ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering
Tome XV [2017] – Fascicule 4 [November]

ISSN: 1584-2665 [print; online]
ISSN: 1584-2673 [CD-Rom; online]
a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

[1.]Azem KYÇYKU, [2.]Ramë LIKAJ, [3.]Adelina SHABANI

DETERMINATION OF THE OPTIMAL ECOLOGICAL SPEED OF THE GASOLINE VEHICLES

[1-3.] University of Prishtina, Faculty of Mechanical Engineering, Prishtina, KOSOVO

Abstract: Pollution gas, which is the product of engine internal combustion, is a problem in all countries around the world. The most developed countries in the world have adopted effective regulations to reduce the quantity of gas emission by vehicles during the year. Since the speed represents one of the main vehicle parameters participating in traffic, in this paper is carried out a detailed analyses of all ecological factors depending on the speed of movement. Mathematical models for external gas emissions are derived by relevant institutes, which use the appropriate software's to solve this problem. From these analytical expressions implemented in Mathcad are derived curves of ecological factors, which are of practical interest for further environmental analysis by the field experts. In this research paper, speed limits (minimum and maximum) are set. These are the speeds for which emissions of exhaust gas are within the limits which are set by European norms. The speed of the vehicle for which the emission of harmful substances from the exhaust gas is minimal is called optimal ecological speed.
Keywords: ecological factors exhaust gas, movement speed, and optimal ecological speed

1. INTRODUCTION

The researches in this topic show that passenger vehicles participation in overall pollution with 50%. This pollution is mainly caused by exhaust gas as combustion products. Together with exhaust emissions from vehicle a considerable amounts of CO, CO2, NOx, SO2, cuprum combinations and various particles of soot, metal etc. are released.

Pollution of the environment by road vehicles and other mechanical particles generated by the consumption of pneumatic tires, braking plates, and tribological processes in the engine and other constructive vehicle parts. It is necessary to constantly work in reducing the emission of harmful substances into the exhaust gas. This study is mainly focused on the analytical presentation of ecological factors, respectively the content of the exhaust gas depending on the vehicle speed and the volume of the engine.

Based on the mathematical models for the factors of emission of exhaust gas emitters are obtained different comparative curves. The research will answer the following issues:

- Determination of optimal ecological speed, which represents the speed of the movement for which the emission of harmful substances from the exhaust gas has the minimum value.
- Determining the minimum values for ecological factors that respond to the optimal ecological speed.

2. SPEED DEPENDENT EMISSION FACTORS

The main influence on emissions of the exhaust gas plays the vehicle speed. Emission during the working temperature of the engine depending on the average speed of movement is calculated by the following formula:

$$E_{hot,v} = e_{hot,v} \cdot a \quad (1)$$

where: $E_{hot,v}$ – emission during working temperatures of the engine depending on the average speed of the vehicle [t/vit], $e_{hot,v}$ – speed dependent emission factor during the working temperature on the average speed of the vehicle [g/km], and a – traffic activity [km/vit].

In addition to the average vehicle speed, other factors such as the longitudinal road slope, vehicle load, number of kilometres travelled, environment temperature etc. are also affected by the emission factor.

Taking into the account, the ecological factor can be obtained during the engine operating temperature and is given by the expression:

$$e_{hot} = f \cdot h \cdot m \cdot t \cdot e_{hot,v} \quad (2)$$

where: e_{hot} – ecologic emission factor during working temperature [g/km], f – slope correction factor, h – load correction factor, m – correction factor of the kilometres travelled, t – correction factor of the average environment temperature, and $e_{hot,v}$ – emission factor during working temperatures of the engine depending on the average speed of the vehicle [g/km].

With the help of relevant programs in this field, such as: COPERT etc., are obtained mathematical models for the calculation of emission factors depending on the speed of movement and the volume of the passenger vehicle engine. From these mathematical expressions are obtained the diagrams which are shown in this paper. Passenger vehicles are classified based on a vehicle's volume of the engine, thus: < 1.4 *l*; 1.4 to 2.0 *l*; and > 2.0 *l*.

3. DIAGRAMS OF EMISSION FACTORS DEPENDING ON VEHICLE SPEED

From the mathematical expressions which are not provided in this research paper, using Mathcad program have been shown the diagrams for each emission factor depending on the speed of movement of the vehicle.

Emission factor of CO

In the figures 1 to 8, is shown the emission factor of CO for the vehicle speed from 10 to 130 km/h, for the different ecological categories of vehicles.

