Research Article

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User's determination of a proper method for quantifying fuel consumption of a passenger car with compression ignition engine in specific operation conditions

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Abstract: The present research concerns itself with measuring and evaluating fuel consumption of compression ignition engine in passenger cars by a variety of methods and in different operating modes. The main objective is to compare different procedures for the cars' fuel consumption experimental investigation in the point of view of their accuracy. The measurements were carried out on Citroen Berlingo motor vehicle. The very research is focused on implementing and evaluating the discussed consumption by three different methods, namely calculation from consumed fuel volume measured on fuel station flowmeter (pump stand), recording the data from an on-board computer and obtaining data from a specific application. Given that a certain driving style has a significant impact on fuel consumption, particular examinations were conducted in three operating modes, where the very journeys were made in order to measure the consumption in relation to an economic, a regular and a dynamic driving style. The vehicle being tested was driven on four specified routes that varied in their length, maximum permitted velocity on individual sections and number of intersections, or a city-motorway ratio. To this end, the experimental research resulted in putting toward recommendations and procedures, including appropriate methods, to ensure reliability of fuel consumption measurements with respect to the diverse operating modes of passenger cars.

Keywords: Fuel consumption, compression ignition engine, deviation rate, operating mode, measurement reliability

1 Introduction

Fuel consumption is one of the main criteria when comparing fuel economy of road motor vehicles. Corresponding values of vehicles' fuel consumption may be found in their technical certificate, though the values are inaccurate at times. Thus, it is appropriate for vehicle users to establish a procedure according to which they would be able to calculate the consumption without the help of laboratory equipment.

The main aim of the paper is therefore to suggest a methodological procedure for measuring fuel consumption that would quantify the amount of consumed fuel as accurately as possible. It may be argued that determining the most precise method is important not only from the viewpoint of calculating exact fuel costs.

Furthermore, fuel consumption is also an important indicator of the technical condition of vehicles. Due to increased consumption, it is possible to assume a vehicle failure. High fuel consumption may also be caused, for instance, by a leak in the fuel system, a fault in the injection unit, or even a more serious fault occurring directly in the engine. The previously mentioned applies to the most common types of engines in automobiles – spark ignition engine and compression ignition engine.

Additionally, it is advisable to monitor fuel consumption with regard to the production of harmful engine exhaust gases entering the air. Exhaust pollution is currently a serious issue, causing car manufacturing companies to compete in producing cars with the lowest reported fuel

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consumption. Such companies are also forced to do so by various regulations to limit exhaust emissions [1].

2 Literature review

Numerous publications are focused on the subject of examining the internal combustion engine fuel consumption under different conditions. For instance, Cho and Choi [2] look into possibility of estimation of fuel consumption efficiency by processing and analyzing digital tachograph big data for commercial vehicles using parallel processing with the MapReduce mechanism. Compared to the conventional fuel consumption examination using the On-Board Diagnostics II equipment, the authors implement actual tachograph data and On-Board Diagnostics II fuel consumption data to determine reasonable relationships to quantify fuel efficiency rates. Similarly to the previous case, even the studies [3, 4] discuss the scenarios of measuring and analyzing engine condition data regarding the fuel consumption investigation on the basis of actual driving behaviors in certain transport areas. And by analogy, the authors Baquero-Larriva and Alvarez-Coello develop a data acquisition system, which integrates different devices and technologies in terms of reliable fuel consumption measurement systems [5].

On the other hand, the literatures [6, 7] deal with analyzing specific combustion characteristics occurred in an engine under load. In line with these aspects, the authors in [6] evaluate capabilities of low-temperature combustion concept to operation of a medium-duty compression ignition engine (hereinafter referred to as CI) proposing multiple approaches to solve its crucial challenges. Wu and Jang also carried out engine combustion analysis, in which they designed a modified homogeneous charge compression ignition system for a 150cc motorcycle engine [7].

