ASPECTS REGARDING THE SUSTAINABLE DEVELOPMENT OF MOTOR VEHICLE TRANSPORT IN THE KNOWLEDGE-BASED ECONOMY

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Abstract: *The scientific paper presents a concrete research carried out by the authors in order to implement some technical and economic concepts so that the readers can get acquainted with a certain way of asking the question about the sustainable development of motor vehicle transport. The scientific paper proposes a study carried out from a technical and a managerial point of view with engineering nuances so that the concept of sustainable development can be seen in a global context. The application part of the scientific paper refers to the detailed presentation of real calculations, using a laboratory method regarding the optimized calculation of fuel consumption and pollutant emissions to atmosphere for internal combustion engines. The work as a whole is intended to be a practical approach with correlations in the field of engineering and management, in fact aiming basically at the sustainable development of road transport. Finally, some conclusions and further research directions in this respect are presented.*

Keywords: sustainable development, motor vehicles, pollutant emissions, management, quality

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1. Introduction

Sustainable development in general, as well as the sustainable development of motor vehicle transport, has always been a special concern of

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researchers. Sustainable development management coupled with quality management in the knowledge-based economy and organization can be a way to streamline a global economy, but also a particular organization.

Actual fuel consumption and CO2 emissions from motor vehicles are directly influenced by the way you drive. Since the genesis of the motor vehicle, researchers have been conducting tests, verifications and investigations, constantly looking for solutions around the world, in order to gather as real and accurate data as possible about the styles in which motor vehicles are driven, but also to make more effective, efficient and less polluting motor vehicle engines, in order to reduce fuel consumption and thus the pollutant emissions resulting from the burning of carbon-based fuels.

Globally, the research and design of motor vehicle engines were faced with new problems in the 8th decade. Thus, at the beginning of the decade, the realization of the engine with “clean gases” or the limitation of the pollutants discharged by the engine into the atmosphere was defined as a peak vehicle requirement. Then, from the middle of the decade, the economy of fuel or the realization of high-efficiency engines was established as a direction of action that today concentrates great scientific and technical forces, numerous material means, (Grönwald, p.3, 1980). As from September 1, 2017, the European Union has introduced in the legislation a new procedure regulating the tests for light passenger and commercial vehicles with pollution norm euro 5 and 6, called WLTP (Worldwide Harmonized Light Vehicles Test Procedure), literally, "Globally Harmonized Test Procedures for Light Vehicles". The new globally harmonized test procedure imposes more detailed and strict conditions on European vehicle manufacturers for testing. Whenever performed, the WLTP laboratory test is accompanied by a test of the pollutant emissions eliminated by the engine into the atmosphere, under conditions similar to the real driving RDE (Real Driving Emissions), in translation "CO2 emissions generated in real driving conditions". WLTP

testing management consists of four representative phases, each of which corresponds to a test speed: low, medium, high and very high. Also, specific to each phase, the levels of acceleration, braking and stopping are representative, through which the situations that highlight the different styles in which motor vehicles are driven are defined. The result of the combinations of these phases is the driving cycle, which is communicated by an average value in the data of each motor vehicle manufacturer. For hybrid and electric motor vehicles, the procedure includes the fifth phase for fuel and energy consumption in the urban environment. This phase has been introduced for this type of vehicles, because it satisfies more the urban mobility needs of the population, being driven here at low and medium speeds.

The new procedure was introduced by the European Commission on September 1, 2018 and replaces the old one, called NEDC (the new European driving cycle), which was introduced in 1992 for the same purpose and represents the test cycle until that time, when the conditions in the laboratory test were disadvantageous, because after performing the tests on motor vehicles, they do not accurately give real values for fuel consumption and CO2 emissions.

