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Determining the standard fuel consumption of road vehicles by using method of active type experiment

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Abstract. Many specialists say that the factorial experiment if used properly may bring remarkable results in the practical experiments in the field of motor vehicles. In order to prove these claims, with this paper we will present some theoretical considerations regarding the mathematical model used, but also the practical research carried out to obtain some objective functions such as the average fuel consumption in l/100km. In the context of the research, we present some examples of calculation regarding the actual mathematical modelling as well as, the manner in which one can reach the real values of the objective functions. During the practical research, the influence of disturbing factors suchs as temperature, air presure and humidity, wind speed and vehicle speed, wich can substantially influence the fuel consumption of road vehicle, was taken into account. In the end, some conclusions and directions regarding the research of the modelling are presented.
Keywords: *motor vehicles, ambulance, the normed fuel consumption, factorial experiment, maintenance, experimental plan.*

1. Introduction

The paper presented a research on the methodology developed with the purpose of determining the standard fuel consumption of road vehicles by using the method of the compound factorial experiment of the second order regarding obtaining objective functions namely, the average fuel consumption in l/100 km, the average hourly consumption in l/hour and CO_2 emissions mg/l. Starting from this model, the paper presents step by step the said experiment which leads to obtaining the results of the experimental research. The level of the polluting emissions in mg/m has been determined by installing a gas analyser on the specialised vehicle, the Mercedes Benz 316 CDI, with the help of which the experiment was actually done. For the study of the variation of these parameters a factorial experiment was done in this case study with four influence factors on the three objective functions. The factorial experiment [1, pp. 503-513] to determinate the average fuel consumption and polluting emissions for the motor vehicles. Although the producer of this ambulance, through the Technical Note [2], established the average fuel consumption, for new vehicles given four use for wich average fuel consumption are not established by the current regulations in force, as well as for those that have undergone important transformations during exploitation, in a position to change their average consumption provided, these will be determinate the average consumption real fuel [3, p. 92]. Determining the average fuel consumptions [4] and the correction coefficients is done by the technical commissions established for this purpose and the designated driver. Determining the average fuel consumption is done with minimum 3 vehicles of the same kind and the results are recorded in a protocol which is drawn up for each vehicle. In case there are fewer vehicles than mentioned above, the determinations are made with the available vehicles however, summing up at least three determinations. The method used by the technical commission for establishing the three objective functions is the Factorial Experiment Method [5], [6] , [7, p. 254]. The experiment took place on the A1 highway between km 36-63. The method used to execute the experiment will also be determined, the date when it will take place, an Experimental Plan [8, p. 1], [9, p. 432], [10, pp. 289-333] will be jointly elaborated and approved, so that the said experiment will eventually take place. Figure 1 shows the Mercedes Benz 316 CDI ambulance used in the experimentation process.

For this experiment to take place, the National Meteorology and Hydrology Institute was used as means to study the weather prognosis for the established date (June 25. 2023). This was necessary because the meteorological factors such as the temperature of the surrounding environment, humidity, air pressure and wind speed directly influence the experiment and, at the same time, the average fuel consumption of the motor vehicle. These four parameters need to fit several regulated intervals. Contrary, the experiment will not take place. Other factors such as: the ambulance's speed, its technical condition, the professional training and skills of the drivers, their physical and mental state, the declivity angle of the route (will be determined through mathematical calculation), its length and state, the quality of the fuel in the tank, of the lubricants in the engine and transmission, were also considered. The obtained results were entered ito the MODDE 13 software, wich they was analyzed and interpreted.

Figure 1. Mercedes Benz 316 CDI ambulance.

2. Theoretical considerations

This activity is regulated by Norm L – 4/5 [3, p. 92], Calculation norms for the fuel-lubricants and special liquids consumption for the functioning and maintenance of the vehicles, Annex no. 13, Art. 14, is slightly different than the one made by the car manufacturer, and it states:

The technical and climate conditions that need to be met when determining the fuel consumption are:

a) the motor vehicles need to be running and to have a goof technical condition. For this purpose before beginning the determinations the compression in the engine's cylinders, the distribution control, power and status of the ignition, brakes adjustment, the mounting angles of the steering wheels, transmission, etc. are checked;

b) tires pressure and size and the quality of the fuels and oils used, which to correspond to the manufacturers recommendations;

c) the engine and the motor vehicle's transmission aggregates need to be brought to the operating temperature by making a preliminary run.

For motor vehicles, the road sector for making the determinations needs to be [3, p. 92]:

Road of category *"K"*, D_2 , if possible straight without degradation, dry and with short inclinations, not steeper than 2%. The IInd category roads, D_2, are roads paved with: blocks, normal paving in good condition, macadam and causeway in good condition. The correction coefficient of the travelled equivalent for the motor vehicle travelling on II^nd category roads, $D_2 = 1,0$. These roads need to be found outside localities and to have an average intensity of traffic. In case a road with the above mentioned conditions is not found close by, the determinations can be done on an *"M"*, D_1, category road, with the mention that in the calculation equation the road coefficients *„M"*, D_1 need to be specified. The I, D_1 category of roads are roads that are in good condition: asphalt concrete, asphalt macadam, macadam with double treatment, concrete, gravel, cement.