Multiple literature sources summarize outcomes related to investigation of the fuel consumption of various means of transport, deployed in public passenger transportation, compared to energetic consumption of alternative types of engine propulsion. For example, the manuscript [8] presents the authors' findings associated with the long-term examination of operation characteristics of trolleybus Škoda 26Tr Solaris equipped with energy storage lithium-titanate traction battery, hybrid trolleybus with installed diesel generator, and bus complying with the EURO 6 emission standard in terms of electricity and diesel fuel consumption per 1 km. And also, the paper [9] highlights the uppermost results in the context of energetic attributes of different city bus systems. To this end,

research activities focused on looking into the fuel and energy consumption of two buses fueled by compressed natural gas and engine diesel, trolleybus, and battery-electric bus were rendered while various driving conditions in the certain transport territory.

Unlike the previous articles, the research study [10] describes a life-cycle evaluation of several passenger cars propelled by distinct fuel types to comprehensively assess the fuel consumption as well as environmental impact aspects, *i.e.* internal combustion engine vehicles (fueled by gasoline, diesel, liquefied petroleum gas, methanol, compressed natural gas, hydrogen and ammonia), hybrid electric vehicles (fueled by 50% gasoline and 50% electricity) and electric vehicles. Whereas Polcar *et al.* in the publication [11] emphasize the most significant findings concerning a calibration and its utilization in fuel consumption measurement by using the CAN-Bus network, Skrucany *et al.* assess distinctions in vehicle fuel consumption when installing certain aerodynamical devices through specific telematics SW [12].

3 Data and methods – methodology for quantifying fuel consumption

In order to achieve the mentioned research objective, *i.e.* to find out and determine the most accurate manner in which

Table 1: Specifications of vehicle used for measurements

Specifications	Vehicle	Vehicle with compression ignition engine
Type		Passenger car
Category		M1
Make		CITROEN
Trade name		BERLINGO
Cylinder displacement		1,560
Maximum engine power		88 kW
Fuel type		Diesel + adblue
Transmission		M5
Production year		2016
Drive		Front-wheel
Curb weight		1,630 kg
Fuel consumption	Urban	4.9 l×100 km ⁻¹
	Extra-urban	4.2 l×100 km ⁻¹
	Combined	4.4 l×100 km ⁻¹

Table 2: Specifications of designated routes

Parameters	Routes	Short urban route	Long urban route	Short combined* route	Long combined* route
Length		3.9 km	8.8 km	32.5 km	61.7 km
Maximum permitted speed		50–70 km×h ⁻¹	50–80 km×h ⁻¹	50–130 km×h ⁻¹	50–130 km×h ⁻¹
Number of intersections with significant waiting time		2	1	1	-
City : Motorway ratio		-	-	1:1	1:3

*Combined route = urban + motorway

Table 3: Specifications of measurement techniques

Measurement technique	Purpose	Range of measurement	Accuracy of measurement
Kern FKB Digital scale	fuel weight measurement	36,100g	0.1g
Densitometers	dispensed fuel density measurement	650 – 770 kg×m ⁻³ 760 – 880 kg×m ⁻³	
Jerrycans	dispensed fuel	5 l, 10 l and 20 l	
Fuel tank filler neck – modified	stimulation of pump gun location	-	-
Wireless adapters ELM 327 and V-Car II	fuel consumption of vehicle being examined	-	-
Mobile applications Torque Pro and OBD FUSION			

fuel consumption is to be measured by passenger car users under normal conditions, a specific methodology has been chosen including the following basic steps:

- A) Selection of a motor vehicle;
- B) Selection of measured routes (circular routes);
- C) Use of a measuring technique;
- D) Determination of a measurement procedure.

Petrol (gasoline) and diesel are the most widely used sources of energy worldwide for internal combustion engines [13]. A vehicle powered by compression ignition engine using diesel was selected for the intended examination. The following statistics (Table 1) provide more detailed specifications of the vehicle being tested.