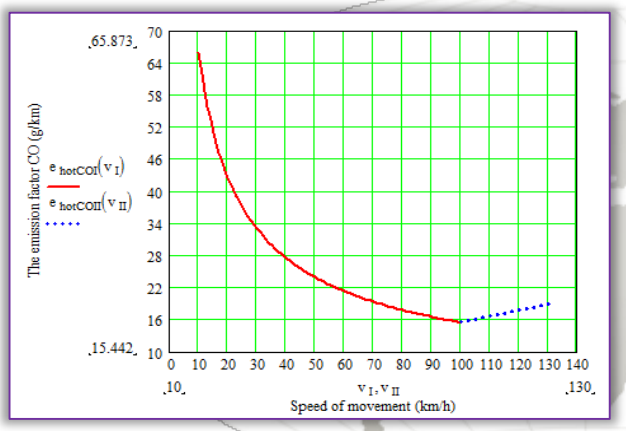

Figure 1. Emission factor of CO (g/km) for "before ECE"

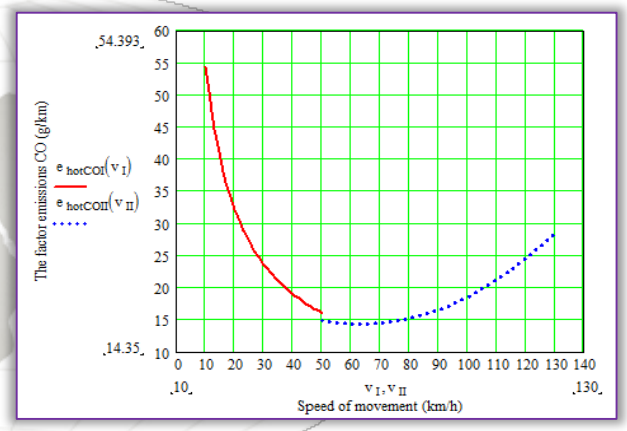

Figure 2. Emission factor of CO (g/km) for "ECE 15-00/01"

From figures is shown that curves have one part which is decreasing, the minimum point and their growth rate with the speed increase. The mathematical character of the curves is different for different ecological categories of vehicles and for different volumes of the engine. Figures 1-5, shows that mathematical models for ecological factors are different at two intervals of vehicle speed.

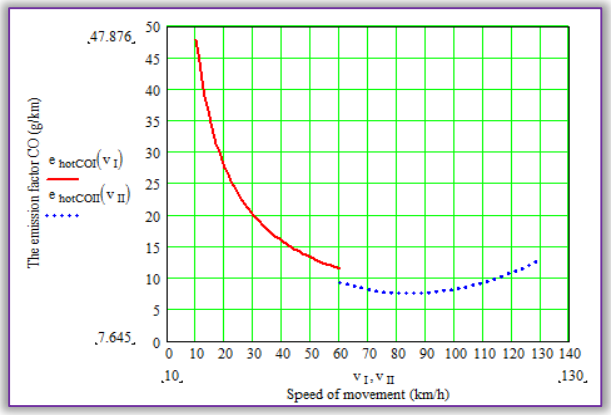

Figure 3. Emission factor of CO (g/km) for "ECE 15-02"

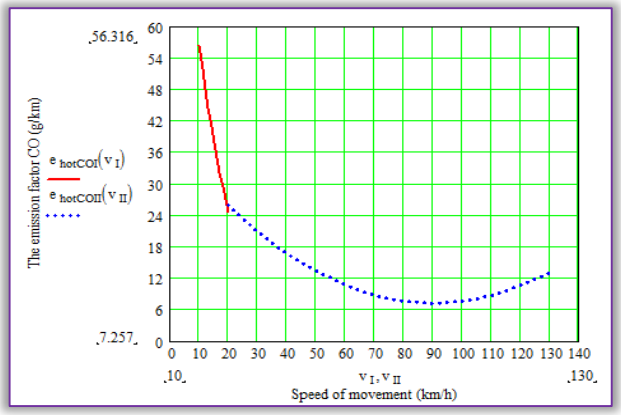

Figure 4. Emission factor of CO (g/km) for"ECE 15-03"

In Figure 6 and Figure 7, are shown the emission factors of OC for the engine with two different volumes, where in Figure 8, for the engine with three different volumes.

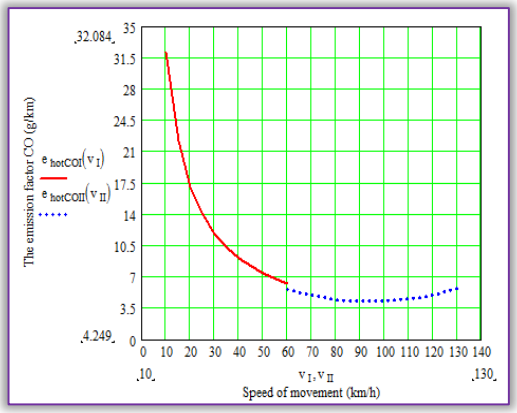

Figure 5. Emission factor of CO (g/km) for "ECE 15-04"

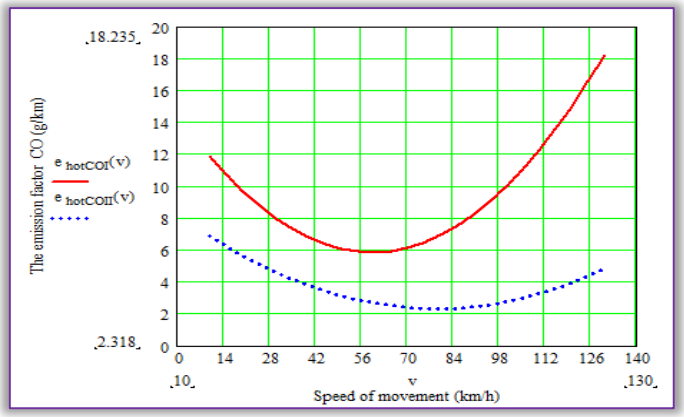

Figure 6. Emission factor of CO (g/km) for vehicle "Without catalyst and with electronic injection" (I – for volume< 1.4 l, II – for volume 1.4-2.0 l).