The correction coefficient of the equivalent travel for most vehicles that travel on *I*, $D_I = 0,9$ road category. The road sector needs to have a length of 10 km and it is travelled twice in both ways, thus making for determination four measurements on a total distance of 40 km. The drivers of the cars for which the average fuel consumption is being determined need to have different levels of training, a very good driver, an average one and a non-experienced driver. For the ambulance for which the average fuel consumption is to be determined, the determinations will be made at the speeds of 70 – 80 km/h.

One will make sure that the speed for the road sector is constant and as close as possible to the mentioned speeds. The determinations are done in good weather, without rain or snow, at outside temperatures from + 5ºC to + 30ºC and atmospheric pressures of 730 – 765 mmHg. The wind speed needs to be lower than 3 m/s. In the case in which the climate conditions mentioned above cannot be met, the determination of the average fuel consumption will be postponed until optimal possibilities can be created for making the determinations [3, p. 94].

Another order that regulates the activity of determining the average fuel consumption of road vehicles in Romania is Order no.14/1982 for approving the Normative regarding the fuel and oil consumption for motor vehicles, states [11]:

According to this standard, the average fuel consumption represents the quantity of fuel necessary for a certain motor vehicle to travel 100 equivalent kilometres. The average consumptions are established under the conditions of equipping the motor vehicles with tires with the dimesnions indicated by the manufacturer. Under completely exceptional cases, when some motor vehicles are equipped with tires having different dimensions (at the axle), the average fuel consumption will be corrected as follows:

- by increasing with 10% if tires of inferior dimesnions are used;
- by decreasing with 10% if tires of superior dimesnions are used.

The above corrections are applicable only for the motor vehicles to which the correction coefficient of the travel metering device has not been updated [11].

The average fuel consumption (C_c), which resulted after making the 4 measurements with one motor-vehicle, is calculated with the equation [11]:

$$Cc = \frac{De}{100} \; x \; Cn \; x \; Uw \; x \; Sc + F_Q, \qquad [litres] \qquad (1)$$

where:

De, represents the equivalent drive on which the measurments were made, calculated according to the methodology.

Cn - the average fuel consumption established for ½ of the cars nominal transport capacity (litres/100 km equivalent), provided in apendics 1.a, 1.c and 1.d. The other elements have the same meanings shown in point 1.1 of this order;

Uw – the fuel consumption correction coefficient for unfavorable weather conditions (point 4.1.2); in favorable climatic conditions, coefficient *A* has the value 1;

Sc – the special fuel consumption correction coefficient for special operating conditions, wich is determined according to the methodology from point 4.1.3; under normal operating conditions the coefficient *Sb* has the value 1;

F_Q – the increase in fuel consumption for certain operating conditions (point 4.2).

The average speed (V_{mx}) used during the consumption determinations needs to be found between 70-80 % from the maximum economic speed foreseen by the current legislation regarding motor vehicles driving on public roads.

The average speed on a certain sector (V_{mx}), with which the road sector *"I"* was travelled is calculated with the equation [11]:

$$V_{mx} = \frac{D_x}{t_x} \; x \; 60, \qquad [km/h] \qquad (2)$$

where:

D_x, represents the length of the road sector "I" (km);

t_x the time of travel for road sector "I" (minutes).

In order to establish the average speed it is necessary for the motor vehicles subject to determination to be fitted with a tachograph device, and in the case this is not possible, the travelling time for the road sector will be measured with a chronometer .

According to the *European Regulation no. 70/220/EEC/20.03.1970* [12, p. 41]**,** [13] – Particular directives applicable to light motor vehicles and their components in the European Union, the fuel consumption of motor vehicles internationally agreed is made out of two parts, it is done by the car manufacturer and it encloses:

a) The active type of experimental method regarding urban testing is done under laboratory conditions, on a roller stand. The motor vehicle tested needs to be parked before the test at the temperature of the surrounding environment which needs to be 20-30 degrees Celsius, with at least 6 hours prior to the test. The same temperature condition needs to be fulfilled by the cooling liquid and the engine oil. The test begins from the moment the engine is started. A cycle consists of a series of accelerations, constant speed, decelerations and idle speed. The maximum speed is 50 km/h, the average speed is 19 km/h. The distance covered is 4 km. [12], [13]. The urban cycle appears in the diagram in the section "*The first part"* (fig. 2).

