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ANALYTICAL AND SIMULATION MODELING OF THE IMPACT OF VEHICLES ON THE ECOLOGICAL SITUATION IN UKRAINE AND THE WAYS OF ITS IMPROVING

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Summary. *A mathematical model, which determines the amount of fuel dependence for a period of time from the life of the total vehicle fleet of the Ukrainian population; the ratio of the number of different power classes of vehicles of the fleet; optimization of traffic conditions on the road. Found the general relationship between fuel consumption, air consumption and emissions of harmful substances resulting from the operation of all types of private vehicles over a certain period of time.*

Key words: *ecology, vehicles, mathematical model, algorithm, prediction, fuel, harmful substances.*

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Problem setting. Our planet is a self-regulating autonomous system of management and renovation of various resources including those necessary for the existence of various green plants, organisms and animals as well as humans. This concern first of all water resources, air with appropriate composition of its components, humus soil with their content, etc.

But the activity of people each year is more powerful that leads to the depletion and destruction of natural resources. As a result of this activity self-regulation of the planet is not able to cope with all the regulation of these processes. As a result there are problems of global warming, atmospheric pollution, pollution of water and soil, reducing the percentage of the necessary components (oxygen, humus, water supplies, etc.) and generally the ecology of the Earth is disrupted.

One of the sources of environmental pollution is the exploitation of different vehicles in an industrial society.

Analysis of the known research results. Modeling, prediction and assessment of air pollution from traffic is carried out as a rule for the areas of cities. This is due to the fact that most emissions from motor vehicles are in the cities where the intensity of transport is the greatest and also uneven traffic with frequent stops at traffic lights and pedestrian crossings and in traffic jams is especially expressed. Prediction and assessment of air pollution in the cities has been conducted in the research papers of Arkhipova H.I., Yepifantsev B.N., Mikhailov Y.M., Arhuchintseva A.V. and others [1-5]. Models on the spread of emissions from the motor vehicles in urban areas have been studied by Mokin V.B., Gamal Kh.V., Plyaschuk L.D. and others [6-8]. To study the interaction between vehicles and infrastructure of cities in Europe and the United States the models OSPM and CALINE-4 are used [9-10]. Obviously, to improve the environmental situation further study of the problem of air pollution from transport is necessary.

Objectives. The purpose of the article is to investigate the possibility of reducing harmful stress on the biosphere of the Earth due to human activities, concerning the use of a variety of individual vehicles, moving due to various fuels.

In general, this problem is very complicated when considering within a country, or some of its area because each individual vehicle uses its own fuel type (petrol, diesel, gas, electricity, energy, etc.), and has an individual consumption of fuel (depending on the type of vehicle, time

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of use, control panel work, etc.), has an individual number of polluting emissions and intensity of use, etc.

Formulation of the problem. We will model the dependence of quantity of fuel consumption in Ukraine or in some of its area by the time period (month, year and etc.) on the total lifetime of total vehicle fleet, on the ratio of different engine cylinder capacity of the fleet, as well as on the optimization of the modes of vehicles on the roads. If it is possible to set the analytical dependence between the consumption of fuel and time, then we will denote it as a cost function $G(n)$ depending on the time period n. Of course it would be better to have information about the mileage of different types of individual vehicles, but this information is not available because the appropriate form of statistical reporting for individual transport is not available. This information can be calculated only approximately, based on the overall fuel consumption for driving of individual cars for the corresponding period of time. Since this information is calculated approximately, then according to the appropriate calculations of the total number of cars the accumulation of errors in calculations is possible. They can be reduced by applying the splitting of the total vehicle fleet into classes according to the engine cylinder capacity and lifetime.

Appropriate generalized statistics on the consumption of different kinds of fuels for an arbitrary mode of transport can be found in the statistical yearbooks of Ukraine and its regions. Knowing the amount of fuel you can find the amount of oxygen that is used for its burning, as well as how many pollutants such as carbon dioxide, carbon monoxide, nitrogen dioxide, soot and other pollutants of the total of over two hundred are emitted because of this. [1, 11, 12].