Four routes were designated to quantify measurement results to be as accurate as possible, with all of the routes starting and finishing at a certain fuel station (hereinafter referred to as FS), where all measurements were also performed [14]. The following table (Table 2) shows parameters of individual routes.

In regard to the research, it is mandatory to use such measurement techniques that would enable one to quantify the exact amounts of fuel tanked up from a dispenser at the FS and then calculate deviations from particular val-

ues indicated on the dispenser [14]. The particular investigating techniques are specified in the following table (Table 3).

Prior to the actual fuel consumption examination, deviation measurements were conducted, namely as follows [15]:

- A) Determination of deviations of the amount of dispensed fuel at the FS in relation to the actually measured amount.
- B) Determination of deviations of the amount of dispensed fuel during automatic pump gun shutting off.
- C) All measurements were taken on the same pump stand and with the same pump gun to eliminate deviations caused by the use of various pump guns.
- D) Measurement preparation and the consumption investigation as such followed next.
- E) Detection of the initial level of fuel in a related fuel tank – *i.e.* the level after the first automatic pump gun shut-off.
- F) Reset of values displayed on available on-board computer and the mobile phone application.
- G) Recording of values of average consumption and traveled distance from the on-board computer.

Table 4: Accuracy of amounts of dispensed fuel – diesel

Diesel	Amount [l]	Weight [g]	V [m ³]	Calculated amount [l]	Deviation [l]	Deviation [%]
	4.83	4,060.5	0.004805325	4.805325444	0.0247	0.51
	10.23	8,573.6	0.010146272	10.14627219	0.0837	0.83
	4.92	4,125.3	0.004882012	4.882011834	0.0380	0.78
	10.26	8,608.8	0.010187929	10.18792899	0.0721	0.71
	4.94	4,136	0.004894675	4.894674556	0.0453	0.93
	7.32	6,140.3	0.007266627	7.266627219	0.0534	0.73
				Mean deviation	0.0529	0.75

- H) Recording of values of average consumption and traveled distance from the application.
 I) Subtraction of refueled amount for calculating fuel consumption displayed on the pump stand.

Each measurement was carried out 3 times on all routes that were completed in different driving styles (economical, regular and dynamic). As for the first style, the vehicle picked up speed slowly and was driven at lower, constant, speeds. Before its stopping, for example, at an intersection, rundown of the vehicle was used. During the dynamic style, however, the vehicle was driven inconstantly, higher gears were put in at higher revs than usual and the measurements were taken at higher speeds. As well as that, the vehicle was not run down, but braking in front of an obstacle was sharp.

The second measurement was conducted in a manner where the initial level of fuel was not seen as the first pump gun shut-off, but the fuel was refilled almost to the brim of the fuel tank filler neck (up to a protrusion in the neck serving as a control mark). The measurement was performed once on each of the routes in the regular style.

4 Obtained results

Prior to commencing the measurements, a standard value of fuel consumption was calculated and assigned as a starting value, on the basis of which other types of consumption measurements were then compared. This implies the necessity for the most accurate determination of the amount of consumed fuel based on calculations from the measured values at the FS and the size of possible deviations related to the calculations [16].

4.1 Investigation of accuracy of the amount of dispensed fuel

The first examination was used to determine accuracy of dispensed fuel at the FS, where the maximum permissible error (i.e. the permissible difference between the displayed and the actual fuel volume) is of $\pm 0.5\%$ of the dispensed quantity. In practice, that accounts for ± 0.1 liters when filling 20 liters of fuel [17].

The aforementioned measurement was carried out by recording weights of fuel from laboratory scales and amounts of fuel dispensed at the FS, which were subsequently compared with calculated values based on the measured weight and fuel density [18]. During the measurement, the fuel temperature was of 8°C and the diesel density was measured at $845\text{ kg}\cdot\text{m}^{-3}$. Measured deviations are given in the following table (Table 4).