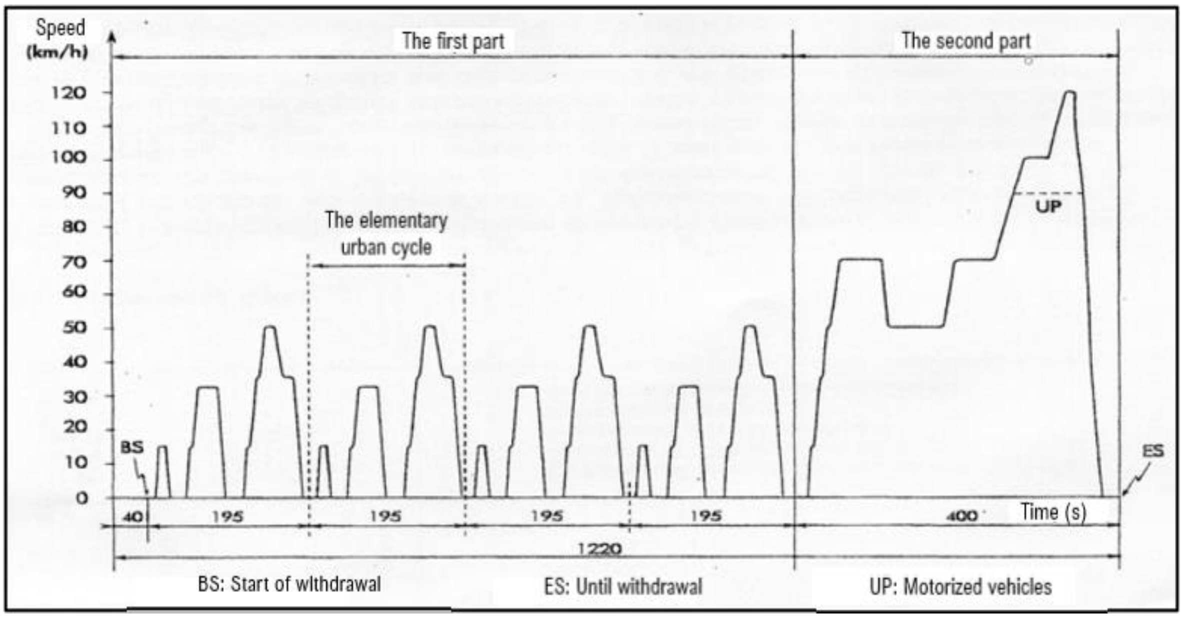


Figure 2. The diagram of the test for determining the fuel consumptions by the motor vehicle manufacturer [13]**.**

b) The active type of experimental method regarding interurban testing is performed immediately after the urban one. The test consists in accelerations, constant speed, decelerations and idle speed. The maximum speed is 120 km/h, the average speed is 63 km/h. The distance covered is 7 km. [12], [13]. The extra urban cycle appears in the diagram in the section "*The second part"* (fig. 2).

c) The combined consumption is determined as average of the urban and extra urban consumptions, balanced with the distances travelled in each case.

The manufacturer does not test each motor vehicle but only one example. It is possible that after the testing of other cars in the series, different results, better or worse, are obtained. Due to infinite possibilities of road conditions, weather conditions, driving styles, the consumption obtained after an experiment regarding the road testing may not coincide with the official one. The motor vehicles used for these experiments need to have a runway of at least 3,000 km [12], [13].

These experiments are also used to determine the pollutant emissions released by the engines of the motor vehicles.

The calculation of the fuel consumption is done according to the equation:

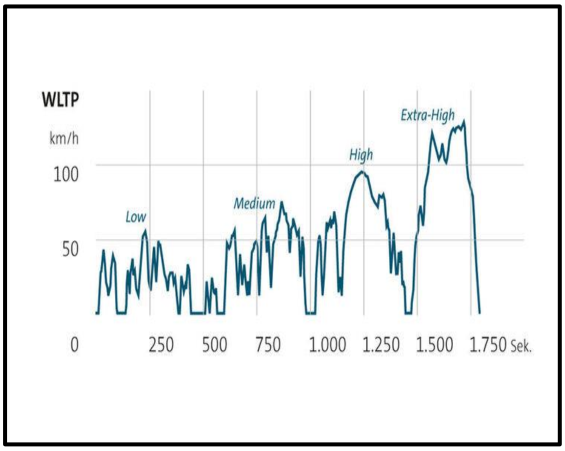
$$C_f = 100\ m/P \times d, \qquad [Kg] \qquad (3)$$

where,

C_f, represents the fuel used expressed in litres;
d - the density reference for the fuel;
P - the distance travelled in the test;
m - the fuel used in kg.

This directive is the first European normative act that regulates the homologation of fuel consumption for road vehicles.

At this time, all car manufactureres in the world use the method for the determine the fuel consumption of road vehicles the WLTP driving cycle (Worldwide Harmonized Light-Duty Vehicles Test Procedure). WLTP driving cycle is a test method introduced and in Europe in order to harmonize global fuel consumption and CO_2 emissions for motor vehicles and light commercial vehicles. It replaced the previous method of determination New European Driving Cycle (NEDC), as from September 1, 2017. Its role is to provide information closer to reality on fuel consumption and pollutant emissions in motor vehicles, using much more dynamic parameters. Figure 3 shows the framework conditions underlying the measurements made by the NEDC method for actual fuel consumption and CO_2 emissions in motor vehicles [14], [15, p. 63].



