REGRESSION ANALYSIS APPLIED TO INFLUENCE OF TRAFFIC FLOW PARAMETERS ON EMISSIONS OF COMBUSTION PRODUCTS

Milan Marković[1]*,
Dragana Velimirović[2]

[1]MTT - SRB Consultancy,
DOO Beograd-Stari Grad,
Belgrade, Serbia

[2]Academy of Applied Technical Studies Belgrade College for Traffic, Mechanical Engineering and Environmental Engineering,
Belgrade, Serbia

Abstract:

The aim of this paper is to analyze the impact of emissions of combustion products in the area of the street network of cities. During the preparation of the paper, we start from the relations that express the dependence of the emission of characteristic compounds, toxic components: carbon monoxide, nitrogen oxides, and solid particles from various parameters related to the street environment and traffic volume. The main contribution is updating the relations to which these dependencies are expressed. The parameters in the relations are the orientation of the street, the concept of the same, whether the street is of the canyon type or not, as well as those related to the volume of traffic. Dependency relations were obtained by regression analysis. We start from the position that the coefficients along with the parameters should be checked in accordance with the greater participation of modern engines on the one hand, but also the dilapidating of vehicles on the other. In order to establish a new state, a new recording of the emission of the mentioned components is performed, on the basis of which up-to-date dependencies are formed. The contribution is in the formation of new relations through regression analysis, for each component, by applying a software package developed by the author of the work on recording the obtained value of toxic components for Despot Stefan Street in Belgrade.

Keywords:

Environmental protection, Traffic, Regression analysis.

INTRODUCTION

Along with the increase in the intensity of traffic in the city network, the greater share of dilapidated vehicles and the bus type of public city transport, there is a need to check the relations that show the dependence of the emission of characteristic toxic components on meritorious parameters. These parameters refer to the orientation of the street, its width, ventilation and the volume of traffic. The relations obtained by regression analysis, which are already applied for the approximate establishment of the composition of combustion products, need to be checked and harmonized with the specific condition of the vehicle fleet. To that end, the authors of the paper approach by recording the participation of Carbon monoxide, nitrogen oxides and solid particles, on the basis of which up-to-date dependencies are formed.

Correspondence:
Milan Marković

e-mail:
kimi.kimi1988@gmail.com

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2. LOCATION OF THE EXPERIMENT

Despot Stefan Street is a characteristic street in Belgrade from the aspect of high pollution with combustion products in SUS engines, [1] and [2]. The main characteristics of the street are Poor ventilation of the street as it is provided at an angle of approximately 90^0 in relation to the wind direction characteristic of the location. Major wind direction stretches from north-west to south-east. Another unfavorable aspect is a large number of huge buildings on both sides of the street, which, in addition, adversely affects the ventilation of the street and forms it to be of a canyon type. The section of the Street from George Washington Street to Brace Jugovica Street is also characteristic from the aspect of: small road widths and - small width of sidewalks on both sides. It is characteristic that the level of toxic components in the emission of combustion products decreases exponentially with distance from the source of pollution. From that point of view, the small width of the sidewalk is a significant problem, [3]. Bearing in mind the possibility of varying parameters:

- Street width [m], - traffic volume [vehicles/h],
- Wind speed [km/h],
- Average vehicle speed [km/h],
- Air temperature [^{0}C],
- Uniformity of traffic flow.

It is possible to set new dependencies by applying regression analysis.

3. EXPERIMENT CONCEPTION

Characteristic toxic components whose participation in the emission of combustion products is found are:

- Carbon monoxide, CO,
- Carbon dioxide, CO_2,
- Parts of hydrocarbon chains or rings: CH components,
- Nitrogen oxides: NO_x,
- Sulfur compounds: SO_2,
- Solid particles.

For carbon monoxide, it is characteristic that it is measured directly next to the source, near the end of the exhaust system, since it is unstable and, almost instantaneously, binds to oxygen free radicals, forming, stable from the labile compound: carbon dioxide, [4] and [5].