4.2 Investigation of deviations of the amount of dispensed fuel during automatic pump gun shutting off

The second examination was aimed at determining deviations of pumped fuel caused by the pump gun shutting off. In order to do so, Škoda Felícia fuel tank filler neck was modified and used to capture a particular position in the tested vehicle as best as possible and also to keep the same position during the measurement. Results are shown in the following table (Table 5).

Following the measured values, an average value of 0.9055 l was then determined. Next, a standard deviation of 0.02297 l was quantified. The values also show that (in certain cases) a deviation caused by the pump gun shutting off may take a value of 0.07 l of fuel.

Table 5: Results of deviation measurement during automatic pump gun shutting off

Order of measurement	1	2	3	4	5	6	7	8	9
Refueled amount [l]	0.91	0.87	0.93	0.92	0.89	0.9	0.91	0.88	0.94

Table 6: Results of the first investigation of fuel consumption related to compression ignition engine

No.	Route*	Driving style*	Distance – PC [km]	Distance – OBD FUSION [km]	Consumpt. – PC [$l \times 100 km^{-1}$]	Consumpt. – OBD FUSION [$l \times 100 km^{-1}$]	Refueled amount [l]	Calculated consumpt. [$l \times 100 km^{-1}$]
1	1	Economical	3	4	5.0	5.81	1.14	38.000
2	1	Regular	3	4.01	5.4	6.71	0.88	29.333
3	1	Dynamic	3	4	7.1	9.49	0.88	29.333
4	2	Economical	9	9.06	4.1	4.38	0.5	5.556
5	2	Regular	9	9.05	5.1	6.17	0.65	7.222
6	2	Dynamic	9	9.05	6.8	8.27	0.6	6.667
7	3	Economical	32	32.32	4.6	5.05	2.1	6.563
8	3	Regular	32	32.72	6.2	7.4	2.61	8.156
9	3	Dynamic	32	32.71	6.9	8.69	2.55	7.969
10	4	Economical	59	59.82	5.2	5.73	2.91	4.932
11	4	Regular	59	59.75	6.2	7.3	3.49	5.915
12	4	Dynamic	59	60.51	7.6	9.61	4.6	7.797

*1 – Short urban route; 2 – Long urban route; 3 – Short combined route; 4 – Long combined route

4.3 First investigation of fuel consumption related to compression ignition engine in passenger car

At the beginning of the first measurement, fuel was refilled until the first pump gun is shut off. The actual measurement started by resetting the previously measured values of fuel consumption and traveled distance in the on-board computer as well as the specific application. The routes were driven gradually in an economical style, a regular style and a dynamic style [19].

The very measurement was performed on Citroen Berlingo with turbocharged diesel engine. Standard On-Board computer (hereinafter referred to as PC), as well as the OBD Fusion application along with the V-Car II Wifi

adapter were used for the very comparison purpose. To reach higher measurement accuracy, only recorded data in the form of an Excel file were drawn from the application, including the length of intervals between individual records, the amount of fuel consumed over that period and the traveled distance [20]. Based on such values, the total fuel consumed on a given route as well as the average consumption may be easily calculated. Results of the first investigation are summarized in the following table (Table 6).

Table 7: Results of the second investigation of fuel consumption related to compression ignition engine

No.	Route*	Driving style	Distance – PC [km]	Distance – OBD FUSION [km]	Consumpt. – PC [$l \times 100 km^{-1}$]	Consumpt. – OBD FUSION [$l \times 100 km^{-1}$]	Refueled amount [l]	Calculated consumpt. [$l \times 100 km^{-1}$]
1	1	Regular	3	4.02	6.1	7.05	0.79	26.33
2	2	Regular	9	9.07	4.8	5.38	0.75	8.33
3	3	Regular	32	32.67	6.2	7.53	2.20	6.88
4	4	Regular	59	59.43	7.2	8.81	4.54	7.69

1 – Short urban route; 2 – Long urban route; 3 – Short combined route; 4 – Long combined route

Figure 1: Comparison of the first measurement values

Figure 2: Comparison of values obtained during the first measurement method

The following evaluation of results was done without consideration of the 1st route measurement. The 1st route measurement is represented by the numbers of rows 1, 2 and 3. There are considerable deviations (calculated results and other two methods). This fact was caused by

pushing a certain amount of fuel through the tank lid when refueling to the full tank volume. This phenomenon is most seen when short-distance measuring routes.