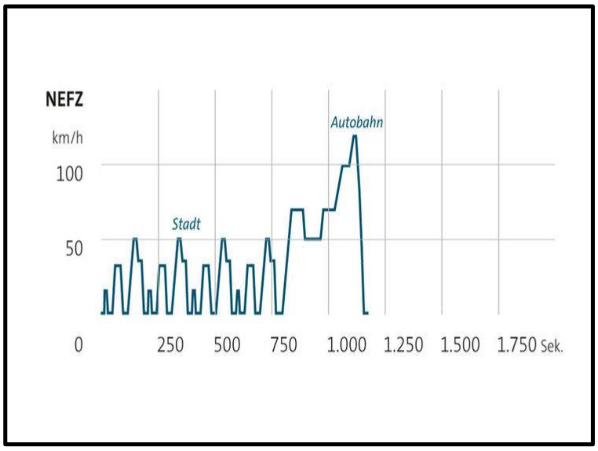


Figure 3. The framework conditions underlying the measurements made by the WLTP and NEDC method for actual fuel consumption and CO_2 emissions in motor vehicles [14].

The WLTP cycle generates and returns values of fuel consumption and pollutant emissions similar to those of the use of motor vehicles in daily practice. The new test parameters consist, for example, of the longer test distance, the longer test duration, the shorter parking time, the higher average speeds and the consideration of optional special features. These changes are often materialized in higher consumption values [14], [15, p. 63]

3. Results and discussions.

3.1Mathematical modelling of the normed fuel consumption

Because the special vehicle belongs to a military unit within the Ministry of National Defense, in this experiment, the research methodology and algorithm was carried out according to the requirments and specifications of Normative L-4/5 issued by the General Staff of Defense, on June 18.2020.

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This experiment practically took place in June and consisted in filling the ambulance's tank and driving the route 2 times both ways by each driver, for 10 km, thus making 4 experiments x 40 km during different hours of the day, and at the end of each route an experiment of the hourly fuel consumption for 10 minutes was made resulting in 16 hourly experiments, alternatively, between 08^{00} - 18^{30}. For this purpose two drivers were used, a beginner and an experienced one. Also, in order to get results as accurate as possible, measurements were made for each departure for the environment parameters: temperature of the surrounding environment, air pressure, wind speed and air humidity.

The tank of the ambulance was filled each time establishing the quantity of the fuel used. The numerical values of the fuel quantities used for additions have been introduced in the equations (11), (16) and (18) in the present paper with the help of which the average normed fuel consumption has been established. The pollutant emissions have also been permanently measured by installing a gas analyser on the ambulance's board (Kane auto 5-1 gas Class 1 car emissions analyzer). The average speed of the vehicle, *Vm,* has been theoretically estimated with the help of equation (6). All data that was obtained was registered in an experimental table.

To measure the CO_2 polluant emissions emitted by the vehicle km [16], [17] at the exhaust pipe, the Kane auto 5-1 gas Class 1 car emissions analyzer [18] was used. The devices and tools with the help of which the measurements will be made are prepared and calibrated. The operation of the gas analyzer is based on the Calibration Certificater no. RMA 652 issued by Kane International Ltd France, on June 07, 2023.

The indications on the ambulance's board computer will also be read and will be considered as guidelines, of a pure informative nature for the experiment regarding parameters, such as: **the average fuel consumption, the distance travelled, the average travelled time, etc**. Analysis and comparisons of the results red off the board device and the one installed on the board with results obtained through mathematical calculations, will be made.

The distance will be travelled: 2 times both ways by each driver, for 10 km, thus making 4 experiments, in total 40 km alternatively, at different hours of the day;

In order to get results as accurate as possible, measurements will be made with every departure for: **the temperature of the surrounding environment, atmosphere pressure, wind speed** and **air humidity**;

The calculation of the inclination angle (longitudinal) determined by altitude for the road on which the experiment will take place, in our case the A1 Bucharest - Pitesti highway [19, pp. 68-173], [20] will be made in the following manner (Fig. 4):

Input data:

- Altitude of Bucharest city: 90 metres above see level;
- Altitude of Pitesti city: 586 metres above see level;
- The length of the A1 Bucureşti – Piteşti highway = 112.000 metres;
- 586 m – 90 m = 496 m. (4)

Using the sines rule we have:

$$\text{Sin (A)} = 496/112{,}000 = 0.0044^{\circ} \quad (5)$$

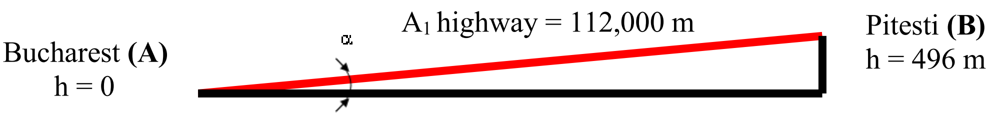

Figure 4. The inclination angle α (longitudinal) determined by altitude for the highway Bucharest – Pitesti.

