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Performances of Motor Vehicles when they Travel in Urban and Extra Urban Environments

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Abstract: The paper presents, in comparison, the main performances that define the dynamism, fuel saving and energetic efficiency of vehicles when traveling in urban and extraurban areas. The values of the indicators that define the dynamism, fuel saving and energetic efficiency of vehicles are highlighted and established. For the comparative study, experimental research was carried out with a Ford Focus car and a Volkswagen Touareg car equipped with supercharged diesel engine and electronic operation control.

Keywords: Vehicle dynamics, dynamism, fuel saving, urban and extraurban environments, dynamic performances

I. INTRODUCTION

Numerous conditions are imposed on current vehicles in order to obtain high performances of traffic safety, comfort, dynamism, fuel saving, energy efficiency, satisfaction of anti-pollution regulations. In the sense of this paper, the performances of dynamism and fuel saving are of interest. As is well known, the requirements of dynamism and fuel saving cannot usually be met at the maximum possible level [1].

II. EXPERIMENTAL RESEARCH

For the study of dynamism and fuel saving, experimental research was conducted using a Ford Focus car equipped with a supercharged diesel engine. The acquisition of the functional parameters was made possible by using the FoCOM interface and software [9], both from Ford. From the experimental data obtained were retained 40 samples in urban areas (symbolized FU1-FU40) and 40 samples in extraurban areas (marked FE1-FE40), more significant for the purposes pursued in the paper.

For example, fig. 1 shows the average values V_m and maximum V_{max} on speed tests when traveling in urban areas (upper graphs) and in extraurban areas (lower graphs).

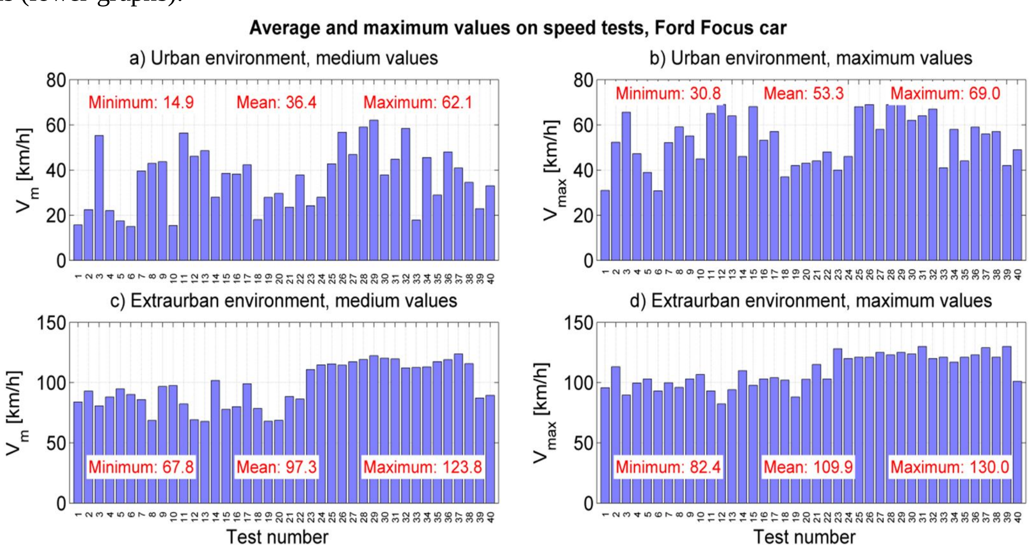

Fig.1. Average and maximum values on car speed tests

The graphs in fig. 1 show that when traveling in extraurban areas, the average and maximum speeds on samples are higher than when traveling in urban areas. Thus, the average value on all tests is higher than 2.67 times (97.3 km/h compared to 36.4 km/h), and the maximum value is 1.88 times (130 km/h compared to 69 km/h).

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It is also observed that in the extraurban environment the variations on tests of the average and maximum speeds are higher than in the urban environment. For example, from fig.1a it is found that in the urban environment the average speeds vary in the range 14.9-62.1 km/h (overall variation 47.2 km/h); from fig.1c it is observed that in the extraurban environment the average speeds vary in the range 67.8-123.8 km/h (overall variation 56 km/h). Similarly, from fig.1a it is found that in the urban environment the maximum speeds vary in the range 30.8-69 km/h (overall variation 38.2 km/h); from fig.1d it is observed that in the extraurban environment the maximum speeds vary in the range 82.4-130 km/h (overall variation 47.6 km/h).

The experiments were also carried out with a Volkswagen Touareg car equipped with a supercharged diesel engine. Thus, in fig. 2 presents the values of the speed of the car for driving in urban and extraurban areas.

As can be seen from the graph, the speed of the car varied in the range of 23-58.1 km/h when traveling in urban areas, the average value being 41.9 km/h. Instead, when driving the car in the extraurban areas, the speed of the car varied in the range of 60.5-145.3 km/h, the average value being 105.3 km/h.