The following graph (Figure 2) captures mean values of the individually measured routes and their standard deviations processed for the methods used in the first measurement.

5.2 Evaluation of the second investigation results being achieved

The graph below (Figure 3) illustrates a particular comparison of measured values of the second measurement.

Figure 3: Comparison of the second measurement values

Measured values of deviation of the second measurement are listed in the following table (Table 9).

The following evaluation of results was done without taking into consideration the 1st route measurement for the same reason as the results from the first measurement (see comments below summarized in the Table 8).

Table 9: Comparison of the second investigation deviation values in relation to fuel consumption of compression ignition engine

No.	Route*	Deviation (PC and calculated) [l]	Deviation (OBD FUSION and calculated) [l]	Deviation (PC and OBD FUSION) [l]	Deviation (PC and OBD FUSION) [%]	Deviation (OBD FUSION and calculated) [%]	Deviation (PC and calculated) [%]
1	1	-20.23	-19.28	-0.95	-15.57	-273.52	-331.69
2	2	-3.53	-2.95	-0.58	-12.08	-54.89	-73.61
3	3	-0.68	0.65	-1.33	-21.45	8.70	-10.89
4	4	-0.49	1.12	-1.61	-22.36	12.66	-6.87
	Ø	-6.23	-5.12	-1.12	-17.87	-76.77	-105.77
	Ø	-1.57	-0.39	-1.17	-18.63	-11.18	-30.46
without 1 route							

In light with the above comparison, a lower deviation was obtained when using the OBD Fusion application (11.18%). Along with the increase in the dispensed fuel accuracy (with a value of 0.75% for diesel), it represents a deviation of approximately 11.93%.

The following graph (Figure 4) captures mean values of the individually measured routes and their standard deviations processed for the methods used while the second measurement.

Figure 4: Comparison of values obtained during the second measurement method

Furthermore, the dependence of the OBD Fusion deviation value on the distance traveled was determined. The equation representing this dependence has the form as follows: $y = 111.12x - 2.928$ (see Figure 5).

Figure 5: Influence of distance traveled on measured deviations – OBD Fusion

Lastly, an equation referring the dependence of the on-board computer (PC) deviation value on the distance traveled was quantified (see Figure 6). The equation rep-

resenting this dependence has the form as follows: $y = 89.477x - 2.798$.

Figure 6: Influence of distance traveled on measured deviations – PC

In Figure 7 below, it can be seen that at some point, the on-board computer achieves lower deviation values compared to the OBD Fusion application, but these values are more stable with less variation of values. If the values of the shortest route are not taken into account, the equation expressing the influence of the consumed fuel amount on the OBD Fusion deviation value has the form: $y = -0.0369x^3 + 0.8856x^2 - 6.6136x + 18.503$ and an equation specifying the influence of the amount of fuel consumed on the on-board computer deviation value has

Figure 7: Influence of the amount of fuel consumed on measured deviations without taking into account the shortest route – PC and OBD Fusion

the form as follows: $y = -0.1842x^3 + 3.1854x^2 - 17.32x + 32.436$.

The following figure (see Figure 8) presents the influence of the distance traveled on the deviation value of the on-board computer and OBD Fusion application without respecting the shortest route.

Figure 8: Influence of the distance traveled on measured deviations without respecting the shortest route – PC and OBD Fusion

In this scenario, when omitting the values of the shortest route, it is again possible to see how the magnitude of the mean deviation decreases with increasing number of kilometers traveled.