Knowing the length and the inclination angle of the road sector (S) which will be travelled, for each experiment, as well as the time needed to travel it, timed, the average speeds with which these distances will be travelled, will be calculated according to the equation:

$$V_{mx} = (60xD)/t, \qquad [Km/h] \quad (6)$$

where,

V_{mx}, represents the average speed of the motor vehicle during determination;

D - the length of the sector travelled, measured in kilometres;

t - the time, measured in minutes.

Mathematical model and examples presented in the previous paper, taking into consideration the fact that we only had two drivers, an experienced one and a beginner, we conducted the experiment following the bellow steps:

1. The distance was travelled: 2 times both ways by each driver, for 10 km, thus making 4 experiments, in total 40 km alternatively, during 08^{00} - 09^{30}, 11^{00} - 12^{30}, 14^{00} - 15^{30} and 17^{00} - 18^{30}.

2. In order to get results as accurate as possible, measurements were made with every departure for: the temperature of the surrounding environment, air pressure, wind speed and air humidity, and these data were registered in table 1.

Table 1. The results of the measurrements obtained over time on the ambient temperature, air pressure, wind speed and air humidity.

Date	Hour	Air temperature [ºC]	Air pressure [mm Hg]	Wind speed [m/s]	Air humidity [%]
June 23. 2023	08^{00}	21	753.5	1.0	84
	08^{30}	21	753.5	1.0	79
	09^{00}	26	753.5	1.0	65
	09^{30}	26	753.5	1.0	60
	11^{00}	26	753.5	1.0	56
	11^{30}	26	753.5	1.0	41
	12^{00}	31	753.0	1.3	46
	12^{30}	31	753.0	1.5	45
	14^{00}	31	753.0	1.4	43
	14^{30}	31	753.0	1.3	42
	15^{00}	32	752.7	1.1	41
	15^{30}	32	752.7	1.1	41
	17^{00}	32	752.7	1.5	40
	17^{30}	32	752.7	1.2	40
	18^{00}	33	752.7	1.8	39
	18^{30}	33	752.7	1.0	41

3. Knowing the length of the road sector (S) for each experiment, as well as the time needed to travel it, timed, the average speeds with which these distances were travelled have been calculated using the equation (6) which were noted in table 2.

Table 2. The average of the speeds obtained depending on the distance traveled over time.

Date	Driver	Hour	Length of travelled sector [km]	Time [min]	Average speed [km/h]
June 23. 2023	Experienced	08^{00}	10	7.58	79.15
		08^{30}	10	7.50	80.00
		09^{00}	10	7.52	79.78
		09^{30}	10	7.55	79.47
	Beginner	11^{00}	10	8.30	72.28
		11^{30}	10	8.45	71.00
		12^{00}	10	8.50	70.58

Date	**Driver**	**Hour**	**Length of travelled sector [km]**	**Time [min]**	**Average speed [km/h]**
		12^{30}	10	8.25	72.72
	Experienced	14^{00}	10	8.12	73.89
		14^{30}	10	7.56	79.36
		15^{00}	10	7.59	79.05
		15^{30}	10	8.03	74.71
	Beginner	17^{00}	10	8.28	72.46
		17^{30}	10	8.15	73.61
		18^{00}	10	8.22	72.99
		18^{30}	10	8.37	71.68

4. Based on the experiment by travelling the established routes and replacing the results obtained in the equations (11), (16) and (18) the average fuel consumptions resulted, noted in table 3.

Table 3. Average fuel consumption obtained by traveling the established routes and stationary.

Date	**Driver**	**Hour**	**Average fuel consumption: [l/100km]**		**Average hourly fuel consumption: [l/hour]**	
			Obtained after each experiment	**TOTAL (averages)**	**Obtained after each experimen t**	**TOTAL (averages)**
June 23. 2023	Experienced	08^{00}	11.3	**11.300**	1.9	**2.1**
		08^{30}	11.2		2.4	
		09^{00}	11.4		1,8	
		09^{30}	11.3		2.3	
	Beginner	11^{00}	11.8	**11.625**	1.85	**2.1**
		11^{30}	11.6		2.35	
		12^{00}	11.6		2.0	
		12^{30}	11.5		2.0	
	Experienced	14^{00}	11.5	**11.425**	2.1	**2.1**
		14^{30}	11.4		2.2	
		15^{00}	11.5		2.0	
		15^{30}	11.3		2.2	
	Beginner	17^{00}	11.8	**11.675**	1.95	**2.1**
		17^{30}	11.5		2.25	
		18^{00}	11.7		2.20	
		18^{30}	11.7		2.0	
FINAL VALUE AVERAGE CONSUMPTION				**11.500**	**-**	**2.100**

5. Cumulating all previously obtained variables and objectives functions, Table 4 with experimental data results. The table includes all cumulative data. The variables are identified on the left side of the table (column 1-9). The objective functions are identified on the right sid of the table (column 10-12).