Presentation of the main material of research with the justification of obtained scientific results. Modeling of individual transport fuel consumption of the population. Let us define by means of $G^i(n)$ consumption function by two-wheeled and three-wheeled motor vehicles (scooters, motorcycles, etc.) and by the vehicles of i-type of fuel (unit of measurement are kilograms, which if necessary can always be converted to liters) for n – period of time, where $i=\overline{1,3}$. The value $i=1$ corresponds to petrol, $i=2$ – corresponds to diesel fuel, and $i=3$ – corresponds to gas (a mixture of propane, butane or methane). Due to β_n^i we will denote the coefficient of restitution of vehicle fleet of population for n – period of time taking into account the relative consumption of i – petrol. The analytical expression of this coefficient for $i=\overline{1,3}$ is as follows:

$$\beta_n^1=\frac{\sigma_0\sum_{s=1}^{3}\sum_{\tau=1}^{4}\omega_{s\tau}^1\left(d_n^{1s\tau}-\nu_n^{1s\tau}+\rho_n^{1s\tau}\right)+\sum_{s=1}^{3}\sum_{q=1}^{4}\Delta_{sq}^1\left(k_n^{1sq}-\lambda_n^{1sq}+\mu_n^{1sq}\right)}{\sigma_0\sum_{s=1}^{3}\sum_{\tau=1}^{4}\omega_{s\tau}^1 d_n^{1s\tau}+\sum_{s=1}^{3}\sum_{q=1}^{4}\Delta_{sq}^1 k_n^{1sq}} \tag{1}$$

$$\beta_n^2=\frac{\sigma_0\sum_{s=1}^{3}\sum_{\tau=1}^{4}\omega_{s\tau}^2\left(d_n^{2s\tau}-\nu_n^{2s\tau}+\rho_n^{2s\tau}\right)+\sum_{s=1}^{3}\sum_{q=1}^{4}\Delta_{sq}^2\left(k_n^{2sq}-\lambda_n^{2sq}+\mu_n^{2sq}\right)}{\sigma_0\sum_{s=1}^{3}\sum_{\tau=1}^{4}\omega_{s\tau}^2 d_n^{2s\tau}+\sum_{s=1}^{3}\sum_{q=1}^{4}\Delta_{sq}^2 k_n^{2sq}} \tag{2}$$

$$\beta_n^3=\frac{\sigma_0\sum_{s=1}^{3}\sum_{\tau=1}^{4}\omega_{s\tau}^3\left(d_n^{3s\tau}+1{,}2\nu_n^{1s\tau}+1{,}2\nu_n^{2s\tau}+\rho_n^{3s\tau}\right)}{\sigma_0\sum_{s=1}^{3}\sum_{\tau=1}^{4}\omega_{s\tau}^3 d_n^{3s\tau}+\sum_{s=1}^{3}\sum_{q=1}^{4}\Delta_{sq}^3 k_n^{3sq}}+$$

$$+\frac{\sum\limits_{s=1}^{3}\sum\limits_{q=1}^{4}\Delta_{sq}^{3}\left(k_n^{3sq}+1{,}2\lambda_n^{1sq}+1{,}2\lambda_n^{2sq}+\mu_n^{3sq}\right)}{\sigma_0\sum\limits_{s=1}^{3}\sum\limits_{\tau=1}^{4}\omega_{s\tau}^{3}d_n^{3s\tau}+\sum\limits_{s=1}^{3}\sum\limits_{q=1}^{4}\Delta_{sq}^{3}k_n^{3sq}} \tag{3}$$

Index s $\left(s=\overline{1,3}\right)$ determines grouping of individual two-wheeled and three-wheeled motor vehicles and cars in terms of lifetime of these means from the production date. The value of index $s=1$ corresponds to the vehicles with lifetime of 5 tears from the date of production, $s=2$ – from 5 to 10 years from the date of production and $s=3$ – more than 10 years from the date of production.

Index τ $\left(\tau=\overline{1,4}\right)$ determines grouping of individual two-wheeled and three-wheeled motor vehicles into classes according to engine cylinder capacity: index $\tau=1$ corresponds to the class of vehicles with engine cylinder capacity to 50 cm^3; $\tau=2$ – from 50 cm^3 to 250 cm^3; $\tau=3$ – from 250 cm^3 to 500 cm^3; $\tau=4$ – more than 500 cm^3 [13].

