Statistical Evaluation of the Emissions Level Of CO, CO_2 and HC Generated by Passenger Cars

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ABSTRACT

This paper aims to make an evaluation of differences emission level of CO, CO_2 and HC generated by passenger cars in different walking regimes and times, to identify measures of reducing pollution. Was analyzed a sample of Dacia Logan passenger cars (n = 515), made during the period 2004-2007, equipped with spark ignition engines, assigned to emission standards EURO 3 (E3) and EURO4 (E4). These cars were evaluated at periodical technical inspection (ITP) by two times in the two walk regimes (slow idle and accelerated idle). Using the t test for paired samples (Paired Samples T Test), the results showed that there are significant differences between emissions levels (CO, CO_2, HC) generated by Dacia Logan passenger cars at both assessments, and regression analysis showed that these differences are not significantly influenced by turnover differences.

Keywords*: emissions of CO, CO_2 and HC generated by passenger cars, Paired Samples T Test, regression analysis*
JEL: *L*

1. INTRODUCTION

Emissions of CO, CO_2 and HC generated by passenger cars is one of the most complex environmental problems due to negative effects on the human body and ecosystems. The reduction of the emissions level is one of the most important objectives of international environmental policy. Results of annual reports (TERM (2013), LRTAP (2014)) show that, in recent years, both manufacturers of passenger cars and authorized institutions adopt new measures to reduce emissions level of CO, CO_2 and HC evacuated into the

atmosphere. These measures are not effective due to legislative or technological causes. Thus, in some studies from literature some authors (An and Sauer (2004), Fontaras et al. (2009, 2010), Judge et al. (2014)) highlighted the need to revise the standards governing emissions from passenger cars. In other studies (Zachariadis (2001), Marr and Harley (2002), Pandian et al. (2009), Carslaw et al. (2013)) it is argued that emissions generated by passenger cars depends on the simultaneous action of factors such as: engine type, deceleration and acceleration speed, the waiting time in idle mode, traffic flow, fuel used, weather conditions, driving behavior, pedestrians behavior or road conditions. Also, in literature (Ntziachristos and Samaras (2000), Chen et al. (2008)) is considered that another factor that may affect emissions level generated by passenger cars is turnover. Regarding the effect of turnover, some authors have found that, the emissions level of CO, CO_2 and HC of passenger cars varies with the level of turnover and is different in the two types of walking (slow idle, accelerated idle).

Given the issues raised, the purpose of this study is to realize an assessment of the differences between the emissions level of CO, CO_2 and HC generated by passenger cars Dacia Logan, and a measurement of the influence of differences in turnover on the differences between emissions. In line with the established purpose, it is aimed to verify the following research hypotheses:

Hypothesis 1: There is no significant differences in the level of CO, CO_2 and HC recorded at different times, for the walk regime of slow idle and accelerated idle.

Hypothesis 2: Differences between the emissions level of CO, CO_2 and HC recorded at different times, for the walk regime of slow idle and accelerated idle are not influenced by differences of turnover.

The paper is organized in following sections. Section 2 discusses the research methodology: population, variables and methods of data analysis used. Section 3 presents the empirical results. Section 4 concludes the study.

RESEARCH METHODOLOGY

Population. Variables

The study realized by authors Ursu and Moroşanu (2013) shows that the mark with the largest share in the national fleet of passenger cars, in period 2007-2012 is Dacia. Given this result, in the present study reference is made to

the emissions level of CO, CO_2 and HC Dacia Logan passenger cars equipped with spark ignition engines, assigned to emission standards EURO3 (E3) and EURO4 (E4), that were presented at ITP (Periodical Technical Inspection), in the period 2008-2011. The statistical data used were extracted from reports of a representative ITP Dacia in Neamţ county, given that, in total, are two such offices in the county out of which only one accepted the collaboration in order to achieve this study.