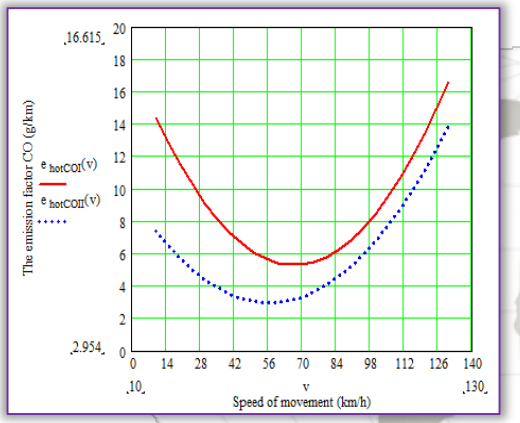

Figure 7. Emission factor of CO (g/km) for catalyst "vehicles without lamda sond"

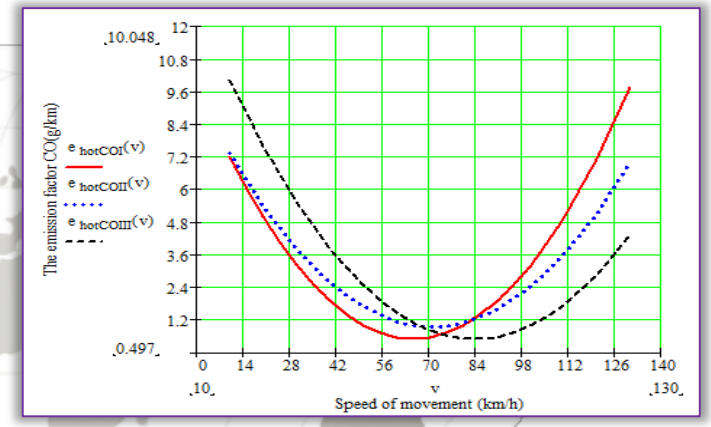

Figure 8. Emission factor of CO (g/km) to the vehicles based on "Euro I" (I – for volume <1.4 l, II - for1.4...2.0 l, III – for volume >2.0 l).

It can be seen from these figures that the engine volume affects the emission factor of CO. From Figure 1 to Figure 8, the minimum emission factor values are read CO, $e_{hotCO}(v)$ (gr/km).

Emission factor of HC

Emission factor of HC for different ecological groups of vehicles depending of vehicle speed, are shown in figures 9 to 14.

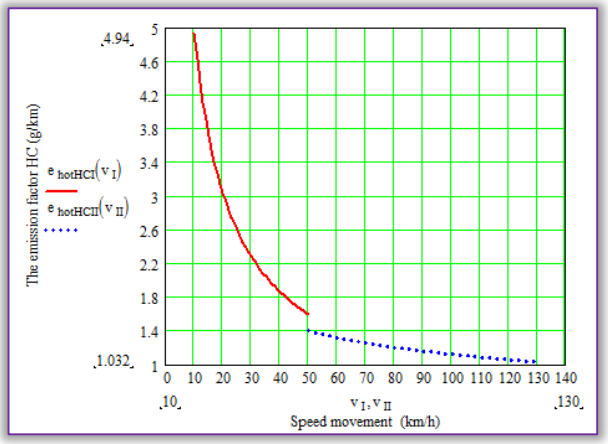

Figure 9. Emission factor of HC (g/km) for "ECE 15-00/01"

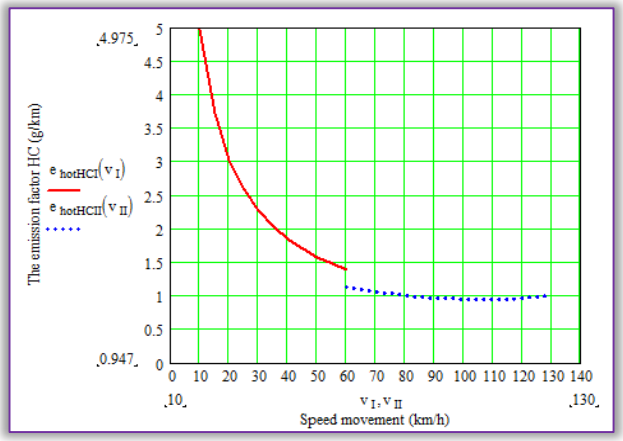

Figure 10. Emission factor of HC (g/km) for "ECE 15-02/03"

From Figure 9, it can be observed that for vehicle speed less than 50 km/h, which is practically speed limit at urban areas, the values of this factor are very large. For the speed interval more than 60 km/h, the values of the emission factor are very small and the minimum value is obtained for speed 130 km/h.