Therefore, when traveling in the extraurban environment, the speeds are higher than those in the urban environment and as a result the distances traveled are longer.

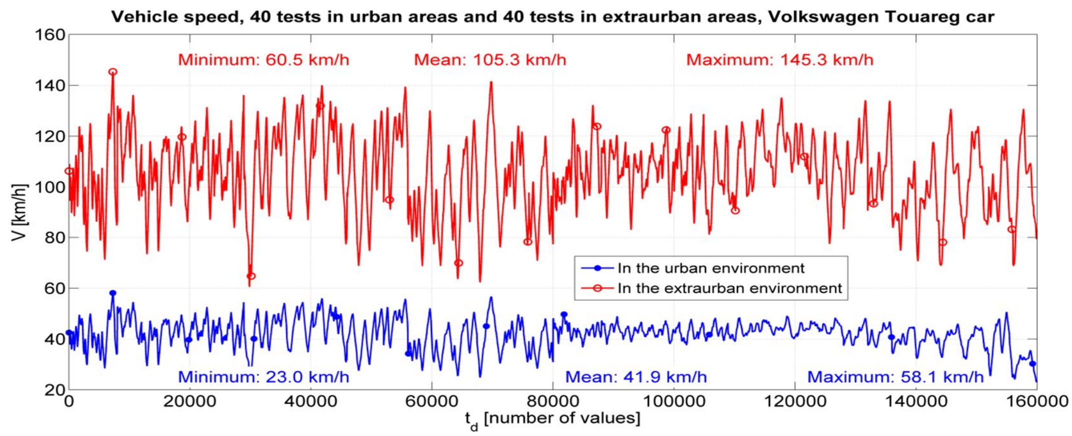

Fig.2. Volkswagen Touareg car speed values

For example, fig. 3 shows the graph of traveled distance *S* - speed *V* - time *t* when driving a Ford Focus car. The graph confirms that in the extraurban environment the travel speeds are higher than those in the urban environment and as a result the space traveled is higher. Indeed, the total space traveled in the extraurban area is 419.806 km, and in the urban area of 162.118 km, is almost 2.59 times larger in the first case.

In fig. 4 shows some functional dependencies in the case of the Volkswagen Touareg car. Thus, in fig. 4a the values of the car's speed and its acceleration are shown. The graph confirms the higher speeds when the car travels in extraurban areas. The graph also shows that the car's accelerations are lower in the suburban environment, obviously due to the higher gear shift of the gearbox.

In fig. 4b shows the values of the position of the accelerator pedal and the engine speed. The graph shows that when traveling in an extraurban environment, the engine speed and accelerator pedal positions are higher than in urban areas.