This compound plays a key role in creating the greenhouse effect. It is important to emphasize that Diesel engines are significantly higher pollutants than OTTO engines, given that combustion products are more toxic in terms of carcinogenicity. The reason is the structure of hydrocarbon compounds, the basic components of petroleum distillates. Petrol is light hydrocarbons, [6], consisting of easily dissociable lower hydrocarbon chains. These are paraffin hydrocarbons, as well as isooctane. Unlike these paraffin hydrocarbons, diesel fuel consists of isoparaffin chains, but also difficult-to-separate cyclic hydrocarbons - naphthenes. Due to their more difficult decomposition, naphthenes can also cause more serious consequences for the environment, [7] and [8]. Having in mind the strong and conditionally pleasant, aromatic smell, these hydrocarbons are also called aromatics.

The harmfulness of combustion products can be reduced. This is achieved by more complete combustion by optimizing the participation of oxygen, which affects the mixture in the combustion process, as well as by burning exhaust gases by injecting additional fuel. Also, the process of transformation of nitrogen monoxide into, less harmful to the environment, nitrogen dioxide is being realized. The realization is performed by catalysts, that is, by accelerating chemical reactions in the combustion process in the engine as well as by acting on the combustion products in the process of blowing. This represents the engines: EURO 5 and EURO 6, [8]. One of the results of this process is a significantly lower temperature of the exhaust gases, which achieves their lower inertia and penetration as well as the distance they reach when leaving the exhaust system. This is the reason why the relationships that established the participation of certain components in the emission of exhaust gases are to be checked and changed. Existing relationships may not be valid for modern engines, which are largely represented today. Those relations are defined by the exploration of experts for urban transport andmembersr othe f Serbian Academy of Sciences and Arts, Vukan Vucic. Mentioned relations are presented in [12], part II, chapter 6 and they are the subjects of verification:

- For the participation of carbon monoxide:

$$CO[ppm] = 2.26 + 0.14 \cdot T_v - 0.394 \cdot V\left(Q / V_{sr}\right) \cdot \left(0.048 \cdot V_s + 1.152 / D\right), \quad (1)$$

Where are:

- T_v – Air temperature [^{0}C],
- V – Wind speed [km/h],
- Q – Volume of traffic [vehicles/h],

- $V_{sr.}$ – Average speed of traffic flow [km/h],
- D – driveway width [m],
- V_s – uniformity of traffic flow,

V_s= 0.94 to V_s= 1.13 for: Q=300 to 2000 vehicles/h,

- For the participation of nitrogen oxides:

$$NO_x[\mu g/m^3]=46.9-0.036\cdot Q+40\cdot 10^{-6}\cdot Q^2, \quad (2)$$

- For the participation of solid particles:

$$P[\mu g/m^3]=0.0431+0.000249\cdot Q. \quad (3)$$

3. RESULTS OF RECORDING THE EMISSION OF COMBUSTION PRODUCTS

Recording of the participation of individual toxic components in the emission of combustion products is being realized for the section of Despot Stefan Street in Belgrade from the street: George Washington to Brace Jugovica Street during the day and is presented in Table 1.

Road data are as follows:

- T_v = 10^{0}C to 20^{0}C – Air temperature, as shown in Table 1,
- V = 5 km/h – Wind speed,
- Q – 1508 to 2480 vehicles./h – Total volume of traffic, as shown in Table 1,
- $V_{sr.}$ = 5 to 27 km/h – Average speed of traffic flow, as shown in Table 1,
- D = 7m – driveway width,
- V_s=1 – uniformity of traffic flow.