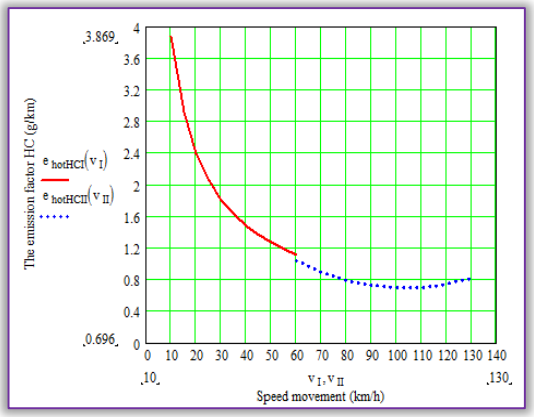

Figure 11. Emission factor of HC (g/km) based on "ECE 15-04"

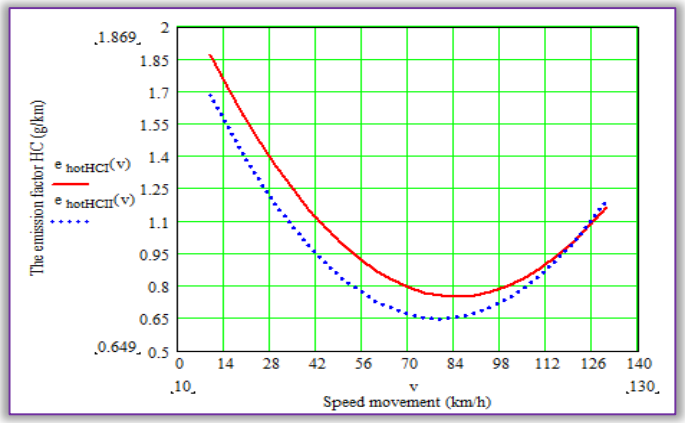

Figure 12. Emission factor of HC (g/km) for vehicles "Without catalyst and with electronic injection"

From the Figure 12, it can be seen that the vehicles with smaller engine volume than 1.4 *l*, have the emission factor of HC bigger than vehicles with engine volume from 1.4-2.0 *l.*

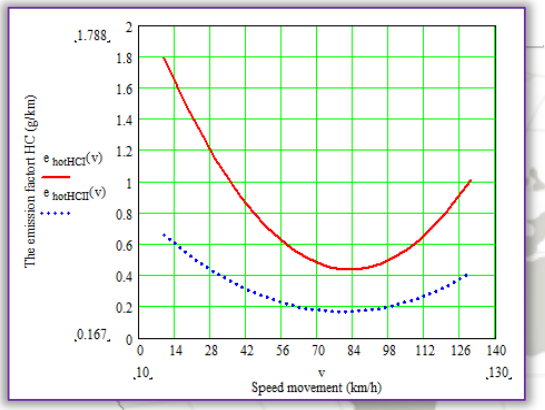

Figure 13.Emission factor of HC (g/km) for vehicles "without catalyst and sound lamp"

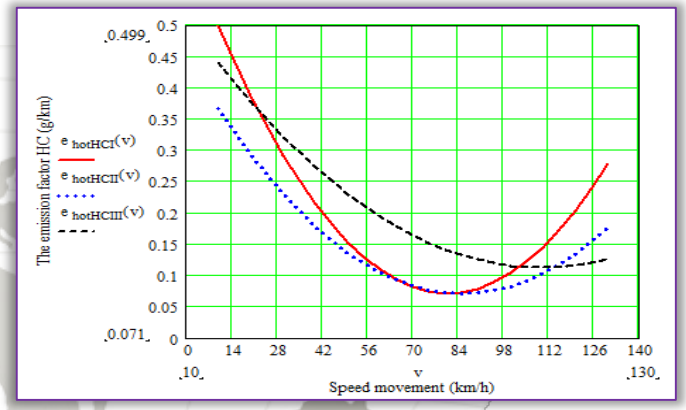

Figure 14. Emission factor of HC (g/km) for vehicles based on "Euro I" (I – for volume smaller than 1.4 l, II – volume 1.2 – 2.0 l, III – engine volume bigger 2.0 l)

From Figure 13, it can be seen that the vehicles with smaller engine volume than 1.4 *l* (curve I – emission factor changes substantially) in comparison with the vehicles volume from 1.4-2.0 *l* – curve II. From Figure 14, it can be concluded that the emission factor of HC for the vehicles based on Euro I depends largely on the volume of the engine.

Emission factor of NO_X

From Figure 15 to Figure 21, is shown the emission factor of NO_X for all ecological groups of vehicles considered in this paper for relevant engine volumes.