Index q $\left(q=\overline{1,4}\right)$ determines the grouping of individual cars into classes according to the volume of the working cylinder of engine: index $q=1$ corresponds to the class of especially small cars with the engine cylinder capacity of 1.2 liters; $q=2$ – corresponds to the class of small cars with engine cylinder capacity over 1.2 liters and 1.8 liters; $q=3$ – corresponds to the middle class cars with engine cylinder capacity over 1.8 liters and 3.5 liters; $q=4$ – corresponds to class of large vehicles with engine cylinder capacity over 3.5 liters [1, 14].

Coefficient σ_0 $\left(0<\sigma_0\le 1\right)$, which sets the percentage of two-wheeled and three-wheeled motor vehicles at an annual cycle, includes the natural zones. It is clear that in winter these vehicles are not used. In particular for Ukraine we have – in the winter months $\sigma_0=0$, in the summer months $\sigma_0=1$, while in the annual cycle studies can be considered $\sigma_0=0{,}5$.

Expression $d_n^{is\tau}$ sets the number of two-wheeled and three-wheeled motor vehicles of the appropriate category on initial moment of n – period. Expression k_n^{isq} sets the number of vehicles of the appropriate category on initial moment of n – period.

Expressions $\nu_n^{1s\tau}$ and $\nu_n^{2s\tau}$ set the number of converted at n – time period of two-wheeled and three-wheeled motor vehicles of appropriate category, working on petrol ($\nu_n^{1s\tau}$) and diesel fuel ($\nu_n^{2s\tau}$) into gas fuel. Such vehicles rarely change the type of fuel, with its small cost compared with cars. Expressions λ_n^{1sq} and λ_n^{2sq} set the number of converted vehicles of the relevant category in n - period of time, working respectively on petrol (λ_n^{1sq}), and on diesel fuel (λ_n^{2sq}) into gas fuel. This saves on the cost of fuel (gas fuel is cheaper than petrol and diesel), but the amount of consumed fuel when transitioned to gas increases by 20 percent (coefficient 1.2 in the formula (3)).

Expression $\rho_n^{is\tau}$ sets the change at n - time period of the number of two-wheeled and three-wheeled motor vehicles of the appropriate category by purchase, sale or withdrawal from use for scrap, etc. (transition to gas is taken into account before).

Obviously, if $\rho_n^{is\tau}>0$ then the number of vehicles of appropriate category increases, if $\rho_n^{is\tau}<0$ then it decreases.

Expression μ_n^{isq} sets the change for n – time period of a number of vehicles of the appropriate category using the same means for both two-wheeled and three-wheeled motor vehicles. Obviously, if $\mu_n^{isq} > 0$ then the number of vehicles of the appropriate category increases, and if $\mu_n^{isq} < 0$ then it decreases.

The expression $\omega_{s\tau}^i$ sets the average costs i – type of fuel in liters per 100 km in the urban cycle (possible consideration of any cycle just the same for all values $\omega_{s\tau}^i$ in formulas (1) – (3) according to the average indicators s – period released of τ – class of two-wheeled and three-wheeled motor vehicles.

The expression Δ_{sq}^i sets the average costs of i -type of fuel in liters per 100 km in the urban cycle (possible consideration of any cycle just the same for all values Δ_{sq}^i in formulas (1) – (3) according to the average indicators s – period of release of q – class on volumes cylinder capacity of cars.

If some country or region regulates the actions of the change of the number of vehicles of some categories by means of legal actions, then the coefficient β_n^i will have a very specific analytical view function $\beta_n^i(t)$ depending on the time t.

In formulas (1) – (3) grouping of vehicles by date of release can be made with different gradation number of years, for example at intervals of three or four years, and it is also possible to spend more detailed gradation of vehicles that are older than 10 years. In this case, in formulas (1) – (3) index i can be more than three.

In addition grouping of two-wheeled and three-wheeled motor vehicles can be carried out not only by engine capacity, but applying firstly the division into classes by function, and within these classes then to divide them into categories based on engine capacity [13].