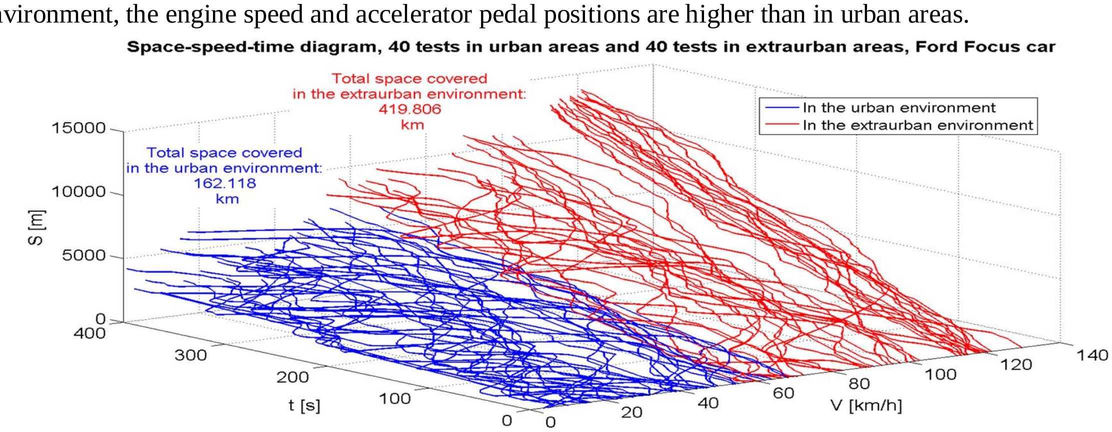

Fig.3. Space-speed-time diagram

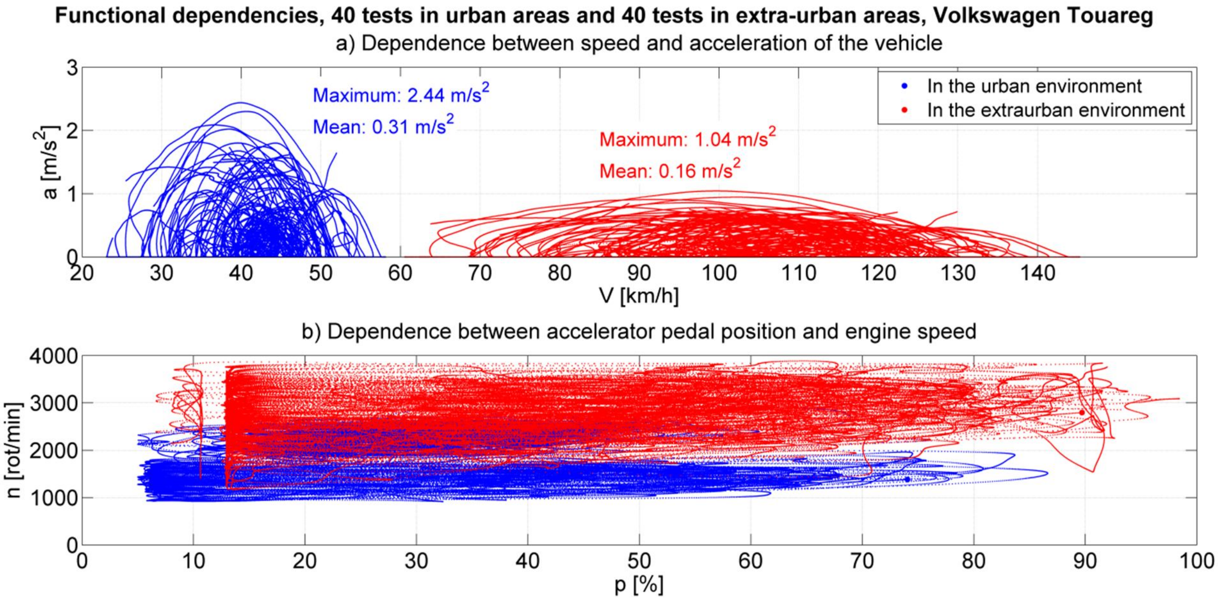

Fig.4. Functional dependencies, Volkswagen Touareg car

III. VEHICLE'S DYNAMISM

Frequently, in the specialized literature are used two criteria for assessing the dynamism: the starting time t_d and the starting space S_d. In addition, for the third criterion, values of the average accelerations a_m by vehicle categories are given, without making further details. A fourth criterion is the average speed V_m. A fifth criterion is the double produced between the average speed and the average acceleration [4, 5, 7, 8].

In order to highlight a certain aspect, in fig. 5 are presented the average values on tests of the travel speed V_m and of the acceleration of the car a_m in case of driving in the urban environment, by vehicle categories, without making further details.

Given the values presented, the graphs also show the classification of the samples in ascending order of the car's dynamism. For example, if the dynamism is estimated by the average value of the speed, then from fig.5a it results that the best dynamism is that of the sample FU29 which has V_m=62.1 km/h, and the weakest dynamism is that of the sample FU6 which has V_m=14.9 km/h. On the other hand, if the dynamism is estimated by the average value of the acceleration, then from fig.5b it results that the best dynamism is that of the sample FU25 which has a_m=1.63 m/s^2, and the weakest dynamism is that of the sample FU9 which has a_m=0.12 m/s^2. As can be seen from this example, the assessment of dynamism by the two parameters leads to different conclusions, which is also confirmed in the case of travel in extraurban areas.