4. MATHEMATICAL MODEL FOR APPROXIMATION OF EMPIRICALLY OBTAINED DEPENDENCE BY MULTI-PARAMETER REGRESSION ANALYSIS

Analytically, the dependence of the participation of individual components in the emission of combustion products on the parameters follows in the form of functions, [9] and [10]:

- First degree – linear, t=1:

$$y_t= a_0 + a_1x_1 +a_2x_2 + ...+ a_nx_n, \quad (4)$$

- Second degree – quadratic, t=2, for n=3 parameters:

$$y_t = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4 x_1^2+ a_5 x_2^2+ a_6 x_3^2 \text{ and} \quad (5)$$

- High degree, t=3, for three parameters:

$$y_t = a_0\cdot x_1^{a_1}\cdot x_2^{a_2}\cdot x_3^{a_3}. \quad (6)$$

Recording	Tv[^{0}C]	Q [vehicles/h]	V_{sr} [km/h]	participation recorded state / expressions: 1, 2 and 3		
				CO[ppm]	NOx[μg/m³]	P[μg/m³]
1	10	2050	16	18/28	135/141	0.50/0.55
2	10	2160	12	21//39	137/156	0.51/0.58
3	11	2305	14	28/36	142/176	0.52/0.62
4	13	2260	16	29/31	140/170	0.52/0.61
5	13	2121	18	24/26	136/150	0.51/0.56
6	13	2045	20	18/23	134/141	0.50/0.55
7	15	1850	26	12/17	110/117	0.46/0.50
8	15	1650	20	11/19	91/96	0.42/0.45
9	17	1780	24	13/18	98/110	0.43/0.48
10	18	2065	19	22/25	135/143	0.50/0.56
11	19	2380	14	26/38	142/188	0.52/0.63
12	19	2480	11	30/50	153/204	0.53/0.66
13	20	2370	18	29/30	143/186	0.52/0.63
14	20	2324	12	28/43	144/179	0.51/0.62
15	20	2450	10	29/54	150/199	0.52/0.65

Table 1 – Results of recording the participation of combustion products.

The correct values of the participation of the parameters found in the recording are presented in the notation: $j = 1, 2 \ldots k$. The deviation of the assumed, analytically obtained value is established: y_j from the recorded one: for all parameters on which the participation of an individual component depends. The total deviation is the sum of the squares of the deviations between the y coordinate of the point corresponding to the selected analytical dependence: y_{tj}, (4) to (6), and the one corresponding to the measured value: $\hat{y}_{tj}$ for that same point in the form, [11]:

$$S_t = \left(\hat{y}_1 - y_{t1}\right)^2 + \left(\hat{y}_2 - y_{t2}\right)^2 + \ldots + \left(\hat{y}_k - y_{tk}\right)^2 = \sum_{j=1}^{k}\left(\hat{y}_j - y_{tj}\right)^2, \quad (7)$$

k – Total number of recordings.

The values of the parameters for which the specific sizes of the components are obtained are in the form of:

$$x_{11}, x_{12}, \ldots\ x_{1k}, x_{21}, x_{22}, \ldots, x_{2k}, x_{31}, x_{32}, \ldots\ x_{3k}.$$

The first index refers to the first, second, and third parameter in the expression: (1); these parameters are wind speed, traffic volume and air temperature, while the other index refers to recordings: 1, 2,..... k. The minimum function required is: S, (7), the sum of the squares of the deviations: $y_{t,j}$ of, by

$$\frac{\partial \sum_{j=1}^{k}\left(\hat{y}_j - y_{tj}\right)^2}{\partial a_i} = 0, \quad t = 1,2,3. \quad (8)$$

Where are:

$i = 0, 1 \ldots 3$ for relation according to (4) and (6), t=1 and 3,

$i = 0, 1 \ldots 6$ for relation according to (5), t=2.

The coefficients: ai are to be found by equalizing the first partial derivative by the coefficients: ai expressions with the sum of the squares of the deviations of the recorded values and the values obtained analytically, for each recording, with zero, according to (5). Solving equation (5) yields a system of 4 algebraic equations with four unknowns for dependence: (4) and (6), i.e., of 7 equations for approximation, by expression (5). In this way, the coefficients are obtained with the parameters, expressions (4) and (6) as well as the exponents: ai, depending on: (5). Based on that, the authoritative dependence is established, as the one where the total deviation, as well as the relative deviations of the analytically obtained values from those measured for all parameters and for all pairs of points, are the smallest. Expression (1) is followed by a multi-parameter correlation since it is a multi-parameter dependence.