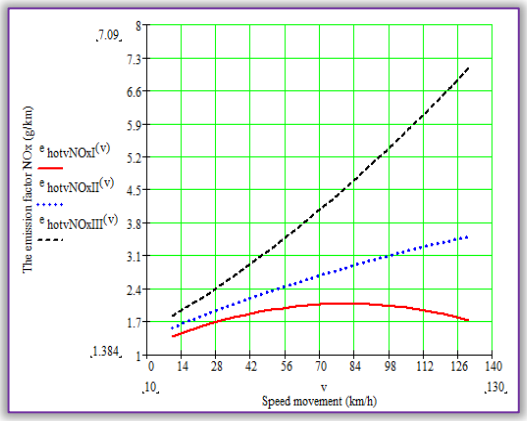

Figure15. Emission factor NO_X (g/km) for "ECE 15-00/01"

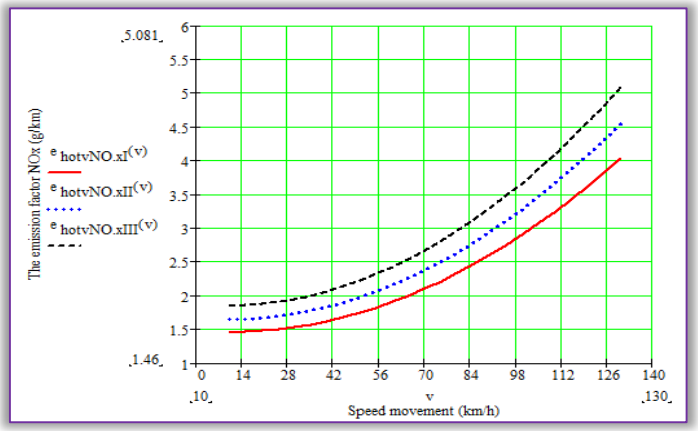

Figure16. Emission factor NO_X (g/km) for "ECE 15-02" (I – volume smaller than 1.4 l, II – volume 1.2 – 2.0 l, (I – volume smaller than 1.4 l, II – volume 1.2 – 2.0 l, III – for engine volume bigger than 2.0 l), III – for engine volume bigger than 2.0 l)

From Figure 15, it can be seen that significant influence on the emission of NO_x have vehicles with the engine volume bigger than 2.0 *l*, because by increasing the speed, the emission factor increases according to the second degree function. From Figure 16, it can be noticed that the three curves have analogous behaviour but are displaced for a distance due to a different engine volume values. The curves show that emission factor of No_x, there is no minimum value for the speed range of 10...130 km/h.

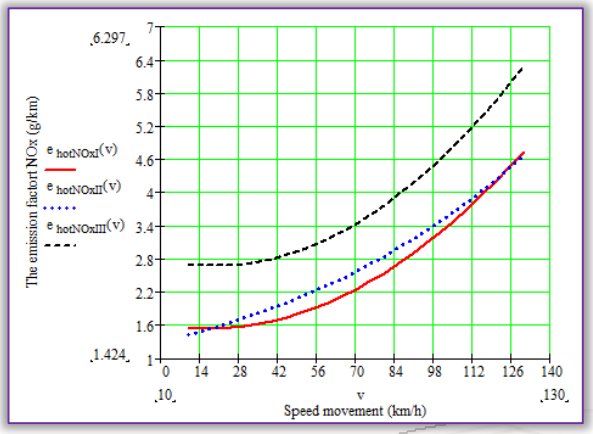

Figure 17. Emission factor of NO_X (g/km) for "ECE 15-03"

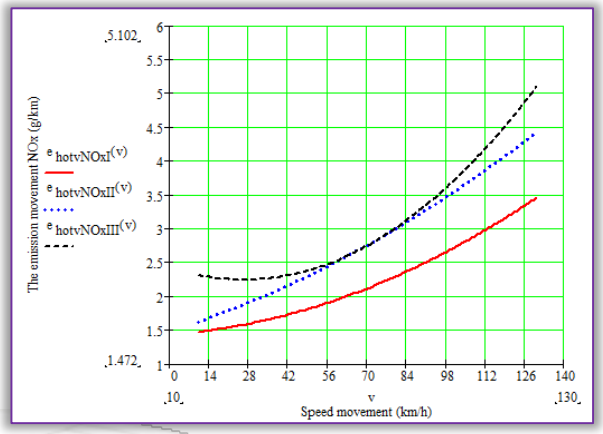

Figure 18. Emission factor of NO_X (g/km) for "ECE 15-04"

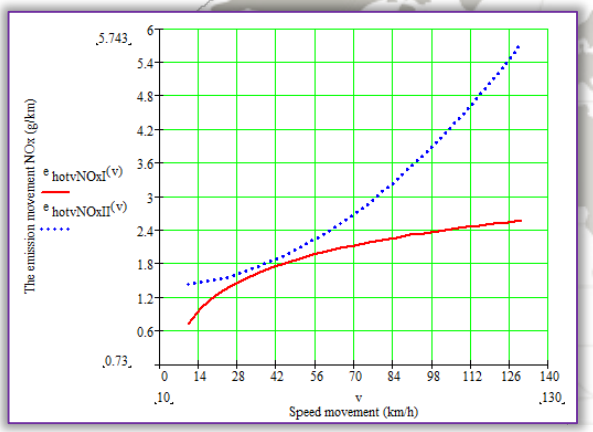

Figure 19. Emission factor of NO_X (g/km) for "Without catalyst and with electronic injection"