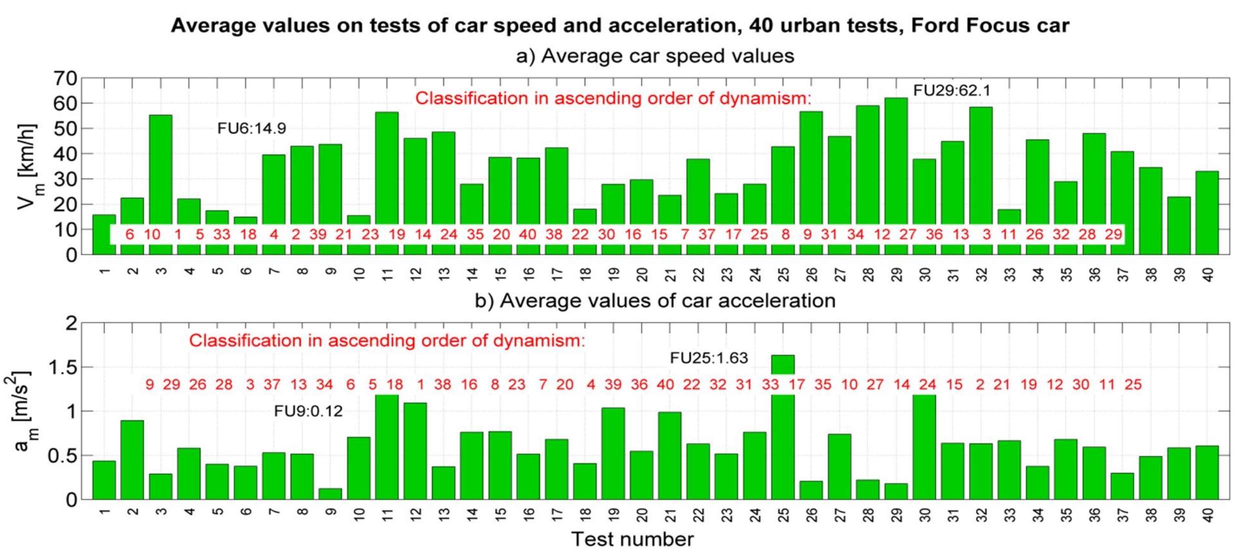

Fig.5. Average values on speed and acceleration tests

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Fig. 6 shows the double produced on tests c_1 between the average speed V_m and the average acceleration a_m in the urban and extraurban case:

$$c_1 = 2V_m a_m \tag{1}$$

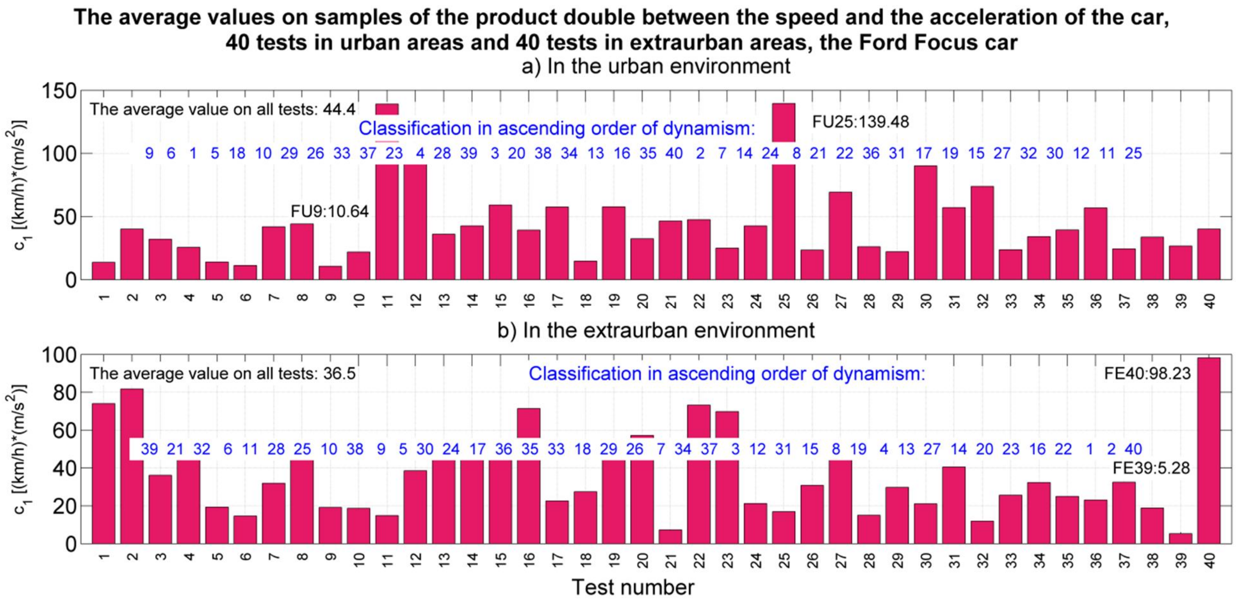

Fig. 6. The double product between average speed and average acceleration

As it results from fig. 6, the classification of dynamism according to this criterion differs from the previous classifications according to other criteria for its appreciation (V_m and a_m in fig. 5), even if there are some similarities. This shows the need to take into account all the criteria for assessing the dynamism of vehicles.

As can be seen in fig. 6, the double produced between the average speed and the average acceleration (the fifth criterion of dynamism) is higher in the case of driving in urban areas; on the whole of the tests, the average value of this criterion is almost 1.22 times higher in the urban environment. According to this assessment criterion, in the urban environment the highest dynamism is at the FU25 test, and the lowest at the FU9 test. Also, in the extraurban environment, the highest dynamism is in the FE40 test, and the lowest in the FE39 test.

IV. VEHICLE'S FUEL SAVING

In the literature, the most used criterion for assessing their fuel saving is fuel consumption per 100 km; volumetric consumption, expressed in liters/100 km, is frequently used, but sometimes it is also expressed by mass consumption, meaning in kg/100 km. In both cases the hourly fuel consumption C_h [liters/h] and the speed of the vehicle V [km/h], two measured quantities are used [2, 6].

