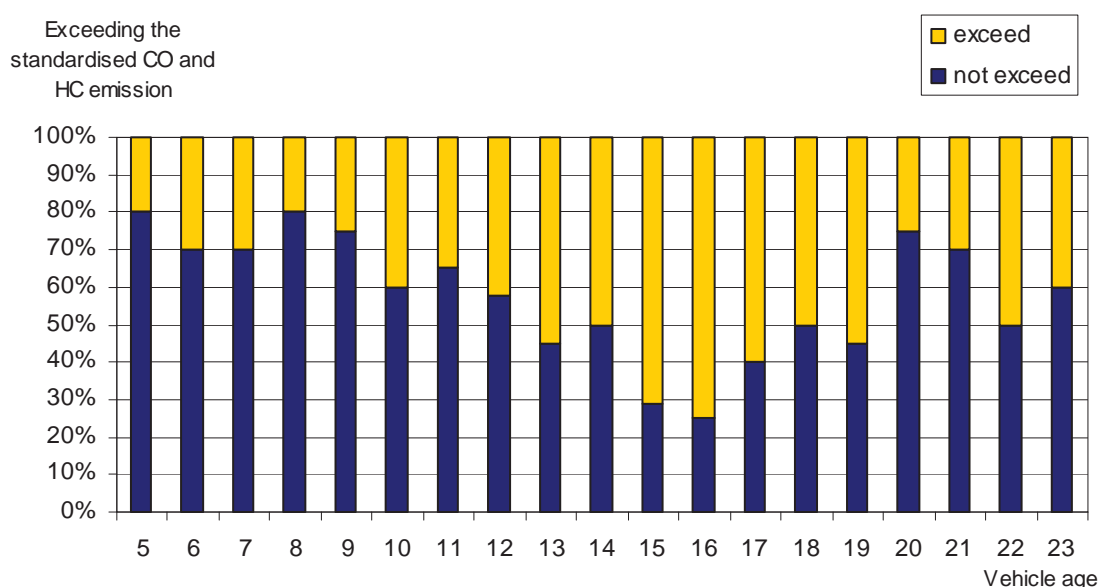


Fig. 2. The relationship between the percentage of vehicles which have exceeded and those which have not exceeded the CO and HC emission standards together with the vehicle age

As the vehicles become older, the number of vehicles which have exceeded the level of CO and HC emission increases. In the group of vehicles older than 16 years the percentage of vehicles which did not meet the requirements, is smaller as the vehicles became older.

The information about the level of emission from each vehicle was also compared with the national emission standards. The percentages of vehicles which have exceeded and those which have not exceeded the national emission standards for each year of a car’s production have been determined. The results have been shown in Fig. 3.

The information about the level of emission from each vehicle, which was compared with the emission standards determined by vehicle manufacturers, has been referred to European emission standards. The European emission standards are connected with the age of vehicle. The relationship between the percentage of vehicles which have exceeded and those which have not exceeded the CO and HC emission standards and European standards has been shown in Fig. 4.

Additionally, the information about the level of emission from each vehicle, which was compared with the national emission standards, has been referred to European emission standards. The relationship between the percentage of vehicles which have exceeded and those which have not exceeded the CO and HC national emission standards and the European standards has been shown in Fig. 5.

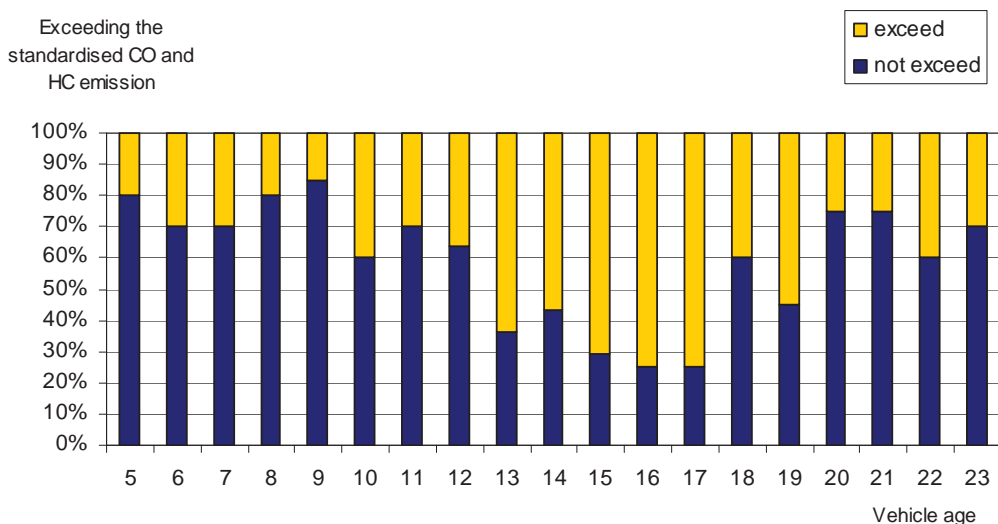


Fig. 3. The relationship between the percentage of vehicles which have exceeded and those which have not exceeded the CO and HC national emission standards together with the vehicle age