The Commission has carried out a detailed analysis of the type-approval procedures, tests and requirements set out in Regulation (EC) no. 692/2008, based on its own research and external information, and found that emissions generated under real road driving conditions by Euro 5/6 motor vehicles significantly exceed the emissions measured in the new European driving cycle (NEDC - New European Driving Cycle) in particular with regard to NOx emissions from diesel motor vehicles (UE Regulation, 2017, p.1)

Although the world's motor vehicle manufacturers establish fuel consumption by established methods, still the Ministry of National Defense establishes the normed fuel consumption by its own approval standard for

the military equipment, which is mostly purchased from major domestic or foreign motor vehicle manufacturers.

However, here, from the entry into the endowment of the armed forces to the type-approval of the standard fuel consumption by military specialists, given the new technique entered in the army endowment for the standard fuel calculation, the consumptions established by the motor vehicle manufacturer are taken into account.

Next, we will present a study on the management of different methods of approval of fuel consumption, performed by different methods, tests and practices of motor vehicle manufacturers, compared to the approvals of such consumption in the Ministry of National Defense and car fleet owners in Romania. Then, we will present the mathematical models for calculating fuel consumption and AdBlue, specifying the role and contributions of these determinations to the sustainable development of motor vehicle transport.

2. Presentation of the proposed research in the current context of sustainable development

In the European Union, the legislation underlying these approvals is as follows:

- For light passenger and commercial vehicles: Commission Regulation (EU) 2017/1154 dated June 7, 2017 amending Regulation (EU) 2017/1151 supplementing Regulation (EC) no. 715/2007 of the European Parliament and of the Council on the type-approval of motor vehicles with regard to emissions from light passenger motor vehicles and light commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information amending Directive 2007/46/EC of the European Parliament and of the Council, of the Commission Regulation (EC) no. 692/2008 and the Commission Regulation (EU) no. 1230/2012

and repealing Regulation (EC) no. 692/2008 and Directive 2007/46/EC of the European Parliament and of the Council as regards emissions from real light passenger motor vehicles and light commercial vehicles (Euro 6);

- For heavy vehicles of category N2, as defined in Annex II to Directive 2007/46/EC, with a technically permissible maximum laden mass of more than 7.500 kg and all vehicles of category N3: Commission Regulation (EU) 2017/2400 dated December 12, 2017 implementing Regulation (EC) no. 595/2009 of the European Parliament and of the Council on the determination of CO2 emissions and fuel consumption of heavy vehicles (Euro 6) and amending Directive 2007/46/EC of the European Parliament and of the Council and the Commission Regulation (EU)) no. 582/2011.

For all units holding vehicles under the subordination of ministries, other central bodies, county people's councils and the municipality of Bucharest, except for units subordinated to the Ministry of National Defense and the Ministry of Interior of Romania: Order no. 14 dated September 27, 1982 for the approval of the norm regarding the consumption of fuel and oil for motor vehicles.

For all types of motor vehicles from the Ministry of National Defense: L-4/5, Norms for calculating the consumption of fuel-lubricants for the operation and maintenance of military equipment, prepared by the Defense General Staff on June 18, 2020.

2.1. NEDC driving cycle

A driving cycle is defined by the conditions under which fuel consumption and CO2 emissions are established and measured by accurate and precise simulation of routine motor vehicle travel. In order to establish these two parameters as accurately as possible, a driving cycle must provide certain framework conditions for measurement tests, such as: vehicle speed, starting temperature and duration of measurements.

As we said, the NEDC method (the new European driving cycle) was introduced by the EU on July 1, 1992 in order to provide at that time comparable values of the two parameters (approval of fuel consumption and CO2 emissions) for all vehicles made in Europe.

It guarantees the unitary determination of the parameters for which it was introduced and allowed their comparison with other motor vehicles, but in reality, fuel consumption often depended on the way the vehicle is driven, but also on the equipment with which it is equipped. Thus, there are differences when the motor vehicle is driven in the city, on roads of other categories or on the highway.

Today, this driving cycle is outdated, inefficient and no longer presents the reality of the current road traffic. The inefficiency of these test methods has also been created by current European environmental requirements. In this regard, the EU has imposed new rules on environmental pollution standards (Euro 6 c, Euro 6d -TEMP and Euro 6 d norms), with nuisances resulting from the burning of carbon-based fuels in the internal combustion engines of motor vehicles.