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Table 4. The final results of the average fuel consumption by traveling the routes and stationary, obtained by cumulating all the variables and objective functions.

Date	Hour	Air temperature [ºC]	Air pressure [mm Hg]	Wind speed [m/s]	Air humidity [%]	Length of travelled sector [km]	Time [min]	Average speed [km/h]	Longitudinal inclination of experimental sector [degrees]	Average fuel consumpti-on obtained		Pollutant emissions [mg/m]
										Liters/100 km	Liters/h	
June 23. 2023	08^{00}	21	753.5	1.0	84	10	7.58	79.15	0.0044	**11.3**	**1.9**	**0.213**
	08^{30}	21	753.5	1.0	79	10	7.50	80.00	0.0044	**11.2**	**2.4**	**0.211**
	09^{00}	26	753.5	1.0	65	10	7.52	79.78	0.0044	**11.4**	**1.8**	**0.215**
	09^{30}	26	753.5	1.0	60	10	7.55	79.47	0.0044	**11.3**	**2.3**	**0.216**
	11^{00}	26	753.5	1.0	56	10	8.30	72.28	0.0044	**11.8**	**1.85**	**0.222**
	11^{30}	26	753.5	1.0	41	10	8.45	71.00	0.0044	**11.6**	**2.35**	**0.218**
	12^{00}	31	753.0	1.3	46	10	8.50	70.58	0.0044	**11.6**	**2.0**	**0.218**
	12^{30}	31	753.0	1.5	45	10	8.25	72.72	0.0044	**11.5**	**2.2**	**0.217**
	14^{00}	31	753.0	1.4	43	10	8.12	73.89	0.0044	**11.5**	**2.1**	**0.217**
	14^{30}	31	753.0	1.3	42	10	7.56	79.36	0.0044	**11.4**	**2.2**	**0.215**
	15^{00}	32	752.7	1.1	41	10	7.59	79.05	0.0044	**11.5**	**2.0**	**0.217**
	15^{30}	32	752.7	1.1	41	10	8.03	74.71	0.0044	**11.3**	**2.1**	**0.213**
	17^{00}	32	752.7	1.5	40	10	8.28	72.46	0.0044	**11.8**	**1.95**	**0.222**
	17^{30}	32	752.7	1.2	40	10	8.15	73.61	0.0044	**11.5**	**2.25**	**0.215**
	18^{00}	33	752.7	1.8	39	10	8.22	72.99	0.0044	**11.7**	**2.2**	**0.22**
	18^{30}	33	752.7	1.0	41	10	8.37	71.68	0.0044	**11.7**	**2.0**	**0.22**
FINAL VALUE AVERAGE CONSUMPTION										**11.5**	**2.1**	**0.217**

The results were obtained by mathematical calculation according to the examples specified below:

Calculation example no. 1 for speed: Knowing the distance of the experimental route [km] and the time [min], based on the equation (6) the average maximum and minimum speeds obtained by an experienced driver were calculated:

1. $Vm_{max.}$= (60x10)/7.50 = 80.00 km/h, the speed obtained in the experiment at 08^{30}; (7)
2. $Vm_{min.}$ = (60x10)/8.12 = 73.89 km/h, the speed obtained in the experiment at 14^{00}; (8)

Calculation example no. 2 for speed: Knowing the distance of the experimental route [km] and the time [min], based on the equation (6) the average maximum and minimum speeds obtained by a non-experienced driver were calculated:

1. $Vm_{max.}$= (60x10)/8.15 = 73.61 km/h, the speed obtained in the experiment at 17^{30}; (9)
2. $Vm_{min.}$= (60x10)/8.50 = 70.58 km/h, the speed obtained in the experiment at 12^{00}; (10)

After the experiment, by travelling the routes, the average fuel consumptions will result which will be calculated using the equation:

$$Cm = 100 \times (Cn_1 – Cn_2) / d \times D, \qquad [l/100\ km] \qquad (11)$$

where,

Cm, represents the average fuel consumption measured in litres for 100 km driven;

Cn_1 - the corresponding quantity of the fuel's initial level in the tanks measured in litres;

Cn_2 - the corresponding quantity of the fuel's level in the tanks after the road section has been travelled, measured in litres;

$(Cn_1 – Cn_2)$ - the quantity of fuel used by the motor vehicle to travel the road section;

d - the length of the road section measured in kilometres;

D - the road coefficient corresponding to the road category on which the determination was done, D_1 or D_2. The specific coefficient specific of category 2 (D_2) roads was used for an objective adjustement of the average fuel consumption.