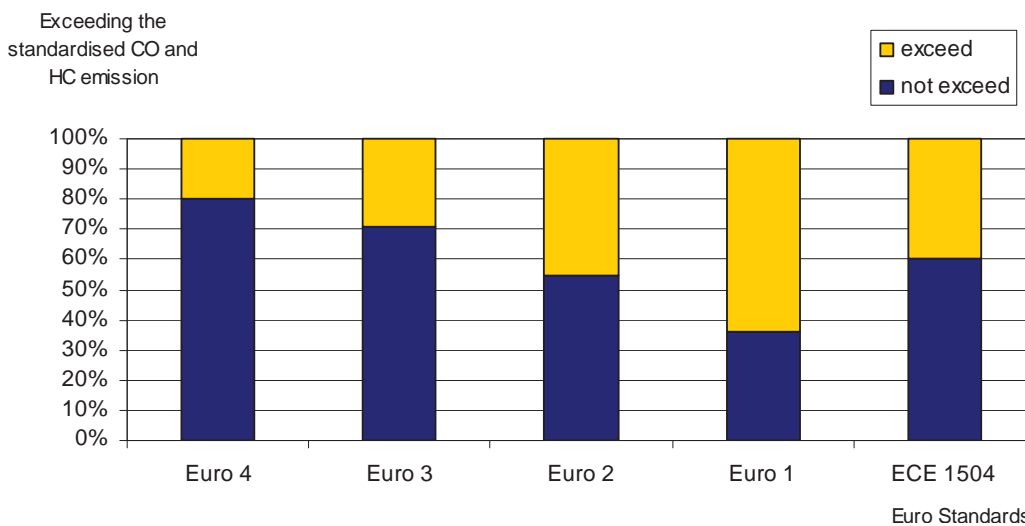


Fig. 4. The relationship between the percentage of vehicles which have exceeded and those which have not exceeded the CO and HC emission standards and the European standards

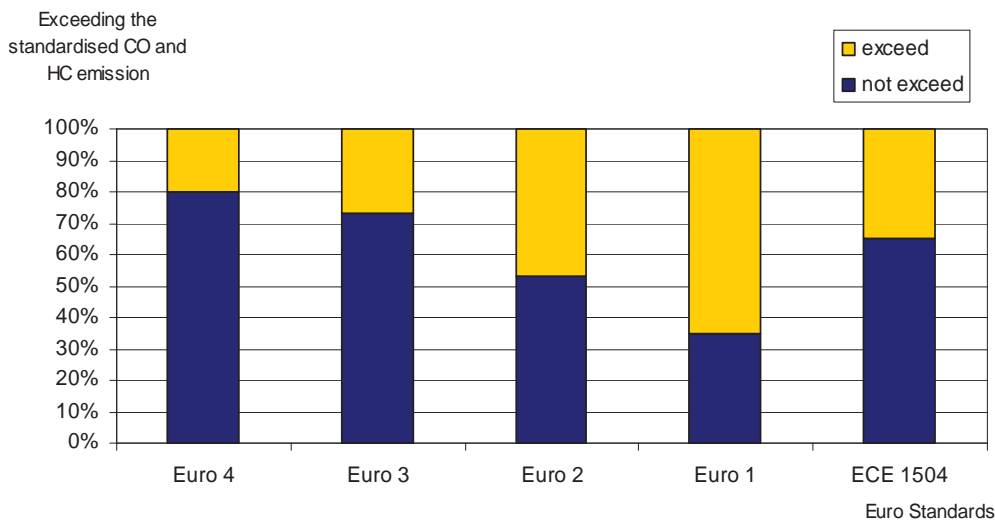


Fig. 5. The relationship between the percentage of vehicles which have exceeded and those which have not exceeded the CO and HC national emission standards and the European standards

The information about the level of emission from each vehicle was compared with the emission standards determined by vehicle manufacturers and with the national emission standards. The percentage of vehicles which have met and those which have not met the appropriate requirements were determined taking into account the vehicle age and the European emission standards.

The European emission standards determined the limits of exhaust emission of currently produced European vehicles. Fig. 4 and 5 have shown how many vehicles, which should meet the requirements of European emission standards, have exceeded the national emission standards and the vehicle manufacturer's emission level standards.