The graphs in fig.7 and fig. 8 show a classification of the vehicle's fuel saving by C_h, respectively by C_{100} for the 40 tests in the urban environment and 40 tests in the extraurban environment. As it is known, based on the hourly fuel consumption, the fuel consumption per 100 km traveled by the C_{100} vehicle [liters/100 km] is also calculated:

$$C_{100} = \frac{100C_h}{V} \tag{2}$$

As it can be seen from fig.7, if the hourly fuel consumption C_h is targeted, in the urban environment the highest fuel saving is presented by the test FU38, and the lowest test by FU31; in the suburban environment, the highest fuel saving is shown by the FU39 test, and the lowest by the FU28 test.

On the other hand, as it results from fig. 8, if it is aimed at the fuel consumption per 100 km traveled C_{100}, in the urban environment the highest fuel saving is presented by the FU9 test, and the lowest by the FU39 test; in the extraurban environment, the highest fuel saving is shown by the FU39 test, and the lowest by the FU30 test.

Therefore, even in the case of fuel saving, the various assessment criteria lead to different results, as in the case of dynamism; this shows the need to take into account all the criteria for assessing the fuel saving of motor vehicles.

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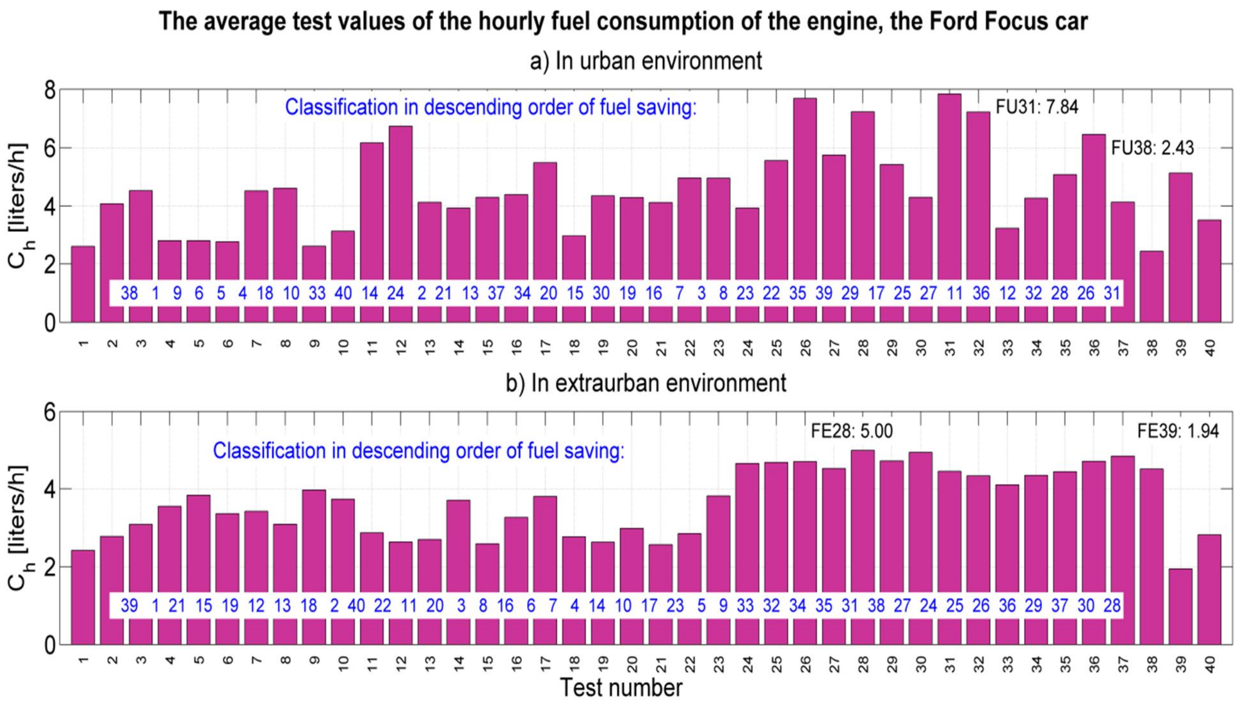