The population analyzed is represented by a random sample of passenger cars (n = 515) that were produced in period 2004-2007. The criterion depending on which was made the selection of 515 passenger cars is the number of evaluations, i.e. two successive presentations at ITP, in the period 2008-2011. At each evaluation (evaluation1 and evaluation2) passenger cars were diagnosed in terms of chemical pollution, for the slow idle ($n \leq 1000$ rot/min) and accelerated idle (2000-3000 rot/min). The variables considered in the study are presented in Table 1 *(next page)*.

CHARACTERISTICS OF CONSIDERED VARIABLES

Table 1

Variable name	Variable definition	Symbol	Variable type
The pollution degree of passenger car	Refers to passenger cars depollution norms.	Degree_pollution	Categorial 1 = E3 2 = E4
Manufacturing period of passenger car	The period of time in which the passenger cars were manufactured.	Period_manufacture	Categorial 1 = before 2005 2 = 2005-2006 3 = after 2006
Turnover	The turnover of passenger cars.	Turnover	Continue
Age	The age of passenger cars.	Age	Continue
CO emissions measured at first evaluation, slow idle	The level of CO emissions measured at the first evaluation, slow idle.	CO_I_ev1	Continue
CO_2 emissions measured at first evaluation, slow idle	The level of CO_2 emissions measured at the first evaluation, slow idle.	CO2_I_ev1	Continue
HC emissions measured at first evaluation, slow idle	The level of HC emissions measured at the first evaluation, slow idle.	HC_I_ev1	Continue
CO emissions measured at first evaluation, accelerated idle	The level of CO emissions measured at the first evaluation, accelerated idle.	CO_I_ev2	Continue
CO_2 emissions measured at first evaluation, accelerated idle	The level of CO_2 emissions measured at the first evaluation, accelerated idle.	CO2_I_ev2	Continue
HC emissions measured at first evaluation, accelerated idle	The level of HC emissions measured at the first evaluation, accelerated idle.	HC_I_ev2	Continue
CO emissions measured at second evaluation, slow idle	The level of CO emissions measured at the second evaluation, slow idle.	CO_II_ev1	Continue
CO_2 emissions measured at second evaluation, slow idle	The level of CO_2 emissions measured at the second evaluation, slow idle.	CO2_II_ev1	Continue
HC emissions measured at first evaluation, slow idle	The level of HC emissions measured at the second evaluation, slow idle.	HC_II_ev1	Continue
CO emissions measured at second evaluation, accelerated idle	The level of CO emissions measured at the second evaluation, accelerated idle.	CO_II_ev2	Continue
CO_2 emissions measured at second evaluation, accelerated idle	The level of CO_2 emissions measured at the second evaluation, accelerated idle.	CO2_II_ev2	Continue
HC emissions measured at second evaluation, accelerated idle	The level of HC emissions measured at the second evaluation, accelerated idle.	HC_II_ev2	Continue

The measurements for recording emission levels of CO, CO_2 and HC were performed using gas analyzer CAPELEC 3200. After recording data related to measurements performed with gas analyzer CAPELEC 3200, extracted from ITP reports, a database was created in Microsoft Excel program.

Methods of data analysis used

The verification and validation of research hypotheses established requires an analysis of the differences of emissions level of CO, CO_2 and HC at different times which coincide with the presentation of the passenger car at ITP in two successive moments (in two years). To achieve this, in the study, an identification of the differences between the second and first evaluation (slow idle and accelerated idle) was made. The calculation of these differences was performed using Excel.

After the calculation of emissions level differences (d) in the two moments was wanted to verify the hypothesis according to which they are significant. For this purpose we used the student t test for the paired samples (Paired Samples T Test). With this test is compared the means for one group observed (same subjects) at two different times, verifying if there are significant differences between mean values (Jaba (2002)).

Graphic representation of the differences in emissions level was performed using "notches" graphs. To determine if the differences found are influenced by differences in turnover level, was used a simple linear regression model. In this model, the dependent variable is the difference between the emission levels and the independent variable is the differences between the turnover levels. Data analysis was performed using the statistical software R.

RESULTS

After data analysis was performed, were obtained results regarding the differences between the emissions level of CO, CO2 and HC. Another result obtained is the influence of turnover differences on differences of emissions level.