All the dependences have shown that the number of vehicles which have exceeded the CO and HC emission increases as the vehicles become older. For vehicles older than 16 years the percentage of vehicles which did not meet the requirements, is smaller as the vehicles became older. The first reason of such results is that for older vehicles the requirements are not as strict as for younger vehicles. Secondly, the owners of the older vehicles are often the vehicle hobbyists or car collectors and they take good care of technical conditions of their vehicles.

4.2. The level of exhaust emission

For the test group of 500 vehicles the average CO and HC emission was estimated. The relationship between the average CO emission for each year and vehicle age have been made. The results for CO emission have been shown in Fig. 6.

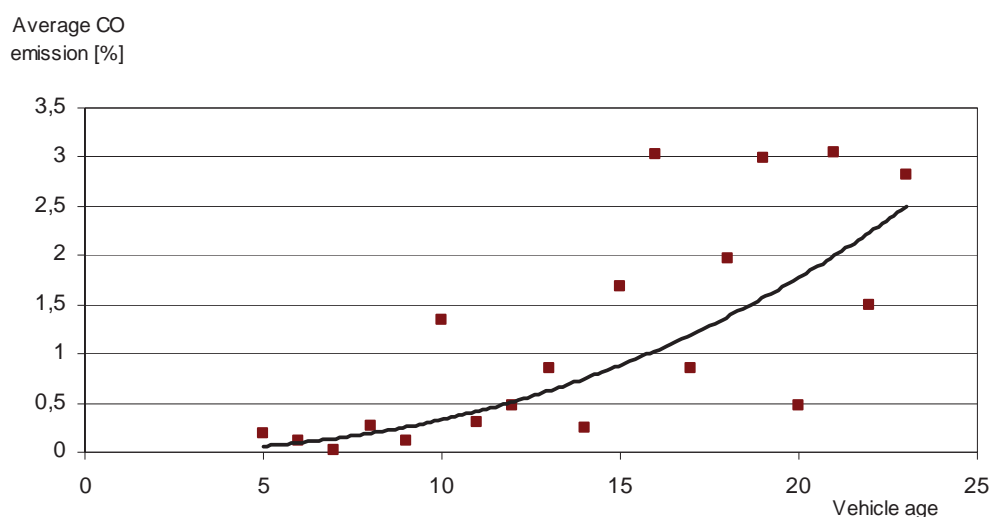


Fig. 6. Average CO emission for a particular vehicle age

As the vehicles become older, CO emission increases. According to Polish legislation, since 1995, CO emission from vehicles should not exceed 0.5 % and since 2004 it should not exceed 0.3%. The results of investigation show that for vehicles older then 12, 13 years the CO emission is higher than 0.5%.

Additionally, the relationship between the average HC emission for each year and vehicle age has been elaborated. The results have been shown in Fig. 7.

The graph shows that HC emission is also growing when vehicles become older. According to Polish legislation, since 1995, HC emission from vehicles should not exceed 100 ppm. For vehicles older then 10 years the emission is higher than 100 ppm.

5. Results of the analysis

For the group of vehicles the likelihood of carbon monoxide and hydrocarbons emission violations has been estimated. The likelihood has been estimated applying logit analysis.

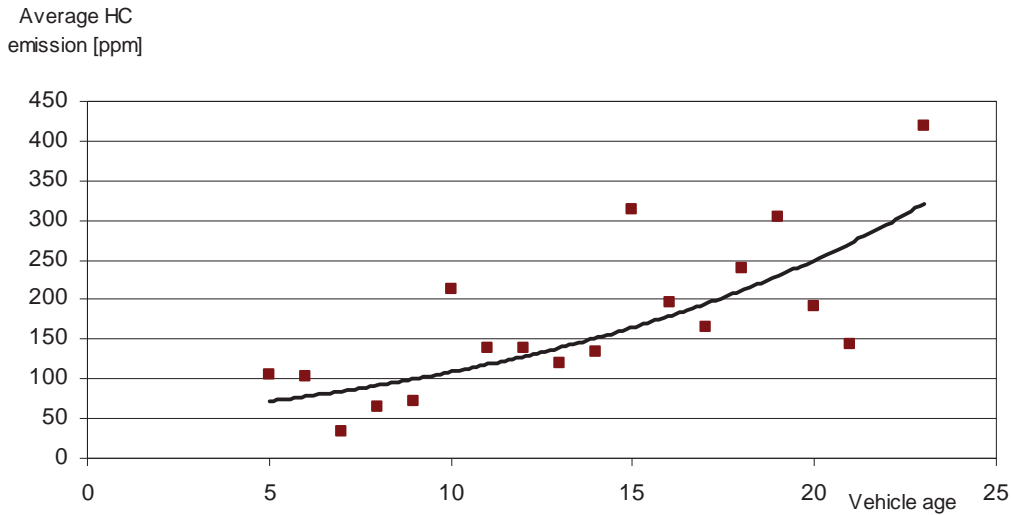


Fig.7. Average HC emission for a particular vehicle age

The probability of emission test failure depends on vehicle characteristics according to a function [6, 12]:

$$P(F = 1) = \frac{\exp(\beta_0 + \beta_1 \cdot x_{1i} + \beta_2 \cdot x_{2i} + \dots + \beta_k \cdot x_{ki})}{1 + \exp(\beta_0 + \beta_1 \cdot x_{1i} + \beta_2 \cdot x_{2i} + \dots + \beta_k \cdot x_{ki})}, \quad (1)$$

where:

$P(F = 1)$ - the probability that the vehicle fails the emission test,

x - represents the logistic cumulative distribution function,

β - the parameters estimated by the maximum likelihood methods.

5.1. Results of the logit analysis

The estimated likelihood of carbon monoxide and hydrocarbons emission violations have been shown in Fig. 8. The calculations have been made in two cases. First, the probability was estimated assuming that the vehicles will fail the emission test in accordance with emission standards determined by vehicle manufacturers and in the second case in accordance with the national emission standards.

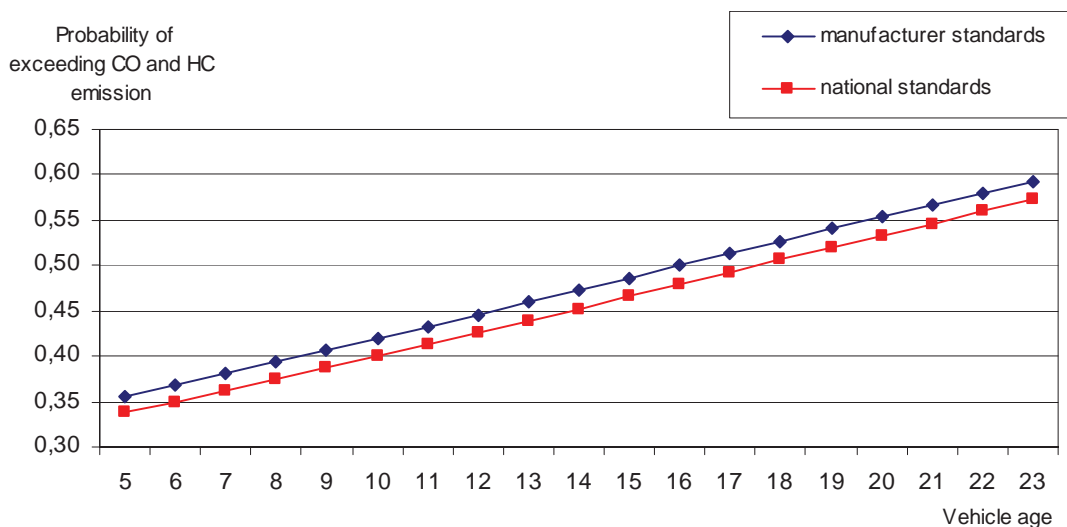


Fig. 8. The estimated likelihood of carbon monoxide and hydrocarbons emission violations

The graph shows that for emission standards determined by vehicle manufacturers, the probability of failing the emission test is higher. The emission standards determined by vehicle manufacturers are stricter than the national emission standards. Some vehicles have exceeded the CO and HC standard determined by the vehicle manufacturers and have not exceeded the CO and HC standard determined by Polish legislation.

6. Conclusions

The calculations and analysis have shown that it is important to determine the level of exhaust emission properly. The investigations have shown that a lot of vehicles have not met the appropriate requirements. In the group of tested vehicles there were vehicles which have not met the requirements of each year of a car's production. The number of vehicles which have exceeded the CO and HC emission increases as the vehicles become older. For vehicles older than 16 years the percentage of vehicles which did not meet the requirements, it is slightly smaller as the vehicles became older.

The results show that the average CO and HC emission is growing when vehicles become older. For vehicles older than 12, 13 years the CO emission is higher than the requirements by Polish legislation which is 0.5 %. For vehicles older than 10 years the HC emission is higher than the required 100 ppm. It is significant because the statistical Polish car is usually 10 years old.

The likelihood of carbon monoxide and hydrocarbons emission violations has been estimated applying logit analysis. That analysis has shown that the probability of failing the emission test is higher as the vehicles become older. The calculations and analysis have shown that more vehicles have not met the emission requirements of vehicle manufacturers but have met the requirements of national requirements. That means that there is high probability of a large number of vehicles in poor technical conditions in Poland according to vehicle manufacturer's requirements.

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