Emission requirements for vehicle type-approval have gradually become significantly more restrictive, with the introduction and subsequent

revision of Euro standards. While, in general, vehicles have achieved significant emission reductions for the full range of regulated pollutants, not the same thing happened in the case for NOx emissions from light passenger and commercial diesel vehicles. It is therefore necessary to take measures to correct this situation. (UE Regulation, 2017/1154).

Technical aspects and conditions required by the NEDC type-approval method may be presented by:

- Testing is performed in urban and extra-urban environments;
- The temperature in the test chamber must be between 20 and 30°C;
- The distance covered is 11 km;
- The cycle lasts 20 minutes;
- The cycle consists of two phases: the first phase - 13 minutes of simulated driving in the city; the second phase - 7 minutes of simulated driving outside the city;
- The average speed is about 33 km/h;
- Parking times are 25%;
- The maximum speed is 120 km/h;
- The moments when the gear is changed for models with manual transmission are accurately predicted;
- Special equipment and air conditioning are not taken into account

Figure 1 shows the framework conditions underlying the measurements made by the NEDC method for actual fuel consumption and CO2 emissions in motor vehicles (https://www.volkswagen.ro/wltp).

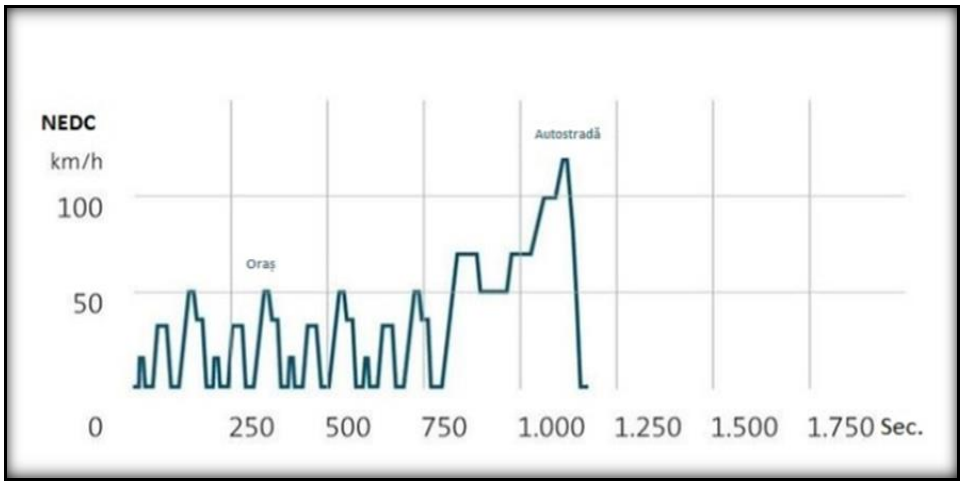

Figure 1. The framework conditions underlying the measurements made by the NEDC method for actual fuel consumption and CO2 emissions in motor vehicles. (https://www.volkswagen.ro/wltp)

2.2. WLTP driving cycle

The WLTP driving cycle (Worldwide Harmonized Light-Duty Vehicles Test Procedure) is a test method introduced by the EU in order to harmonize global fuel consumption and CO2 emissions for motor vehicles and light commercial vehicles. It replaced the previous method of determination (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.

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.

In order to integrate all these different aspects, the theoretical conditions of the NEDC cycle are transformed into a dynamic driving cycle, which is based on statistical data and the evaluation of average user profiles: overall, a higher level of acceleration, a higher average speed, as well as a higher maximum speed are considered. Also, driving in urban areas and driving in extra-urban areas are no longer simulated mixed, but the motor vehicle is now being tested in four phases at different speed intervals. (https://www.volkswagen.ro/wltp)

The main objective of the WLTP standard is to ensure standards-compliant means for all determinations of pollutant emissions and fuel or energy consumption for several types of engines (petrol, diesel, CNG and electric), and motor vehicles of the same type, on which these engines are fitted, must have the same results anywhere in the world, of course if the WLTP approval procedure has been properly applied. This is, in fact, the essential requirement for comparison, but also the reason for performing measurements for this method in the laboratory, fuel consumption and pollutant emissions being analyzed under test conditions, on the dynamometer test stand with rollers, based on a dynamic driving profile.