Testing the differences in emissions level of CO, CO_2 and HC

The results of the t test for paired samples are shown in Table 2.

TESTING DIFFERENCES BETWEEN THE EMISSIONS LEVEL OF CO, CO_2 AND HC RECORDED AT SLOW IDLE AND ACCELERATED IDLE (FIRST AND SECOND EVALUATION)

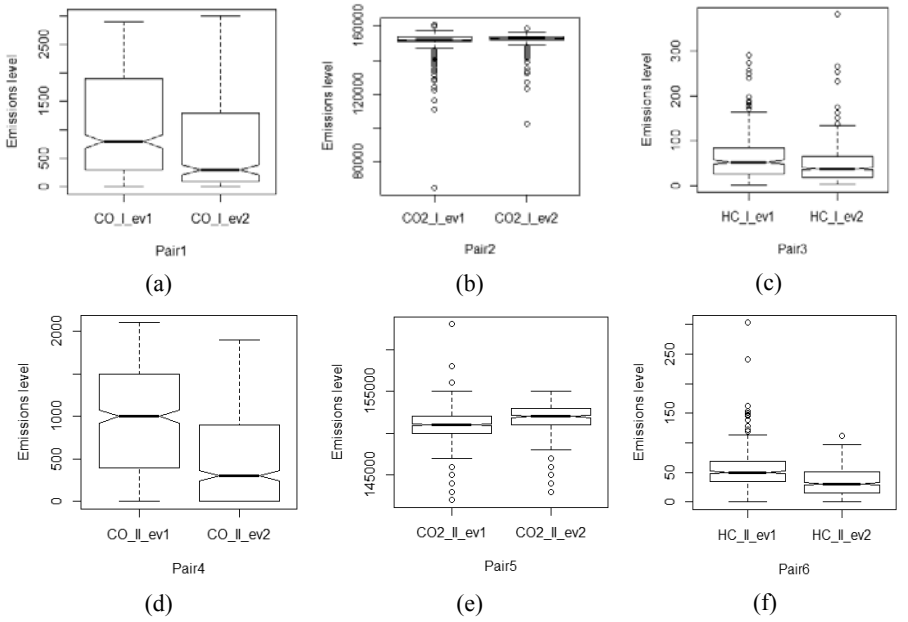
Table 2

Mode	Pairs		t	df	p-value	Confidence interval		Differences mean
						Lower	Upper	
Slow idle	Pair1	CO_I_ev2; CO_I_ev1	6.9163	514	0.0000	245.6556	440.5851	343.1204
	Pair2	CO2_I_ev2; CO2_I_ev1	-3.85	514	0.0001	-1873.9271	-607.6263	-1240.777
	Pair3	HC_I_ev2; HC_I_ev1	5.9913	514	0.0000	9.4602	18.6912	14.0757
Accelerated idle	Pair4	CO_II_ev2; CO_II_ev1	13.4659	514	0.0000	392.7230	526.8887	459.8058
	Pair5	CO2_II_ev2; CO2_II_ev1	-8.4301	514	0.0000	-1398.2479	-869.7133	-1133.981
	Pair6	HC_II_ev2; HC_II_ev1	11.4519	514	0.0000	15.1002	21.3540	18.2271

From Table 2 we observe that the differences between emissions level of CO and HC are significant. For differences between emissions level of CO_2 is found that the t test value is -3.85 for the first pair and -8.43 for the second pair. In this case, we admit that, in slow idle mode and in accelerated idle mode, differences identified between emission levels of CO_2 are significant. These results are confirmed and through graphic representations from Figure 1.

DIFFERENCES BETWEEN THE EMISSIONS LEVEL OF CO, CO_2 AND HC AT THE LEVEL OF OBSERVED LOT OF PASSENGER CARS

Figure 1



From the graphs presented in Figure 1 it is observed that for the emissions level of CO and HC recorded at the first evaluation, the median is significantly higher than the median recorded for emissions level of the second evaluation. In the case of CO_2, the median is higher in the second evaluation. This behavior can be determined by several constructive factors (compression ratio, construction of engine combustion chamber, wall material of combustion chamber) or the operating conditions (engine speed, load, temperature, walls condition of combustion chamber or fuel nature) specific to a particular regime.