5. APPLICATION OF "INTER5" SOFTWARE TO FIND THE DEPENDENCE OF COMBUSTION PRODUCT EMISSIONS ON INFLUENTIAL PARAMETERS

In order to find out the influence of traffic volume, air temperature and traffic flow speed on the emission of carbon monoxide, nitrogen oxides and solid particles, the authors developed a software package that is based on multi-parameter regression analysis for carbon monoxide emission analysis and polynomial dependence for other two components of combustion products, which is obtained by the minimum squares method. Relations that have got by multi-parameter regression analysis are presented in listing 1.

A comparison of the results has got by regression analysis described above with the recorded value for carbon monoxide in the function of T_{air} [^{0}C] is given in Table 2, of Q[vehicles/h] in Table 3 and in the function of V [km/h] in Table 4.

Results presented in Tables 3, 4 and 5 have got from the recording realized by the Academy of Applied Technical Studies Belgrade College for Polytechnic. Measuring was performed by exhaust gas analyzer, produced by IMR Environmental Equipment, Inc. Method for analysis is performed by infrared gas analyzing, thermo-

APPROXIMATION BY SQUARE DEGREE FUNCTION:

CO = 8.979797E-03+ (0.6545994)*T_{air} + (-3.047681E-02) * Qv+ (2.097633)*V+(-0.022809)*T_{air}^2+ (1.405257E-05)*Qv^2+ (-0.0571197)*V^2,

APPROXIMATION BY HIGH DEGREE FUNCTION, BY SAMPLES VARIABLES:

CO = 1.001688 * (0.0869) ^ T_{air} * (0.6342716) ^ Qv *(-0.7328007) ^ V,

APPROXIMATION BY SINGLE DEGREE FUNCTION:

CO = 0.1021261 + (0.1018782)* T_{air} + (1.402836E-02)* Qv + (-0.5542434)* V,

APPROXIMATION BY HIGH DEGREE FUNCTION, BY PARAMETRES:

CO = 0.9997994 *T_{air}^ (0.9940598)*Qv^ (1.001433)*V^ (1.004146).

VALUE OF CARBON OXIDE PARTISIPATION DEPENDING TO: T_{air} EQUEL TO 21^{0}C, Qv EQUEL TO 2500 vehicles/h, and V EQUEL TO 11km/h IS, ACCORDING TO SQUARE DEGREE FUNCTION IS 31.49ppm.

Listing 1 – Relations that have got by multi-parameter regression analysis.

conducting and thermo-magnetic analyzing devices, all incorporated into a unit, Fig. 1. Traffic flow density, as well as average vehicles speed, were measured by test cars. Air temperature and wind speed were obtained by Meteorological Institute.

Relative deviations for carbon monoxide participation depending on regression function type are presented in Table 5.

Total declination for square regression: 19.48787

Total declination for linear regression: 32.14518

Total declination for high degree regression by samples: 48.76285

Total declination for high degree regression by parameters: 28.25685

T_{air}	Square Regression	Linear Regression	High degree per parameters regression	High degree per samples regression	Recorded
10	19.79	21.01	20.22	18.95	18
10	20.95	24.77	25.81	21.82	21
11	27.03	25.80	24.22	26.92	28
13	26.50	24.26	22.00	25.15	29
13	22.49	21.20	19.39	20.78	24
13	20.21	19.03	17.54	18.79	18
15	12.33	13.17	13.75	14.40	12
15	11.77	13.50	14.38	12.77	13
17	12.26	13.50	14.38	12.76	13
18	20.63	20.37	18.85	18.69	22
19	29.45	27.67	25.92	28.58	26
19	31.22	30.73	31.75	32.57	30
20	28.51	24.85	21.37	26.89	29
20	25.99	28.09	28.71	26.00	28
20	28.92	30.97	33.93	30.89	29

Table 2 – Regression relations: carbon monoxide in the function of T_{air} [^{0}C].