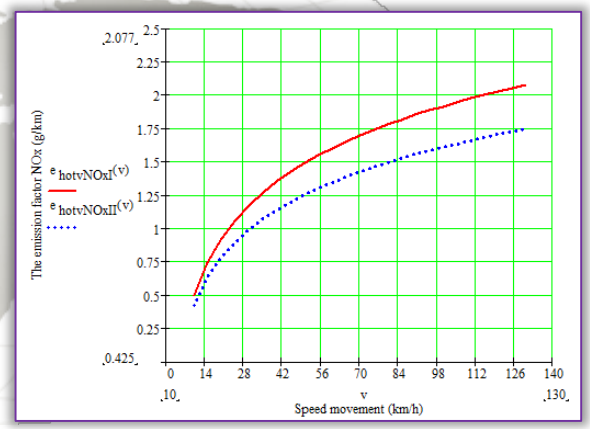

Figure 20. Emission factor of NO_X (g/km) "without catalyst and sound lamp" (I – for volume smaller than 1.4 l, II –for volume 1.4 – 2.0 l).

From Figure 19 it can be seen that the impact of engine volume on the emission factor is substantial for the vehicle speed 70 km/h. From Figure 20, it can be concluded that for vehicles without catalyst without sound lamp, emission factor of NO_x increases by increasing the speed, while it decreases by increasing engine volume.

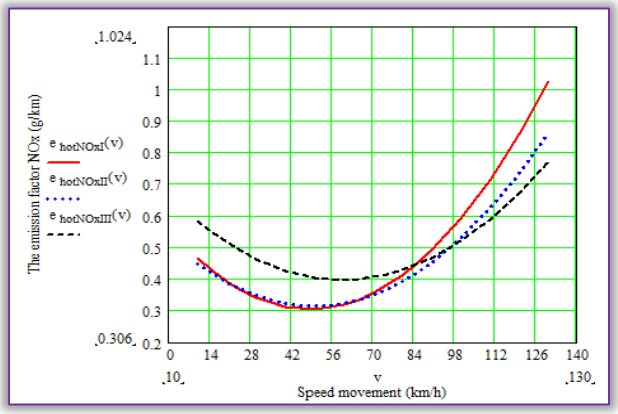

Figure 21. Emission factor NO_X (g/km) for vehicles "Euro I" (I – for volume smaller than 1.4 l, II – for volume 1.2 – 2.0 l, III – for volume bigger than 2.0 l).

From the Figure 15 to Figure 20, it can be seen that optimal ecological speed is dependent on this factor, which is practically the vehicle speed from 10 km/h. From Figure 21, it can be concluded that for the

vehicles according to Euro I by the increase of speed from 50-60 km/h, the emission factor is decreasing, while for the increase of speed this factor is noticeably increased. From the curves are read the speeds of movement for which this factor has minimum value.

Emission factor of CO_2

In Figure 22 to 29 is shown the emission dependence of CO_2 for the different groups of vehicles according to ECE and for engine volume smaller than 1.4 l, 1.4- 2.0 l, and above 2.0 l.

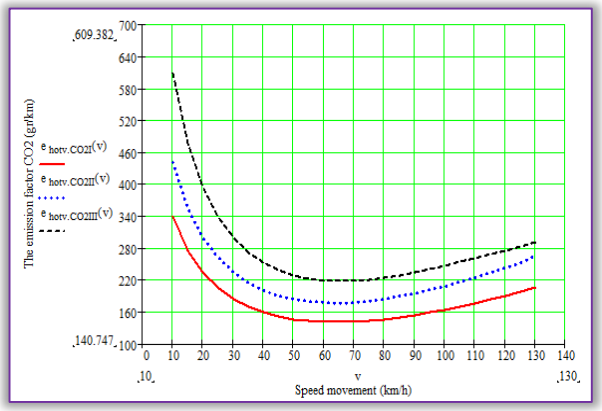

Figure 22. Emission factor of CO_2 (g/km) for "before ECE "

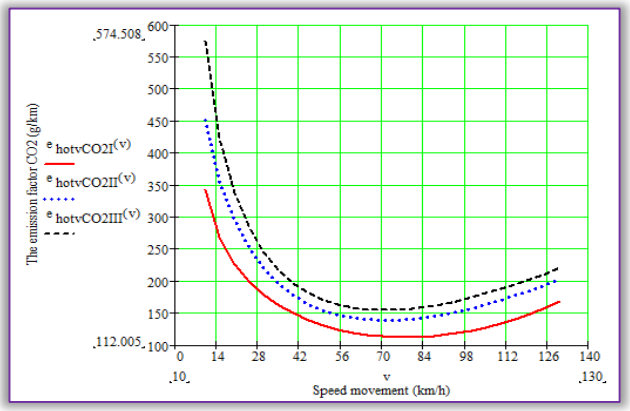

Figure 23. Emission factor for CO_2 (g/km) according to "ECE 15-00/01" (I – for volume smaller than 1.4 l, II – for volume 1.2 – 2.0 l, III – for volume bigger than 2.0 l)

From Figure 22, is noticed that during the vehicle speed at low speed, the emission values of this factor are bigger. It is also seen that there is an interval of speed where the values of this factor are minimal.