Fig.7. Average values per tests of hourly fuel consumption

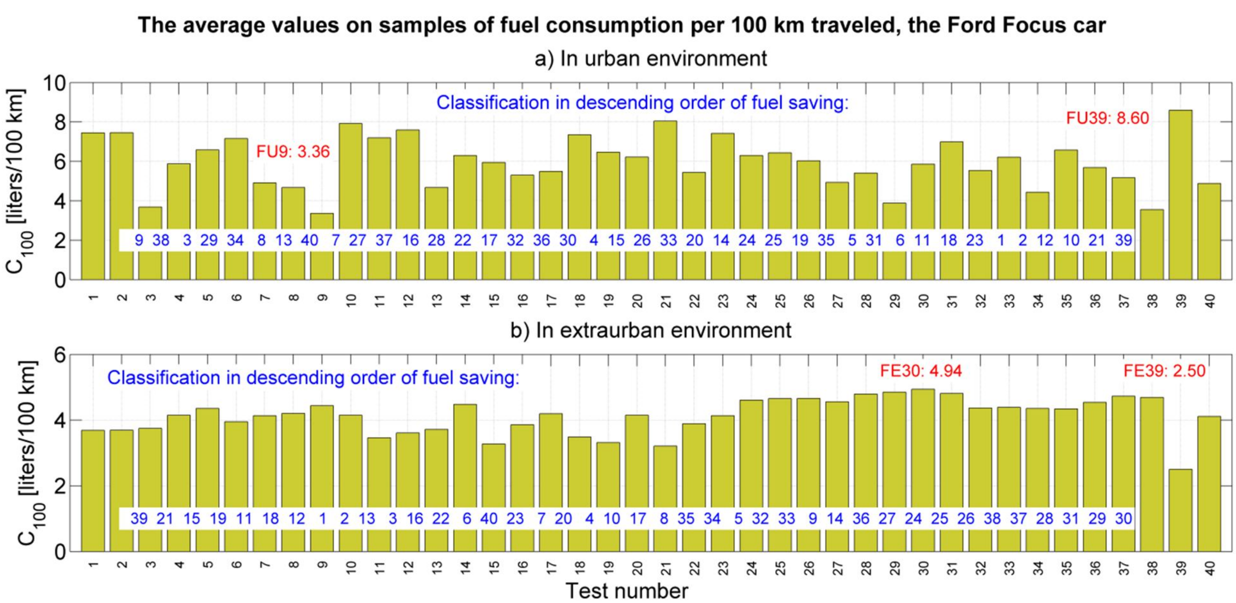

Fig.8. Average values per tests of fuel consumption per 100 km

The upper graphs in Fig. 9 show another criterion for assessing fuel saving, namely the mileage made with a liter of fuel, symbolized mpg:

$$S_m = \frac{\rho V}{0.354 C_h} \tag{3}$$

where □ represents the density of the fuel.

The above graphs show that in the case of traveling in the extraurban environment, the average value on all samples is 1.4 times higher than in urban areas (58 mpg compared to 41.4 mpg).

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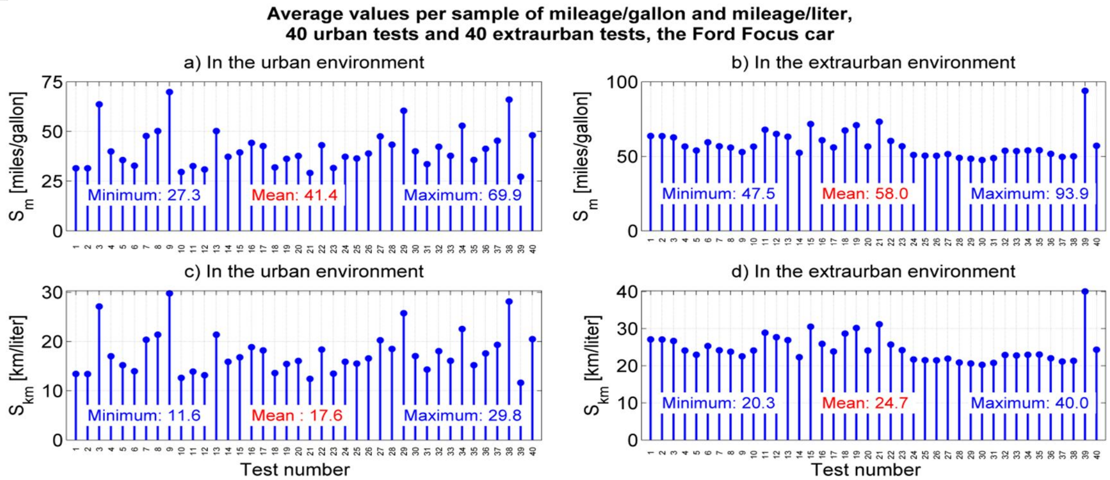

Fig.9. The average values on tests of the distance traveled

The graphs in fig. 9 show another criterion for assessing fuel saving, the distance in kilometers made with 1 liter of S_{km} fuel [km/liter], which is calculated with the formula:

$$S_{km} = \frac{100}{C_{100}} \tag{4}$$

As can be seen from the graphs below, in the case of traveling in extraurban areas, the average value on all samples is 1.4 times higher than in urban areas.

Therefore, these last two criteria from fig.9 show that ***in the extraurban environment a superior fuel saving*** of the vehicle is obtained.

V. VEHICLE'S ENERGETIC EFFICIENCY

The energetic efficiency of a vehicle simultaneously targets its dynamism and fuel saving. For this purpose, different criteria for assessing energy efficiency are used, to determine how to use the fuel.