5.3 Recommendations and determination of procedure for measuring fuel consumption

To determine the exact fuel consumption, the authors would recommend the first of the measurement methods from the results being obtained. This is because the accuracy of applying this method is higher than the second one, as well as because the deviation caused by switching off the pump gun can be taken into account when calculating the very accuracy.

Furthermore, results of the investigation and above compiled charts and tables confirm that the greater the amount of fuel consumed and the longer the route section being examined, the lower the deviations among individual measurements. The authors certainly do not recommend conducting relevant experiments on a route shorter than 30 km, since measurements themselves at shorter distances are very inaccurate (see Figure 5 and 6). Therefore,

for the most accurate calculation, the authors recommend the longest possible route section being examined.

With regard to the results of investigation, the accuracy of approx. 9% can be demonstrated in the interval up to a distance of 8.8 km. At distances of 30 km and more, the accuracy is about 4%, while long-term is at the value of 5.18% as for the OBD Fusion application and of 5.27% as for on-board computer.

In addition, the results of measurements show that the deviation value when consumption of about 1 liter of fuel is at the level of about 12% as for the OBD Fusion application and up to 15% as for on-board computers. More accurate and constant values of deviations at the level of about 1.5-4% can be achieved by consuming at least 3 liters of fuel.

6 Conclusion

The main objective of this research work was to find out how to determine fuel consumption of compression ignition engine in passenger cars as accurately as possible from their users' perspective. The paper looked into the implementation and evaluation of fuel consumption quantifications by calculation methods, recording data from the above mentioned on-board computer and the specific mobile phone application called OBD Fusion.

The very examinations were performed on Citroen Berlingo motor vehicle and consisted of the following parts: selection of vehicles, designation of routes to be driven, description of used measuring technique, determination of proposed measurement procedure, measurements of accuracy of the amount of dispensed fuel as well as deviations of the amount of dispensed fuel during automatic pump gun shutting off, application of the first measurement method and subsequently the second measurement method related to searching for initial fuel levels during the examinations. To meet the objective, a certain degree of deviation on investigating the discussed fuel consumption was determined.

Based on the conducted experiments and their findings, the most accurate method related to quantifying the fuel consumption from the user's standpoint has been established, and the specific methodology of such investigation when defining four measurement stages has been proposed.