Gradation of cars of different categories can be done not only by the volume of the cylinder of the engine, but also for the European system under the overall length of the car, by the official qualifications accepted by the US Agency for Environmental Protection EPA (United States Environmental Protection Agency) according to special techniques, taking into account the internal dimensions of the passenger compartment with two rows of seats and amount of luggage and other countries [15]. In this case, in the formulas (1) – (3) the index can take different values depending on the classification system.

Forecast of the number of costs i – type of fuel for $n+1$ period of time, based on fuel consumption for n time period and change over this period of quantitative and qualitative composition of vehicles, can be defined as follows

$$G^i(n+1) = \beta_n^i \, G^i(n), \; i = \overline{1,3}, \tag{4}$$

where the coefficients β_n^i are set in correlations (1) – (3).

In the mathematical model (4) the availability and change of the number of electric vehicles are not taken into account. Obviously, if a citizen has acquired an electric car, then he either get rid of his previous car or use it much less and consumption of carbohydrate fuel thus decrease. Thus the number of cars will be reduced that use petrol, diesel fuel or gas as fuel, and it accordingly will be considered in correlations (1) – (3).

During its movement the cars can be in the following four possible modes: idling (or full braking), acceleration, motion with the usual speed and deceleration. It is clear that the percentage of each of these modes in the full cycle of movement depends on where the traffic is on the highway or in the city and on the population of the city, on the number of forced stops (traffic lights, pedestrian crossings, traffic jams and their length, etc.), on the quality of the roads and the number of pits on them, on the availability of bypass roads in cities and others. The experience of cars exploitation has shown that the time of engine work in some modes is:

on the mode of idling – 35%, with the acceleration – 22%, in the modes of constant rotational speed – 29%, with the deceleration – 14% [12].

Obviously, each of these modes will have different fuel consumption and different harmful emission. The best efficiency of fuel consumption and reduction of emissions will be at maximum magnification of the mode of movement with established speed and with a corresponding reduction of idling (useless fuel consumption and emissions realization) and acceleration. For example, when accelerating and braking in utilized gases the content of carbon monoxide increases almost 8 times, and while the work of engine is idling emissions of carbon monoxide is 6 times greater than when driving at a speed of 60 km/h [16, 17]. So the most optimal as to the reduction of emissions is the movement with established speed.

The optimum efficiency of transport use is a long known fact and is widely used to reduce the emissions particularly in many countries of Europe. This is primarily the quality of the roadway and the number of bands of movement, reducing the number of forced transport stops at traffic lights, crossings, etc., a network of bypass roads around settlements, limiting traffic in the central parts of settlements, etc. Vehicle requirements in terms of emissions which are constantly more stringent contribute to considerable improvement of ecology.

Let us denote by means of θ_n^1 the average proportion of idle mode from the general mode of movement of vehicles, by means of θ_n^2 – the average proportion of acceleration, by means of θ_n^3 – the average share movement with established speed, and by means of θ_n^4 – the average proportion of slowing down during n – period.

Obviously, that if $0 < \theta_n^j < 1$ if $j = \overline{1,4}$ and $\sum_{j=1}^{4} \theta_n^j = 1$. Reduction of the share of the idle mode is especially important, because there is excessive fuel consumption and therefore excessive pollution, and the movement is not happening. Let in n – period, the proportion of idle mode was θ_n^1, and at the beginning of $(n+1)$ – period is θ_{n+1}^1. Thus in idling mode on average γ_1^i per cent of fuel is spent on the amount of spending in driving mode with optimal fuel consumption in the case of stoichiometric mixture of air and fuel (with a coefficient of excess of air $\alpha = 1$). The optimum ratio of mix of air with fuel for petrol engines is theoretically 14.8 kg of air for combustion of each kilogram of petrol, for diesel engine respectively – 14,4 kg: 1 kg, for engines that work on propane – 15.64 kg: 1 kg in butane – 15.43 kg: 1 kg, and in methane 17.2 kg: 1 kg [18, 19]. If the air is less than the optimal number($\alpha < 1$),then respectively, the amount of oxygen will be insufficient for complete combustion of fuel and some part of fuel materials, formed in the combustion chamber of the engine to be released into the atmosphere (acceleration mode).

If the air is more optimal number ($\alpha > 1$), then in this case the amount of harmful emissions will reduce, but the engine power also drops.