For example, fig. 10 shows the fuel consumption required to obtain a power of 1 kW and a motor torque of 1 Nm, established with the relations, with C_{ml} [milliliters]:

$$k_1 = \frac{C_{ml}}{P_e}; \quad k_2 = \frac{C_{ml}}{M_e} \tag{5}$$

As can be seen from fig.10a and fig.10c, on the whole of the tests in the extraurban environment, 1.5 times less fuel is consumed per unit of power. Also, from fig.10b and fig.10d it is found that on the whole of the samples in the extraurban environment, 1.47 times less fuel is consumed per unit torque.

The graphs in fig.10 also show that more fuel is consumed per unit of power than per unit of torque, both in urban and extraurban areas.

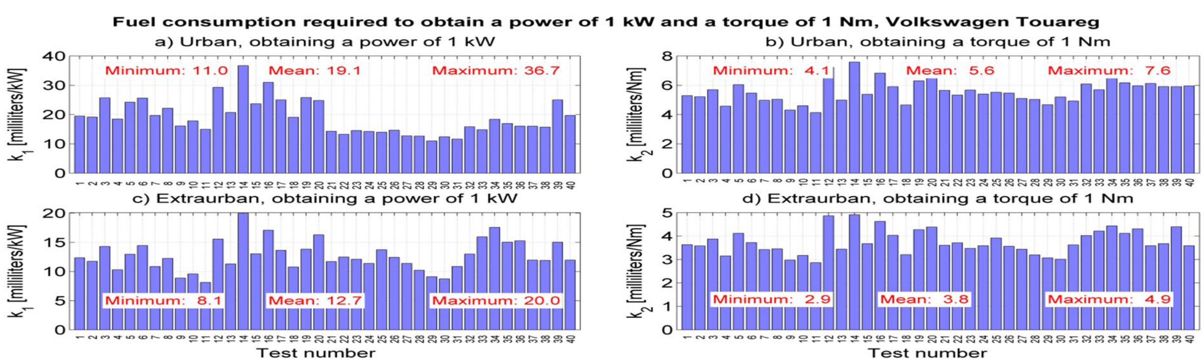

Fig.10. Fuel consumption required to obtain a power of 1 kW and a torque of 1 Nm

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Fig. 11 shows the fuel consumption required to obtain a speed of 1 m/s and an acceleration of 1 m/s^2, determined by the expressions:

$$k_3 = \frac{C_{ml}}{V}; \quad k_4 = \frac{C_{ml}}{V} \tag{6}$$

From fig.11a and fig.11c it results that on the whole of the tests, in the extraurban environment 1.78 times less fuel is consumed than in the urban environment per unit speed. Also, from fig.11b and fig.11d it results that on the whole of the tests, in the extra-urban environment, 1.42 times less fuel is consumed than in the urban environment on the acceleration unit. Finally, fig. 11 shows that more fuel is consumed per unit of speed than per unit of acceleration, both in urban and extraurban areas.

The graphs in fig.10 and fig.11 show that in the extraurban environment the energetic efficiency of the car is higher than in the urban environment.

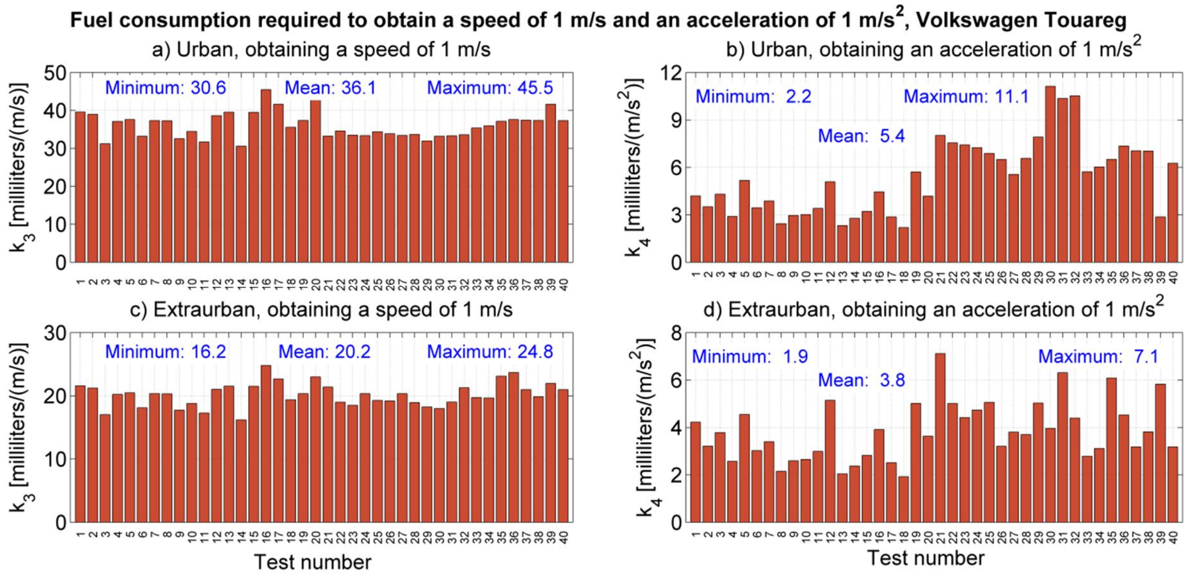

Fig.11. Fuel consumption required to obtain a speed of 1 m/s and an acceleration of 1 m/s^2

VI. CONCLUSIONS

The comparative study of the dynamics of motor vehicles when traveling in urban and extraurban areas showed that the various criteria for assessing their dynamism and fuel saving offer different conclusions. For this reason, all the criteria frequently used in the literature must be taken into account.