Q	Square Regression	Linear Regression	High degree per parameters regression	High degree per samples regression	Recorded
1650	11.77	13.69	15.50	10.55	11
1780	12.26	13.50	14.38	12.77	13
1850	12.33	13.17	13.75	14.40	12
2045	20.21	19.03	17.54	18.79	18
2050	19.79	21.01	20.22	18.95	18
2065	20.62	20.37	18.85	18.69	22
2121	22.49	21.20	19.39	20.78	24
2160	20.95	24.77	25.81	21.82	21
2260	26.50	24.26	22.01	25.15	29
2305	27.03	25.80	24.22	26.92	28
2324	25.99	28.09	28.71	26.00	28
2330	28.51	24.85	21.37	26.89	29
2380	29.45	27.66	25.92	28.58	26
2450	28.92	30.97	33.93	30.89	29
2480	31.22	30.73	31.75	32.57	30

Table 3 – Regression relations: carbon monoxide in the function of Q [vehicles/h].

V	Square Regression	Linear Regression	High degree per parameters regression	High degree per samples regression	Recorded
10	28.92	30.97	33.93	30.89	29
11	31.22	30.73	31.75	32.57	30
12	20.95	24.77	25.81	21.82	21
12	25.99	28.09	28.71	26.00	28
14	27.03	25.80	24.22	26.92	28
14	29.45	27.67	25.92	28.58	26
16	26.50	24.26	22.00	25.14	29
16	19.79	21.01	20.22	18.95	18
18	28.51	24.85	21.37	26.89	29
18	22.49	21.20	19.39	20.78	24
19	20.63	20.37	18.85	18.69	22
20	20.21	19.03	17.54	18.79	18
20	11.77	13.69	15.50	10.55	11
24	12.26	13.50	14.38	12.77	13
26	12.33	13.17	13.75	14.40	12

Table 4 – Regression relations: carbon monoxide in the function of *V* [km/h].

Figure 1 – Exhaust gas analyzer IMR 2800P.

Recording	Square Regression	Linear Regression	Upper grade regression by parameters	Upper grade regression by samples
1	1.8	3.02	0.96	2.23
2	0.04	3.78	0.83	4.81
3	0.096	2.20	1.07	3.77
4	2.49	4.73	3.85	6.99
5	1.5	2.79	3.21	4.60
6	2.22	1.03	0.80	0.46
7	0.34	1.18	2.40	1.76
8	0.78	2.70	0.45	4.50
9	0.73	0.51	0.23	1.39
10	1.37	1.62	3.30	3.15
11	3.45	1.67	2.58	0.07
12	1.23	0.74	2.58	1.75
13	0.49	4.15	2.11	7.63
14	2.00	0.1	1.99	0.72
15	0.07	1.97	1.89	4.94

Table 5 – Relative declinations for carbon monoxide participation depending to regression function type.

Relations that have got for polynomial dependence of nitrogen oxides to *Q* [vehicles/h] are given in listing 2

Function value for arbitrary value for Q=1500km/h, depending on the degree of the polynomial is given in Table 6.

Degree of polynomial	NO_x [*μg/m³*]
2	80.34
3	60.73
4	65.22
5	63.51

Table 6 – Function value for arbitrary value for Q=1500km/h, depending on the degree of the polynomial

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-Polynomial of second degree: (-110.7766)*x^ 0 + (0.1585238)*x^ 1 + (-2.074109E-05)*x^ 2,
Value of function approximated by polynomial of second degree for Q= 1500[vehicles/h] is: 80.34µg/m³.
-Polynomial of third degree: (-556.6325)*x^0+ (0.6797687)*x^1+ (-2.08401E-04)*x^2+ (1.973757E-08)*x^ 3,
Value of function approximated by polynomial of third degree for Q=1500[vehicles/h] is: 60.73252µg/m³.
-Polynomial of forth degree:
(-346.192)*x^0+ (0.3647974)*x^1+ (-3.967294E-05)*x^2+ (-1.830413E-08)*x^ 3 +(3.013003E-12)*x^ 4,
Value of function approximated by polynomial of forth degree for Q= 1500[vehicles/h] is 65.2168µg/m³.
-Polynomial of fifth degree:
(-389.7654)*x^ 0 +( 0.4084071 )*x^ 1 +(-4.240591E-05 )*x^ 2 +(-2.768787E-08 )*x^ 3 + ( 6.298993E-12 )*x^ 4 +(-3.114152E-16 )*x^ 5, Value of function approximated by polynomial of fifth degree for Q= 1500[vehicles/h] is: 63.50912µg/m³.
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Listing 2 – Relations that have got for polynomial dependence of nitrogen oxides to *Q* [vehicles/h].