This approach is similar to a synthetic laboratory test and mainly serves to facilitate comparisons between different motor vehicles, without realistically reflecting actual consumption. While consumption values were previously measured in abstract laboratory conditions, the new procedure now allows a more accurate prediction of the actual consumption of the motor vehicle, thanks to optimized test parameters. WLTP aims to simulate a more realistic operation of the motor vehicle, in order to obtain more realistic results. (https://www.volkswagen.ro/wltp)

In all motor vehicle manufacturers, the WLTP test procedure performed in the laboratory is always followed by measurements of emissions when driving on the road, in traffic. The determination of RDE

(Real Driving Emissions), in translation “CO2 emissions generated under real driving conditions”, is performed in order to establish that the limit value of nitrogen oxides (NOx) emissions and the amount of particles do not exceed in these conditions the values established on the stand, in the laboratory.

The technical aspects and the conditions imposed by the method of approval of pollutant emissions on the route by the RDE - WLTP method can be presented in a concrete way by the following ideas: (https://www.volkswagen.ro/wltp)

- The test is performed on a mix of routes composed 1/3 in urban areas and 2/3 on roads of category 1-6;
- Random and constant accelerations and decelerations, in compliance with traffic rules;
- The average speed in the urban environment is between 15-40 km / h, max. 60 km / h;
- Average speed on heavy unpaved roads 60-90 km / h, and on the highway 145-160 km / h;
- The motor vehicle is equipped with a PEMS (Portable Emission Measurement System) measuring device, which measures the amount of nitrogen oxide and carbon monoxide released into the atmosphere;
- Test times 90-120 minutes;
- Outdoor ambient temperature: -7 to +35°C;
- Auxiliary equipment to be started during testing is considered.

The technical aspects and the conditions imposed by the WLTP approval method in the laboratory on the test stand can be presented by the following ideas: (https://www.volkswagen.ro/wltp)

- Testing is performed in a laboratory on a test stand;

- The temperature in the test laboratory must be 23°C;
- The distance covered is 23 km;
- The cycle lasts 30 minutes;
- The cycle is composed of four phases (low, medium, high);
- The average speed is 47 km/h;
- Parking times are 13%;
- The maximum speed is over 130 km/h;
- The moments of changing gears are calculated for each motor vehicle, in advance;
- The weight of the motor vehicle and the additional equipment are taken into account;
- All possible combinations of engines and transmissions are measured.

Figure 2 shows the framework conditions underlying the measurements made by the NEDC method for actual fuel consumption and CO2 emissions in motor vehicles. (https://www.volkswagen.ro/wltp)

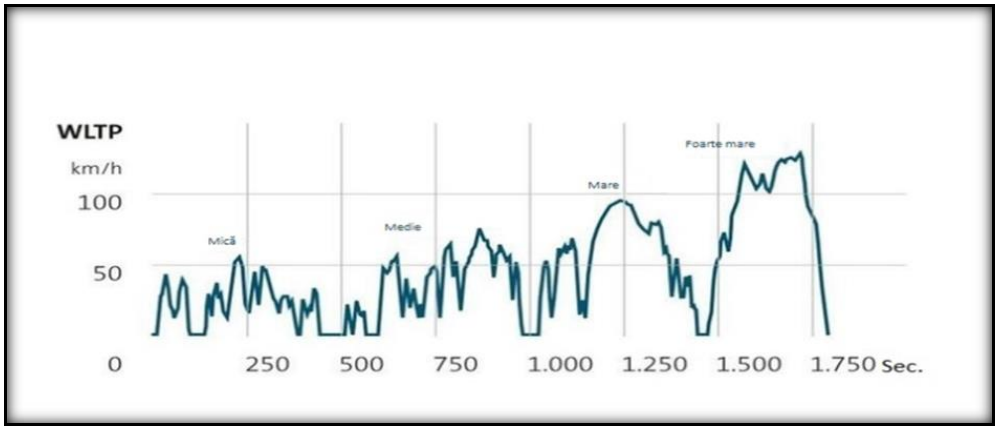

Figure 2. The framework conditions underlying the measurements made by the WLTP method for actual fuel consumption and CO2 emissions in motor vehicles. (https://www.volkswagen.ro/wltp)