The study, part of which is presented here, also showed that in the extraurban environment a higher economy and energetic efficiency of the vehicle is obtained compared to that related to the urban environment.

In view of the above, it is of interest to establish the energetic efficiency of the vehicle [3], which simultaneously aims at its dynamism and fuel saving. This is important given that the aim is to increase energetic efficiency in the future by improving fuel saving by reducing vehicle dynamism.

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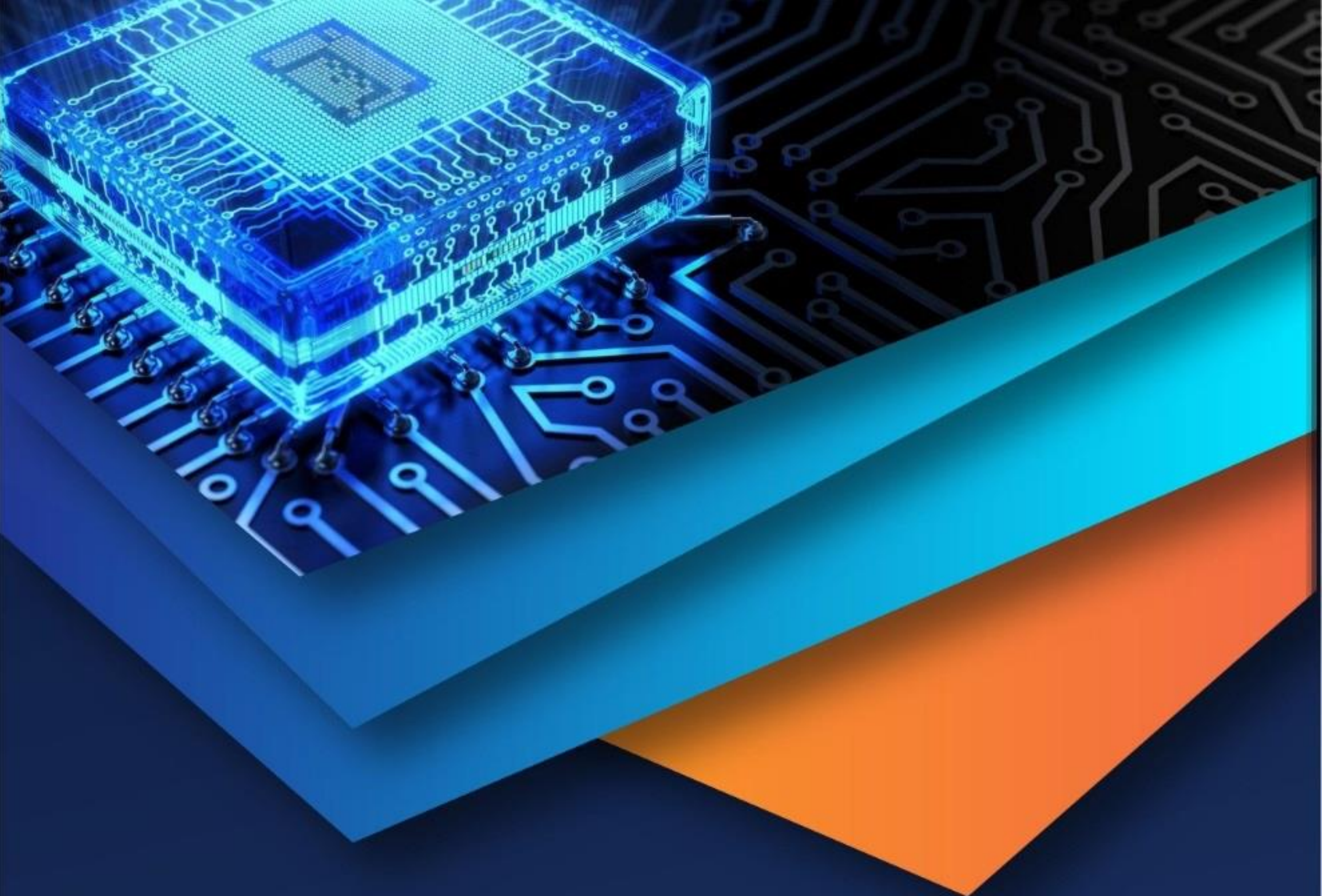

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