Calculation example no. 3 for fuel consumption: Knowing the quantity of fuel used by the ambulance for travelling the road sector, the length of the road sector measured in kilometres and the road coefficient corresponding to the road category on which the determination was made, D_2, based on the equation (11) the average minimal and maximal consumptions obtained by an experienced driver were calculated, in the following manner:

1. $Cm_{max.}$ = 100x(90–88.85)/10x1.0 = 11.5 litres of diesel/100 km, quantiy obtained during experiments done at 14^{00} and 15^{00}; (12)
2. $Cm_{min.}$= 100x(90–8.88)/10 x 1.0 = 11.2 litres of diesel /100 km, quantiy obtained during experiments done at 08^{30}; (13)

Calculation example no. 4 for fuel consumption: Knowing the quantity of fuel used by the ambulance for travelling the road sector, the length of the road sector measured in kilometres and the road coefficient corresponding to the road category on which the determination was made, D_2, based on the equation (11) the average minimal and maximal consumptions obtained by a non-experienced driver were calculated, in the following manner:

1. $Cm_{max.}$= 100x(90–88.82)/10x1.0 = 11.8 litres of diesel/100 km, quantiy obtained during experiments done at 11^{00} and 17^{00}; (14)
2. $Cm_{min.}$= 100x(90–88.85)/10x1.0 = 11.5 litres of diesel/100 km, quantiy obtained during experiments done at 12^{30} and 17^{30}; (15)

The average consumption of fuels, in litres for 100 kilometres, established after determination, represents the arithmetic average of the consumptions resulted in the 4 measurements according to the equation:

$$Cm = (Cm_1 + Cm_2 + Cm_3 + Cm_4)/4, \qquad [litres] \qquad (16)$$

Calculation example no. 5 for average fuel consumption: Knowing the values of all average fuel consumptions, based on the equation (16) the average fuel consumption obtained by the ambulance was calculated in the following manner:

$$Cm = (11.5 + 11.2 + 11.8 + 11.5)/4 = 11.5 \text{ l diesel/100 km.} \qquad (17)$$

The average hourly fuel consumption will be made at the end of each drive, for 10 minutes. There will be 16 experiments x 10 minutes, at different hours of the day, with the ambulance on hold having the engine, air conditioning installation on, and the medical equipment will be connected to the electrical socket. Before beginning each experiment of this type the tank of the ambulance will be filled (80 litres). After every hour, the engine will be stopped end the tank re-filled.

The calculation of the average hourly fuel consumption will be made using the equation:

$$Cm = 60 \times (Cn_1 - Cn_2) / t, \qquad [litres] \qquad (18)$$

where,

Cm, represents the average fuel consumption measured in litres after one hour of functioning;

60 - the number of minutes the engine is on;

Cn_1 - the quantity corresponding to the initial level o the fuel in the tank, measured in litres;

Cn_2 - the quantity corresponding to the level of the fuel in the tank after the idle working of the engine with the air conditioning installation and the medical devices connected to the electrical socket, measured in litres;

$(Cn_1 - Cn_2)$ - the quanity of fuel used by motor vehicles at the idle working of the engine engine with the air conditioning installation and the medical devices connected to the electrical socket, measured in litres;

t - the time of working while on hold with the engine on, measured in hours.

Calculation example no. 6 for the hourly consumption: Knowing the quantity of fuel used by the ambulance at the idle working of the engine with the air conditioning installation and medical devices connected to the electrical socket and the functioning time on hold with the engine on, measured in hours, based on the equation (18) the average hourly minimal and maximal fuel consumptions obtained were calculated in the following manner:

1. $Cm_{max1.}$= 60x(90-87.60)/60 = 2.4 litres of diesel used in one hour, quantiy obtained during experiments done at 08^{30}; (19)

2. $Cm_{min1.}$= 60x(90-88.20)/60 = 1.8 litres of diesel used in one hour, quantiy obtained during experiments done at 09^{00}; (20)

3. $Cm_{max2.}$= 60x(90–87.65)/60 = 2.35 litres of diesel used in one hour, quantiy obtained during experiments done at 11^{30}; (21)

4. $Cm_{min2.}$= 60x(90–88.15)/60 = 1.85 litres of diesel used in one hour, quantiy obtained during experiments done at 11^{00}; (22)

The average fuel consumption in litres after one hour of functioning, which will be established after the determination, represents the arithmetic average of the consumptions which will result in the 4 measurements according to the equation:

$$Cm = (Cm_1 + Cm_2 + Cm_3 + Cm_4)/4, \quad [litres] \quad (23)$$

Calculation example no. 7 for the average hourly consumption: Knowing the values of all hourly average fuel consumptions, based on the equation (23), the average hourly fuel consumption obtained by the ambulance was calculated in the following manner:

$$Cm = (2.4 + 1.8 + 2.35 + 1.85)/4 = 2.1 \text{ litres diesel/h} \quad (24)$$

Conclusions and directions for modeling research

Out of the experimental researches made regarding the effect of the objective functions on the functioning of the diesel engine with direct injection, both regarding the energetic performances and the polluting ones, the following conclusions can be drawn:

- Through the case study presented one wished to establish some objective functions, aspect done by checking the hypothesis according to which the mathematical model leads to obtaining the results of the experimental research. As a consequence, the mathematical calculation method was used as means of knowing the correct reality;
- In the research for establishing the objective functions, as object subject to research in the case study, all conditions and details regarding the manner in which the measurements, the purpose of the experiment, the nature of the measured or neglected parameters and the purpose of processing the data were made, have been attentively observed;
- Based on the experimental analysis it was noted that in the case of this experiment no perturbing agents, such as failure or errors that occur in the mathematical calculation or in the measuring and control devices, have occurred during registration;
- The experiment took place in the natural environment and as a consequence it was desired to experiment according to the micro-climate of the A1 highway, km 36-63, and not to experiment according to certain imposed influence factors;
- The analysis of the data in the mathematical model afferent to the experiment reveals the result of some maximal and minimal values of the objective functions followed;
- Processing the data obtained after the mathematical calculation in the experiment, through the MODDE 13 software, both in the histogram of the average fuel consumption [l/100 km] done after travelling the distance, and in the average hourly fuel consumption [l/h], one can see a focus of the process in the area of the value 11.5 l/100 km for the road consumption and of the value 2.1 litres for the average hourly consumption done while on hold, after the idle working of the engine with the air conditioning installation and the medical devices connected to the electrical socket. The average CO_2 emission was at the level of 0.217 mg/m (217 g/km). The resulting value falls within the norm established by the manufacturer and were determined with specifiv equipment;
- It is known that the engines with internal combustion that equip the motor vehicles frequently end up functioning at surrounding variable temperatures and have an estimable influence on the power and consumption performances. The problem is, if this influence is big, then it must be taken into consideration in order to limit pollution and to reduce the fuel consumption. In reality, together with the increase of the surrounding temperature the degree of filling the engine's cilinders decreases and the mass of air left in the cylinder for combustion reduces the cyclic dosage of fuel which remains

unmodified. In this case, froma technical and functional point of view, the burning of the fuel in the engine is incomplete, thus leading to the decrease of the engine's power, increasing the degree of environmental pollution;

- The environmental factors influence in a direct manner the good functioning of the engines with internal combustions through the effect they have on the combustion process of the fuel in its cylinders, as well as the constructive elements of the motor vehicle, leading to the increase of the fuel consumption and the pollution of the surrounding environment;
- With the case study presented one wished to establish the three objective functions, aspect accomplished by checking the hypothesis according to which certain climate factors as well as factors related to the motor vehicle's dynamics influence them. As a consequence, the experimental method was used as means of knowing the correct reality;
- In order to observe and analyse the influence of the climate factors and the experimented parameters the factorial experimentation strategy was used in the case study presented;
- The small variations of the climate factors in the month of June 2023, have represented a new reason for using the factorial experiment, method which allows the making of a clear delimitation even in the case of very small variations of the variables;
- The analysis of the data from the experiment shows the existence of 4 maximal values and 4 minimal values of the average fuel consumption in l/100 km and of the polluting emissions in mg/m. 16 experiments of the average hourly fuel consumptions were also made, thus obtaining 8 maximal values and 8 minimal values. Even so, for each experiment considered there were no values registered that would surpass the limits imposed by the legislation in force regulating the maximum quantity of allowed fuel consumption and polluting emissions;
- The low temperature of the air allowed in the diesel engine also influences the level of the temperature on a cycle leading to a non-corresponding pulverization of the fuel into the cylinders. The increase of the gas environment's viscosity from the combusting chamber in the injection moment influences the speed of the fuel's combustion front, resulting in the formation of polluting compounds. On the other hand, one knows that together with the increase of the inspired air's temperature its density and the engine's filling up degree ηv decreases and in the end the mass of the air left in the engine's cylinders at the end of aspiration decreases. Under these conditions we can expect an incomplete combustion of the fuel and thus, a reduction in the engine's power on one hand, and the increase of the pollution degree and fuel consumption on the other hand. The increase of the surrounding environment's temperature determines the modification of the admission temperature in the engine, the decrease of the immediate performances and power, at the same time with an increase of the specific effective fuel consumption and polluting emissions.
- Both the cloudiness and the rains influence the wind speed, air humidity, air pressure and temperature of the surrounding environment, as deciding factors, of the motor vehicle's movement on the running route, of the corresponding functioning of engines with internal combustion, as well as for the polluting emissions. All these variables influence one way or another, the fuel consumption and the polluting emissions for the motor vehicle with the help of which the experiment is conducted.
- In the end, one can state that:
- a) the approach of the climate factors as well as those regarding the motor vehicle's dynamics as object subject to research within the factorial experiment strategy has brought valuable results from the point of view of the relationships existing between the motor vehicle, road, driver and environment;
- b) the general objective regarding establishing the 3 optimal objective functions by means of the specific objectives have been reached.

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