Figure 3 shows in color the countries in which the method of approval of fuel consumption and CO2 emissions is applied in WLTP motor vehicles.

Figure 3. Countries where the WLTP driving cycle is used.
(https://www.skoda.ro/despre-skoda/wltp)

According to existing data, the WLTP type-approval method applies in European countries, but also in other countries where motor vehicles manufactured in Europe are marketed, as follows, (https://www.skoda.ro/despre-skoda/wltp):

- 28 countries in the European Union - green;
- Switzerland, Lichtenstein, Norway, Iceland - light gray;
- Turkey, where WLTP applies only to imported motor vehicles. For the production of domestic motor vehicles, the NEDC type-approval method is still applied - black;
- Israel and more distant regions (La Reunion Martinique, Guadeloupe, French Guiana, St. Martin, Mayote), where the situation is still unclear - black;

Partial implementation: South Korea and Japan, where the WLTP approval cycle is partially used (planned) without a very high speed phase;

China and India where the WLTP approval cycle is partially used (planned) only for CO2 emissions and the NEDC approval cycle still applies for consumption - dark gray.

3. Applicability of a fuel consumption and AdBlue type-approval method to motor vehicles

According to the regulations and instructions regarding the maintenance of the equipment and for the vehicles newly entered under the management of the Ministry of National Defense, regulated fuel consumption is established. This activity is regulated by Norm L - 4/5, Norms for calculating the consumption of fuels-lubricants for the operation and maintenance of military equipment, Annex no. 13, Art. 17, is slightly different from that performed by motor vehicle manufacturers.

The technical aspects and conditions imposed by the type-approval method of the standard fuel consumption and AdBlue for motor vehicles in the Ministry of National Defense can be highlighted by the following: (Normativul L - 4/5, p. 93-94)

- The determination is performed in the environment with a minimum number of 3 motor vehicles, and if the number of motor vehicles is less than three, the test will be performed with the existing ones, but totaling at least three determinations;
- The motor vehicles with which the determinations are made must be run-in and have a good technical condition;
- The pressure in the tires, their dimensions, as well as the quality of the fuels and lubricants used must correspond to the requirements of the construction companies;
- The road sector on which the determinations are performed must be: highway / express road / European national road / national road. As far as possible rectilinear, without degradation, dry and with

short ramps, not exceeding 2%, also be located outside the localities and have an average intensity of road traffic;

- The road sector on which the normed fuel consumption is determined must have a length of 50-100 km;
- Determinations are made at the following speed:
  - 70-90 km/h for heavy-duty road tractors;
  - 90-100 km/h for motor vehicles and derivatives, on the road;
  - 70-90 km/h for motor vehicles intended for the transport of materials, except for dump trucks, as well as for special vehicles made on their chassis, on the road;
  - 80-90 km/h for buses, special minibuses made on their chassis, on the road;
  - 70-80 km/h for dump trucks, on the road.
- It will be ensured that the speed of the road sector is constant and as close as possible to the speeds specified above;
- Determinations are made for motor vehicles with 50% of the nominal payload and fully equipped for normal operation, including refueling;
- The determinations are made in favorable weather, without rain or snow, at ambient temperatures from +5 °C to + 30 °C, at atmospheric pressures of 730-765 mm Hg;
- Wind speed must be less than 3 m/second.