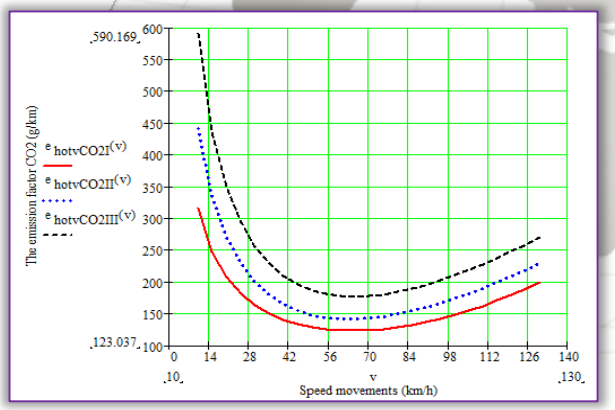

Figure 24. Emission factor of CO_2 (g/km) for " ECE 15-02"

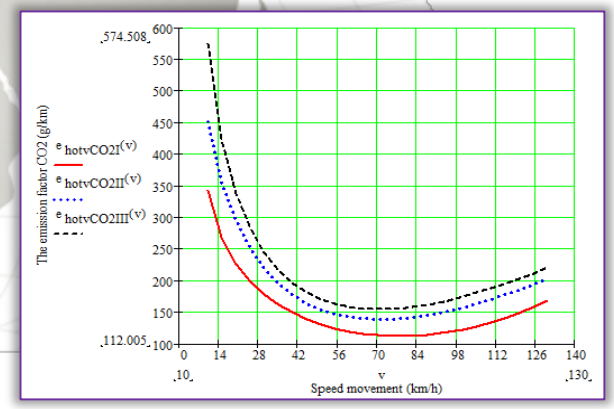

Figure 25. Emission factor of CO_2 (g/km) for " ECE 15–03 "

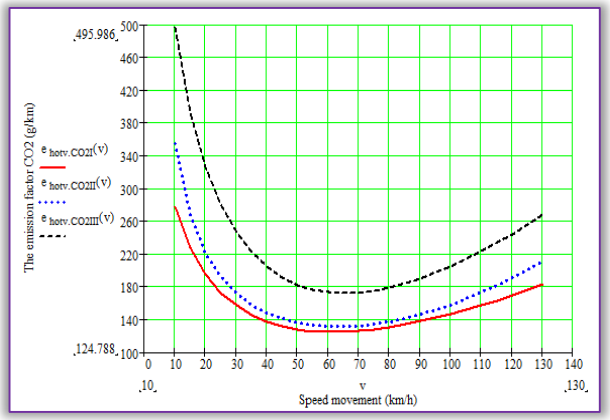

Figure 26. Emission factor of CO_2 (g/km) for "without catalyst and sound lamp"

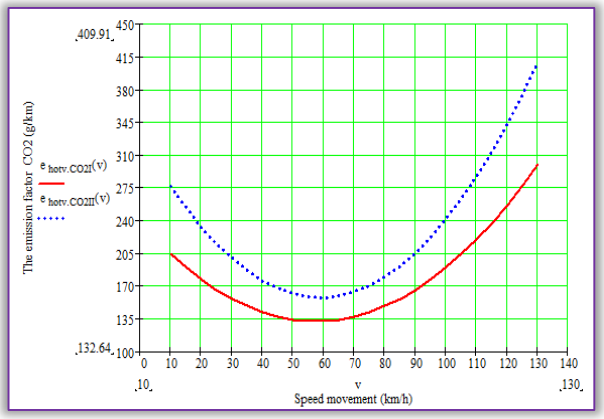

Figure 27. Emission factor of CO_2 (g/km) for "ECE 15–04" (I – for volume <.4 l, II – for engine volume 1.4 – 2.0 l)

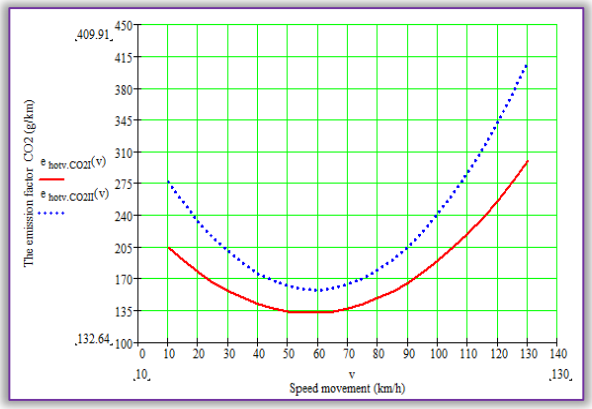

Figure 28. Emission factor of CO_2 (g/km) for "without catalyst and without sound lamp"