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References

- [1] Caban J, Drożdż P, Ignaciuk P, Kordos P. The impact of changing the fuel dose on chosen parameters of the diesel engine start-up process. *Transp. Prob.* 2019;14(4):51-62.
- [2] Cho W, Choi E. DTG big data analysis for fuel consumption estimation. *J. of Informat. Proc. Syst.* 2017;13(2):285-304.
- [3] Mohd Suhaimi MF, Mohd Salleh NA, Madani Sahari DTM, Sarip MS. Development of Kuala Lumpur driving cycle for the estimation of fuel consumption and vehicular emission. *IOP Conf. Ser.: Mater. Scien. and Engin.*, 2020;834(1): Article no. 012040. 6th Intern. Conf. on Adv.in Mech. Engin. 2019, ICAME 2019, Sabah, Malaysia; 14-16 August 2019.
- [4] Zheng X, Lu S, Yang L, Yan M, Xu G, Wu X, Fu L, Wu Y. Real-world fuel consumption of light-duty passenger vehicles using on-board diagnostic (OBD) systems. *Front. of Environ. Scien. and Engin.* 2020;14(2):Article no. 33.
- [5] Baquero-Larriva A, Alvarez-Coello G. Low cost data acquisition system to register fuel consumption in diesel engine vehicles. *Congr. Internac. De Innovac. y Tenden. En Ingen.* (4th Innovat. and Tren. in Engin. Congr.), CONIITI 2018, 2018:Article no 8587057, Bogota, Colombia, 3-5 October 2018.
- [6] Benajes J, Pastor JV, García A, Boronat V. A RCCI operational limits assessment in a medium duty compression ignition engine using an adapted compression ratio. *Ener. Conver. and Manag.* 2016;126:497-508.
- [7] Wu YY, Jang CT. Combustion analysis of homogeneous charge compression ignition in a motorcycle engine using a dual-fuel with exhaust gas recirculation. *Energies* 2019;12(5):Article no. 847.
- [8] Hurtova I, Sejkorova M, Verner J, Sarkan B. Comparison of electricity and fossil fuel consumption in trolleybuses and buses. *Engineering for Rural Development. 17th Intern. Scien. Conf. Engin. for Rur. Devel.*, ERD 2018, 2018;17:2079-2084, Jelgava, Latvia, 23-25 May 2018.
- [9] Tomić MV, Jovanović ZS, Mišanović SM, Živanović ZM, Masoničić ZM. Some energetic and ecological aspects of different city bus drive systems. *Therm. Scien.* 2018;22(3):1493-1504.
- [10] Bicer Y, Dincer I. Life cycle environmental impact assessments and comparisons of alternative fuels for clean vehicles. *Resou., Conserv. and Recyc.* 2018;132:141-157.
- [11] Polcar A, Cupera J, Kumbar V. Calibration and its use in measuring fuel consumption with the can-bus network. *Ac. Univers. Agric. et Silv. Mendel. Brun.* 2016;64(2):503-507.
- [12] Skrucany T, Figlus T, Abramović B, Čupera J, Csiszár C. Influence of Vehicle Aerodynamical Devices on Fuel Consumption Evaluated Using Telematics Tools. In 8th Intern. Scien. Conf. CMDTUR 2018, 2018:384-392, Zilina, Slovakia, 4-5 April 2018.
- [13] Narayn S, Milojević S, Gupta V. Combustion monitoring in engines using accelerometer signals. *J. of Vibroengin.* 2019;21(6):1-12.
- [14] Kovács G, Gubán M. Planning of Optimal Fuel Supply of International Transport Activity. *Perio. Polyt. Transp. Engin.* 2017;45:185-196.
- [15] Rajamani R. *Vehicle dynamics and control*, Springer, New York, 498 p. 2012. ISBN 978-1-4614-1432-2.
- [16] Csiszár C, Földes D. System Model for Autonomous Road Freight Transportation. *Promet – Traf. & Transp.* 2018;30(1):97-103.
- [17] Van der Krieke J, Van Raemdonck G. Analyzing Fuel Savings of an Aerodynamic Drag Reduction Device with the Aid of a Robust Linear Least Squares Method. *SAE Int. J. Commer. Veh.* 2014;7(2):675-684.
- [18] Erd A, Jaśkiewicz M, Koralewski G., Rutkowski D., Stokłosa J. Experimental research of effectiveness of brakes in passenger cars under selected conditions. In 11th Intern. Scie. and Techn. Conf. Autom. Saf. 2018, Casta, Papiernicka, Slovakia, 18-20 April 2018, Code 136991.
- [19] Kobryn J, Figlus T. Similarity numbers in the two-zone combustion model. *J. of Mid. Eur. Constr. and Des. of Cars* 2012;10(1):22-27.
- [20] Barth M, Boriboonsomsin K. Energy and Emissions Impacts of a Freeway-Based Dynamic Eco-Driving System. *Transp. Res., Part D: Transp. and Envir.* 2009;14(6):400-410.
- [21] Jaśkiewicz M, Lisiecki J, Lisiecki S, Pokropiński E, Więckowski D. Facility for performance testing of power transmission units. *Scien. J. of the Marit. Univ. of Szcz.* 2015;42(114):14-25.
- [22] Ondruš J, Kohút P, Jurina R, Brösdorf K. How do Today's Modern Passenger Cars Brake? LOGI – Scient. J. on Transp. and Logist. 2018;9(1):83-93. DOI: 10.2478/logi-2018-0010.