The use and implementation of the procedure for the approval of standard fuel consumption and AdBlue for motor vehicles needs a special management briefly presented by the following (Normativul L - 4/5, p. 94-95):

- The measuring equipment is mounted on the motor vehicle, according to its use instructions and it is put into operation;

- If the determinations are performed by the method of measuring the amount of fuel consumed in the tanks, they are fully refueled;
- Start the engine and leave the motor vehicle on the spot, accelerating and changing gears, until you reach the specified speed directly, which remains as uniform as possible, in relation to road traffic, along the entire length of the sector;
- After completing the route established for the execution of the determination, the motor vehicle and the engine stop in the same place from where the determination started and the amount of fuel and AdBlue consumed is read / measured.

4. Contributions to the sustainable development of motor vehicle transport by mathematical modeling of the approval of standard fuel consumption in motor vehicles

Order no. 14/1982 for the approval of the Norm regarding the consumption of fuel and oil for motor vehicles provides:

The average fuel consumption is the amount of fuel required for a given motor vehicle to cover 100 km equivalent. The average consumption is set in the conditions of equipping motor vehicles with tires of the dimensions indicated by the manufacturer. In completely exceptional situations, when some motor vehicles are equipped with tires of other sizes (at the axles), the average fuel consumption is corrected as follows:

- By an increase of 10% if smaller tires are used;
- By a 10% reduction if larger tires are used.

The above corrections are only applicable to motor vehicles for which the correction coefficient of the track gauge has not been updated. (Ordinul nr. 14/1982, p. 8)

The average fuel consumption (C_m) resulting from performing the 4 measurements with a motor vehicle, is calculated with the ratio:

$$C_m = \frac{C}{P_e} \cdot 100 \text{ [liters/100km equivalent]} \quad (1)$$

where:

C, represents the total fuel consumption during the 4 measurements (liters);

P_e - the equivalent route over which the measurements were made, calculated according to the methodology" (Ordinul nr. 14/1982, p. 11).

"The average speed (V_m) with which it circulates during the consumption determinations must be between 70 - 80% of the maximum economic speed provided by the current legislation regarding the circulation of motor vehicles on public roads.

The average speed on a certain section (V_{mi}), with which the road sector "i" was traveled is calculated with the ratio:

$$V_{mx} = \frac{P_i}{T_i} \cdot 60 \text{ [km/h]} \quad (2)$$

where:

P_x, represents the length of the road sector "i" (km);

t_x - travel time of the road sector "i" (minutes).

In order to establish the average traffic speed, it is necessary that the motor vehicles subject to the determinations be equipped with tachograph devices, and in case this is not possible, the travel time of the road sector will be measured with a stopwatch." (Ordinul nr. 14/1982, p. 12).

According to Norm L - 4/5, Norms for calculating the consumption of fuels-lubricants for the operation and maintenance of military equipment,

Annex no. 13, Art. 17, (Normativul L - 4/5, p.95-96), Ci fuel consumption is calculated with the ratio:

$$C_i = \frac{100 \cdot C}{S} \quad (3)$$

where:

C_i = fuel consumption for motor vehicle i, expressed in liters per 100 km;

C = amount of fuel consumed during the determination, expressed in liters;

S = length of the road sector, expressed in km.

The average standard fuel consumption, in liters per 100 km, established after the determination, represents the arithmetic mean of the resulting consumptions for the three motor vehicles, according to the ratio:

$$C_i = \frac{C_1 + C_2 + C_3}{3} \quad (4)$$

The travel time of the road sector is measured with a stopwatch. Its indications are used to calculate the average speed of the motor vehicle V_n, according to the ratio:

$$V_n = \frac{60 \cdot S}{t} \quad (5)$$

where:

V_n = average motor vehicle speed during determination, expressed in km / h;

S = length of the sector traveled, expressed in km.

t = time, expressed in minutes;

AdBlue consumption is determined by the ratio:

$$C_{ai} = \frac{C_{ad}}{C_i} \cdot \quad (6)$$

where:

C_{ai} = AdBlue consumption for motor vehicle i, expressed as a percentage of the amount of fuel consumed;

C_i = fuel consumption consumed during the determination of motor vehicle i, expressed in liters;