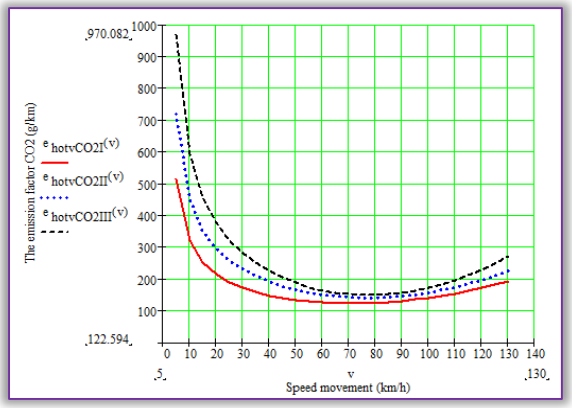

Figure 29. Emission factor of CO_2 (g/km) for the vehicles according to "Euro I"

4. DETERMINATION OF THE OPTIMAL ECOLOGICAL SPEED

From the curves which are shown in the paper, are read the speed values for which the emission factors have minimal values. In ecological terms this is the preferred speed of movement. This speed is called optimal ecological speed. Table 1 shows optimal ecological speed and minimum emission factor values for gasoline-fuelled vehicles.

Table1. Minimum values of ecological factors the optimal ecological speed

Pollutant	Ecological classification of vehicles							
	Before ECE	ECE 15-00/01	ECE 15-02	ECE 15-03	ECE 15-04	Improved conventional vehicles	With catalyst and without regulation	EURO I
CO_{min} (gr/km)	16	15	7.5	6.2	4	6	5.2	0.60
						2.1	3.0	1.00
								0.60
v_{opt} (km/h)	65	65	85	90	95	60	60	60
						80	56	70
								85
HC_{min} (gr/km)		1.10	0.98	0.98	0.76	0.75	0.42	0.075
								0.075
						0.65	0.18	0.12
v_{opt} (km/h)		130	100	100	105	85	85	80
								80
						80	80	112
NO_{xmin} (gr/km)		0.85	1.5	1.6	1.5	0.7	0.5	0.30
		1.0	1.7	1.5	1.7	1.5	0.4	0.30
		1.9	1.9	2.7	2.25			0.40
v_{opt} (km/h)		<10	<10	<10	<10	<10	<10	50
		<10	<10	<10	<10	<10	<10	50
		<10	<10	<10	28			60
CO_{2min} (gr/km)	130	120	125	125	130	120	135	120
	135	135	140	135	135	150	155	130
	170	152	180	178	170			135
v_{opt} (km/h)	60	80	60	60	60	55	60	65
	60	70	60	64	62	60	60	70
	65	70	60	65	65			70

5. CONCLUSIONS

Based on the analysis which is carried out in this paper, for the determination of the optimal ecological and minimal ecological factors for the gasoline fuelled vehicles, it can be concluded that:

- The speed of movement has a dominant influence on the values of ecological factors.
- From the graphical presentation of ecological factors (emission) can be seen speeds for which these factors are decreased, increased and have minimal values.

- From the curves presented in the paper are determined the optimal ecological speeds for each emission factors.
- Environmental factors also depend on the volume of motor vehicle, the group to which they belong and its general technical conditions, and particularly from the outer gas system.
- Emission factors during the movement of the vehicle at slow speed mainly have high values, except NOx -it.
- Table 1 shows that optimal ecological speeds are high enough to be achieved during the movement in urban areas of Kosovo,
- Mathematical models which are given for Euro I are used for the calculation of the ecological factors even for subsequent generation of vehicles, but by reducing the respective coefficients of each generation.

Therefore, the results obtained in this paper and comments made for each curve of ecological factors depending on vehicle speed and the determination of optimal vehicle speeds are of practical and engineering interest and in the field of vehicles ecology.

Acknowledgements

The first author is profoundly thankful to the corresponding author Rame Likaj, which has paid attention to fulfil all requirements about this research work.

References

[1] Golubic, J. (2006), Promet i okolis, Zagreb.
[2] Kyçyku, A. (2012),Konstruktimi ekologjik (skriptë), Prishtinë,
[3] INRETS, MEET Methodology for calculating transport emisions and energy consumption, Office for Official Publications of the European Communities, Luxemburg, 1999.
[4] Shabani, A. (2015), Analiza e faktorëve ekologjik te automjetet me lëndë djegëse benzinë", Punim i Masterit, Prishtinë.
[5] Medvedev, S. (2004),Procjena emisije ispusnih plinova u cestovnom prometu koristenjem metode MEET, Diplomski rad, Zagreb.
[6] Group of authors (1999), COST 319 Estimation of Pollutant Emissions from Transport, Office for Official Publications of the European Communities, Luxemburg.
[7] Centar za vozila Hrvatske: " Strucni bilten broj 87" Zagreb 2000.
[8] INFRAS (1995), Workbook on emission factors for road transport, INFRAS, Bern.
[9] VTI (1996), Influence of ambient temperature on warm engine exhaust emission from passenger cars, VTI, Linkoping.
[10] Serie E., Joumard R. (1997), Modelling of cold start emissions for road vehicles", INEWRTS, Bron.