Let us denote by means of η_{n+1}^i the coefficient of relative change of fuel on idling mode of vehicles due to modernization of traffic and road quality for n – period of time

$$\eta_{n+1}^i = \left(\theta_{n+1}^1 - \theta_n^1\right)\gamma_1^i, \tag{5}$$

where θ_n^1 and θ_{n+1}^1 relatively are the shares of idling mode at the beginning of n – and $(n+1)$ – periods of time, coefficient γ_1^i of fuel consumption in this mode with respectively to the movement with the stoichiometric composition of air and fuel. Moreover, if, $\theta_{n+1}^1 < \theta_n^1$, then $\eta_{n+1}^i < 0$ and it leads to the reduction of the overall fuel consumption $G^i(n+1)$ by reducing the share of the idling mode. If $\theta_{n+1}^1 > \theta_n^1$, then $\eta_{n+1}^i > 0$ and it gives the general increase in fuel consumption. Then, using the equation (5), mathematical model (4) can be more accurately presented for the general consumption of fuel of i – type of fuel $G^i_{gen}(n+1)$

$$G^i_{gen}(n+1) = \left(1+\eta^i_{n+1}\right)G^i(n+1) = \left(1+\eta^i_{n+1}\right)\beta^i_n G^i(n),\ i=\overline{1,3}. \tag{6}$$

The equations (4) and (6) may be considered under certain transformations can be reduced to difference equations with the corresponding discrete time interval (year, quarter, month, etc.).

There is an important task of reducing of overall fuel consumption by regulating values $\rho_n^{\text{is}\tau}$, $\nu_n^{\text{is}\tau}$, μ_n^{isq} and λ_n^{isq} and the share of the idle mode θ^1_{n+1}, i.e. minimizing of functions $G^i_{gen}(n+1)$, $i=\overline{1,3}$ [20]

$$G^i_{gen}(n+1) \to \min\ ,\ i=\overline{1,3}. \tag{7}$$

Knowing the function of the total costs of the proper fuel $G^i_{gen}(n+1)$ it is possible to calculate the total cost of the air $A^i(n+1)$ during the combustion of this amount by the vehicle engines. In case of burning of petrol by the engines we have the predicted loss of air $A^1(n+1) = 14{,}8\,G^1_{gen}(n+1)$, in the case of diesel fuel – $A^2(n+1) = 14{,}4\,G^2_{gen}(n+1)$. Let us consider separately gas fuel. It is known that individual vehicles can work (with appropriate equipment) on liquefied mixture of propane and butane or on compressed gas the main component of which is methane. Today propane-butane mixture is used more than the compressed gas [21]. Therefore, in the case of burning of gas fuel by the engines let us take the arithmetic average of stoichiometric ratios for propane and butane, i.e. 15.5 kg of air for 1 kg of fuel. Then we have that $A^3(n+1) = 15{,}5\,G^3_{gen}(n+1)$. The total predicted use of air by individual transport for $(n+1)$ period of time is

$$A(n+1) = 14{,}8\,G^1_{gen}(n+1) + 14{,}4\,G^2_{gen}(n+1) + 15{,}5\,G^3_{gen}(n+1). \tag{8}$$

But as far as the air contains 20.95% of oxygen, then its total costs $O(n+1)$ are

$$O(n+1) = 0{,}2095\,A(n+1). \tag{9}$$

Let us consider separately the amount of exhaust emissions. During the combustion of one kilogram of fuel the appropriate amount of air is involved. The weight of exhaust gases of the vehicle must be equal to the total weight of the fuel and air that are involved in work. For each type of fuel the average share of pollutant emissions is known (carbon dioxide CO_2, carbon monoxide CO, nitrogen oxides NO_x, soot, etc.) of the total volume of the exhaust gases.