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- Polynomial of second degree:  (-0.5429083)*x^ 0 + (8.749957E-04)*x^ 1 + (-1.795907E-07)*x^ 2,
Value of function approximated by polynomial of second degree for Q= 1800[vehicles/h] is:
0.4502101µg/m³.
- Polynomial of third degree:
(-6.774442E-02)*x^ 0 + (1.713299E-04)*x^ 1 + (1.642255E-07)*x^ 2 + (-5.546015E-11)*x^ 3,
Value of function approximated by polynomial of third degree for Q= 1800[vehicles/h] is:
0.4492966µg/m³.
- Polynomial of forth degree:
(-0.1832796)*x^ 0+( 9.235148E-04 )*x^ 1+(-7.699401E-07 )*x^ 2 +( 3.689458E-10 )*x^
3+(-6.556882E-14)*x^ 4,
Value of function approximated by polynomial of forth degree for Q= 1800[vehicles/h] is:
0.4478176µg/m³.
- Polynomial of fifth degree:
(0.0853321)*x^ 0 +(-1.7632E-04 )*x^ 1 +( 3.89889E-07 )*x^ 2 +(-6.731721E-11 )*x^ 3 +(-
3.084162E-14 )*x^ 4+ +(7.13882E-18 )*x^ 5,
Value of function approximated by polynomial of fifth degree for Q=1800[vehicles/h] is:
0.4497324µg/m³.
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Listing 3 – Approximation of emission of solid particles depending on *Q* [vehicles/h] by polynomial dependence.

Degree of polynomial NO_x[$\mu g/m^3$]

A Polynomial approximation of NO_x of *Q* [$\mu g/m^3$] is presented in Table 7.

Q[vehicles/h]	NO_x
1500	63.51
1600	79.73
1700	94.13
1800	106.74
1900	117.59
2000	126.74
2100	134.25
2200	140.17
2300	144.59
2400	147.58
2500	149.23

Table 7 – Polynomial approximation NO_x of *Q*

Function value for arbitrary value for *Q*=1500km/h, depending to the degree of the polynomial is given in Table 8.

Degree of polynomial	NO_x[$\mu g/m^3$]
2	80.34
3	60.73
4	65.22
5	63.51

Table 8 – Function value for arbitrary value for *Q*=1500km/h, depending to the degree of the polynomial

The degree of the polynomial is to be accepted is 5.

A Polynomial approximation of solid particles of *Q* [$\mu g/m^3$] is presented in Table 9.

Q[vehicles/h]	Solid Particles [$\mu g/m^3$]
1500	0.369
1600	0.398
1700	0.425
1800	0.450
Q[vehicles/h]	Solid Particles [$\mu g/m^3$]
1900	0.471
2000	0.489
2100	0.503
2200	0.513
2300	0.520
2400	0.522
2500	0.522

Table 9 – A Polynomial approximation of solid particles of Q [$\mu g/m^3$]

Results which are presented in the tables, express a lower rate of exhaust gas emission. Particularly, participation of components: carbon monoxide, Carbon monoxide, nitrogen oxides and solid particles is lower than before due to the fact that more efficient engines are embedded in vehicles. In the paper presented, relations have got by regression analyzes are applicable to a great range of similar calculations.