C_{ad} = the amount of AdBlue consumed during the determination, expressed in liters;

The average consumption of AdBlue expressed as a percentage of the amount of fuel consumed established after the determination, is the arithmetic mean of the resulting consumption for the three motor vehicles, according to the ratio:

$$C_{ai} = \frac{C_{a1} + C_{a2} + C_{as}}{3} \quad (7)$$

Sustainability in transport derives from a complex system that aims to ensure the mobility needs of today's generation, without contaminating or damaging environmental factors or human health. Applying now a maximum efficiency of the consumption of raw materials and energy, the transport system must satisfy in optimal conditions the economic, ecological and social perspectives of the mobility needs for the generations to come.

In other words, specialists and researchers have the mission to find current transport options that do not pollute the environment and that do not affect human health, and this can be achieved by increasing the energy efficiency of fuels burned in the thermal engines of the means of transport, the

use of more efficient vehicles in terms of fuel consumption, the use of alternative energy for travel and last but not least, the permanent reduction of waste of any kind resulting from the production or decommissioning of means of transport.

Reducing CO2 emissions from motor vehicles is a key objective for the sustainable development of the road transport system. The management of the WLTP type-approval method of the two parameters allows achieving this objective by verifying and documenting the observance of the international CO_2 limits all over the world.

This goal contributes to the durable and sustainable development of motor vehicle transport because, through an ambitious EU programme, it aims to reduce greenhouse gas emissions by at least 60% by 2050.

In addition, transport makes a major contribution to Europe's greenhouse gas emissions, ranking second after the energy sector. Road transport alone accounts for almost a fifth of EU emissions. The mobility sector is therefore particularly important in the EU's efforts to maintain a steady pace towards achieving the goal of a low-carbon economy. As transport activities increase, greenhouse gas emissions must decrease; this is essential for meeting the EU's energy and climate targets for 2030. (Comunicarea Comisiei Europene către Parlamentul European, 2017, p.5).

In conclusion, the WLTP type-approval methodology demonstrates its efficiency and effectiveness by giving rise to more accurate and transparent values for comparing energy consumption and CO_2 emissions for all motor vehicle models. However, in order to meet fuel consumption and thus low emissions, certain motor vehicle models and their engines need to be optimized in order to protect the environment.

5. Final conclusions

The NEDC driving cycle is outdated, inefficient and no longer presents the reality of the current road traffic. The efficiency and effectiveness of the WLTP and RDE type-approval methods is demonstrated by more real, reduced and unit values of the two parameters tested in the laboratory and in traffic, reduced pollutant emissions, environmental protection and better air quality. The effects of these methods on potential buyers of new motor vehicles are evidenced by a unitary certification anywhere in the world and a differentiated taxation. The WLTP and RDE type-approval methods create the prerequisites for a smart, comfortable and efficient driving style and contribute to fuel economy by ensuring driver satisfaction and the sustainable development of transports in general. Similar methods of type-approval of fuel consumption and CO2 emissions are used in other countries of the world.

The driving cycles for measuring emissions and consumption developed in Japan (JC 08) and the USA (FTP 75) are adapted to the specific traffic conditions of those countries. For example, the Japanese cycle includes numerous stop and start phases off the spot. The cycle is run twice: once as a cold start and once as a hot start. (https://www.skoda.ro/despre-skoda/wltp)

The concept of sustainable transport involves the complex transport system that must meet the mobility needs of current generations, without affecting those of future generations. The danger that threatens the mobility needs of future generations is the greenhouse gases from the engines of the means of transport that are increasingly affecting the environment, the inefficiency of energy consumption and the decline in human health. We believe that the methods and means of approving fuel consumption and emissions of polluting gases in motor vehicles are the solution of only part of the environmental problems and bring many other benefits to road transport organi-

zations, ensuring their durable and sustainable development. In the Ministry of National Defense, the type-approval of fuel consumption for motor vehicles is the basis for the standardization of fuel requirements for each type of motor vehicle and it can be taken as a model for motor vehicles whose technical characteristics are similar.

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