Analysis of the effect of turnover differences on emissions level differences of CO, CO_2 and HC

Because we want to analyze the effect of turnover differences on emissions level differences of CO, CO_2 and HC, regression models have the form:

$$d\_CO\_I = \beta_0 + \beta_1 d\_Turnover \quad (1)$$
$$d\_CO_2\_I = \beta_0 + \beta_1 d\_Turnover \quad (2)$$
$$d\_HC\_I = \beta_0 + \beta_1 d\_Turnover \quad (3)$$
$$d\_CO\_II = \beta_0 + \beta_1 d\_Turnover \quad (4)$$
$$d\_CO_2\_II = \beta_0 + \beta_1 d\_Turnover \quad (5)$$
$$d\_HC\_II = \beta_0 + \beta_1 d\_Turnover \quad (6)$$

The results achieved through estimation of these models are presented in Table 3.

ESTIMATED REGRESSION MODELS FOR THE DIFFERENCES OF EMISSIONS LEVEL AND TURNOVER DIFFERENCES (N = 515 PASSENGER CARS)

Table 3

Regime	Dependent variable (Y)	Independent variable (X)	Estimated regression equation
Slow idle	d_CO_I (CO_I_ev1; CO_I_ev2)	d_Turnover	Y = - 471.3 + 0.00592X (0.000) (0.104)
	d_CO2_I (CO2_I_ev1;CO2_I_ev2)	d_Turnover	Y = 995.282 + 0.01134X (1.643) (0.101)
	d_HC_I (HC_I_ev1; HC_I_ev2)	d_Turnover	Y = - 16.26 + 0.0001X (0.000) (0.559)
Accelerated idle	d_CO_II (CO_II_ev1; CO_II_ev2)	d_Turnover	Y = - 482.1 + 0.0010X (0.000) (0.682)
	d_CO2_II (CO2_II_ev1; CO2_II_ev2)	d_Turnover	Y = 1377 - 0.0112X (0.000) (0.257)
	d_HC_II (HC_II_ev1; HC_II_ev2)	d_Turnover	Y = - 22.11 + 0.0001X (0.000) (0.125)

From the results obtained in Table 3 it is observed that the probability values are > 0.05 for all the estimated regression coefficients which represent the turnover differences. Those results indicate that the differences of CO, CO_2 and HC emissions level recorded in the slow idle and accelerated idle (first and second evaluation) are not affected by turnover differences. Also, it is observed that for five estimated models the constant is significant, indicating that he differences of CO, CO_2 and HC emissions levels may be influenced by the action of other factors.

CONCLUSIONS

In this study we aimed to realize an evaluation of differences in emissions level of CO, CO_2 and HC generated by cars at different walk regimes and at successive moments, which may used to identify measures for pollution reduction. The results obtained after data analysis allowed the verification of the two research hypotheses. The first hypothesis assumed was that there are no significant differences in emissions level of CO, CO_2 and HC recorded at

different times for slow idle and accelerated idle. The second hypothesis assumed that the differences in the level of CO, CO_2 and HC recorded at different times, for slow idle and accelerated idle are not influenced by differences in the level of turnover. In our analysis we used data regarding emissions level registered at ITP verifications, of 515 Dacia Logan passenger cars.

The study shows that there are significant differences of the level of CO, CO_2 and HC recorded at different times for slow idle and accelerated idle. This result is confirmed by other researchers (Dubey et al. (2014), Robert et al. (2014)) who argue that in the two walking regime, the amount of pollutant emissions can be high, being determined mainly by the engine type and its operation during the procedure.

For lot of cars analyzed, the results also showed that the differences in emissions level of CO, CO_2 and HC are not influenced by differences in turnover, other factors acting upon them (construction or operation).

Based on the results of such analyzes, manufacturers can adopt a number of measures in the process of passenger cars production to reduce emissions level of CO, CO2 and HC or to neutralize them.

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