6. CONCLUSION

The analysis given in this paper establishes new dependences of the participation of carbon monoxide components, nitrogen oxides and solid particles in the emission of combustion products. The dependence is expressed as a function of traffic volume, air temperature and vehicle speed. The dependence function was formed on the basis of measuring the obtained quantities in a characteristic street in Belgrade and with the help of software developed on the basis of a mathematical model based on correlation analysis with multi-parameter regression functions and polynomial dependencies. A different dependence than the one used so far has been established. The share of the considered combustion products is significantly lower as a result of more modern engines and a lower share of older vehicles. The contribution of the paper is the presentation of the application of the software "INTER5" as well as the preparation of the analysis and presentation of the results. The paper's approach is applicable as a useful tool for analyzing such and similar recording results.

7. REFERENCES

[1] M. Yuan, Y. Huang, H. Shen, T. Li, "Effects of urban form on haze pollution in China: Spatial regression analysis based on PM2.5 remote sensing data", Applied Geography, Vol. 98, pp. 215-223, Sep. 2018, https://doi.org/10.1016/j.apgeog.2018.07.018,

[2] E. Ericsson, "Independent driving pattern factors and their influence on fuel-use and exhaust emission factors", Transportation Research Part D: Transport and Environment, Vol. 6, No. 5, pp. 325-345, , Sep. 2001, https://doi.org/10.1016/S1361-9209(01)00003-7,

[3] G. A. Rhys, Tyler, W. Legassick, M. C. Bell, "The significance of vehicle emissions standards for levels of exhaust pollution from light vehicles in an urban area", Atmospheric Environment, Volume 45, No. 19, Pages 3286-3293, Jun 2011, https://doi.org/10.1016/j.atmosenv.2011.03.035,

[4] Y. F. Wang, K. L. Huang, C. T. Li, H. H. Mi, J. H. Luo, P. J. Tsai, "Emissions of fuel metals content from a diesel vehicle engine", Atmospheric Environment, Vol. 37, No. 33, pp. 4637-4643, Oct. 2003, https://doi.org/10.1016/j.atmosenv.2003.07.007,

[5] D. C. Carslaw, M. L. Williams, J. E. Tate, S. D. Beevers, "The importance of high vehicle power for passenger car emissions", Atmospheric Environment, Vol. 68, pp. 8-16, Apr. 2013, https://doi.org/10.1016/j.atmosenv.2012.11.033,

[6] M. V. Twigg, "Catalytic control of emissions from cars", Catalysis Today, Vol. 163, No. 1, pp. 33-41, Apr. 2011, https://doi.org/10.1016/j.cattod.2010.12.044,

[7] M. Kozak, J. Merkisz, P. Bielaczyc, A. Szczotka, "The Influence of Synthetic Oxygenates on Euro IV Diesel Passenger Car Exhaust Emissions", Fuels and Emissions Conference, 2007, https://doi.org/10.4271/2007-01-0069,

[8] N. Tamsanya, S. Chungpaibulpatana, "Influence of driving cycles on exhaust emissions and fuel consumption of gasoline passenger car in Bangkok", Journal of Environmental Sciences, Vol. 21, No. 5, pp. 604-611, 2009, https://doi.org/10.1016/S1001-0742(08)62314-1,

[9] M. Beydoun, J. M. Guldmann, "Vehicle characteristics and emissions: Logic and regression analyses of I/M data from Massachusetts, Maryland, and Illinois", Transportation Research Part D: Transport and Environment, Volume 11, No. 1pp. 59-76, Jan. 2006,https://doi.org/10.1016/j.trd.2005.09.003,

[10] S. Chatterjee, A. S. Hadi, „Regression Analysis", Wiley series in probability and statistics, John Wiley & Sons 2013, New York, NY, USA,

[11] B. Marković, „Metode optimizacije u saobraćaju i transportu", VIŠS Tehnikum Taurunum, Beograd – Zemun, 2019.

[12] B. Marković, „Javni gradski putnički prevoz", Authorised edition, Beograd – Zemun, 2008,

[13] J. S. Jadhao, D. G. Thombare, „Review on Exhaust Gas Heat Recovery for I.C. Engine", International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 12, June 2013.