Let us denote the average proportion of emission of r – polluting substance for i – type of fuel through δ^i_r (obviously that $0 \le \delta^i_r < 1$), and through w^i_r the coefficient of influence of technical condition of vehicles on emissions of r – polluting substance for i – type of fuel. Then the total combined emission r – of polluting substance D_r in $(n+1)$ – period of time while consuming the fuel by the transport $G^i(n+1)$, $i=\overline{1,3}$ is

$$D_r(n+1) = 15{,}8\delta_r^1 w_r^1 G_{gen}^1(n+1) + 15{,}4\,\delta_r^2 w_r^2 G_{gen}^2(n+1) + 16{,}5\,\delta_r^3 w_r^3 G_{gen}^3(n+1) \qquad (10)$$

So we can calculate the predicted mass emissions of all pollutants in the total fuel consumption $G_{gen}^i(n+1)$.

Obviously, that the solution of the problem (7) leads to the solution of problems that deal with the minimization of the use of air and minimization of the oxygen consumption and emissions of pollutants when using personal vehicles:

$$A(n+1) \to \min \qquad (11)$$

$$O(n+1) \to \min \qquad (12)$$

$$D_r(n+1) \to \min \qquad (13)$$

The solutions of the problems (7) and (11) – (13) have the essential meaning for improvement of the ecological situation in Ukraine by optimizing the fuel consumption of individual vehicles.

Conclusions. Ukraine has a great potential of opportunities for the reduction of the overall fuel consumption, that is solving the problem (7). This can be achieved by improving the quality of roads and increasing their width, improving the system of traffic on the roads. The renewal of vehicle fleet that meet modern standards of fuel consumption and pollutant emissions will also contribute to the problem solving (7).

The correctness of such actions can be seen in the policies of the European Union (EU) on combating against the air pollution by the emissions from vehicles (Regulation EC № 715 / 2007 [22] and other documents). This fight against the air pollution has led to almost complete disappearance on their territories of two- and three-wheeled motor vehicles and cars with a long operation. All these vehicles were sold by the owners in other countries (including Ukraine) or put into scrap metal, and instead new cars were purchased with the minimal fuel consumption and minimal emissions of polluting gases and substances, according to new EU standards. Some EU countries even compensate their citizens some part of expenses for the purchase of electric vehicles. Thus the EU improves the ecological status of their territories. This old vehicle fleet of the countries that that has been replenished with the old cars, including Ukraine, continues with even greater intensity to pollute their territories.

Over the past 25 years hundreds of thousands of cars were imported in Ukraine that have already served their service life. These cars have no catalyst deactivation of toxic substances, their feed system mixes is misalignment and they are a source of toxic emissions [23].

Today the vehicle fleet in Ukraine is one of the most outdated in Europe. At the end of 2014 their average age was 18.8 years (in 2012 the figure was 18.2 years). About 30% of the Ukrainian vehicle fleet – are vehicles older than 25 years [24]. Over 60% of vehicles that are used in Ukraine have been operating for more than 10 years, i.e. these are the cars that had been registered before the introduction of Euro-2, which regulates the content of harmful substances in exhaust gases of vehicles (Euro 2 adopted in Ukraine in 2006, Euro-3 – in 2013, Euro 4 – in 2014, Euro 5 – in 2016). In Europe in 2015 Euro 6 standard has been already valid, and in Ukraine it will operate only from 1 January 2018. According to the norms of this standard carbon dioxide emissions by the new cars must be less than 130 grams per kilometer [25].

It is clear that in addition to burning of oxygen and release into the environment of pollutants, providing opportunities for the operation of vehicles leads to the reduction of land resources suitable for agricultural use(roads, garages and parking space for vehicles, gas stations and service car stations, the factory sites for the production of cars and various components and technical materials for them, etc.), deforestation for the construction of factories, garages, new roads and the expansion of the old ones and others. This is also the pollution of areas by the used parts, tires and fuel-lubricating materials and also the pollution and emissions from the areas where the vehicles are created, repaired and provided with necessary components.

This research makes it possible to predict the appropriate changes in fuel consumption and emissions of toxic substances considering various options for improving the environmental situation in Ukraine due to the qualitative change of the vehicle fleet and the creation of optimal modes of vehicle traffic. Materials of the paper can be used in predicting the changes in the environmental situation due to the adjustments in the system of individual transport in other countries.

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АНАЛІТИЧНО-ІМІТАЦІЙНЕ МОДЕЛЮВАННЯ ВПЛИВУ ТРАНСПОРТНИХ ЗАСОБІВ НА ЕКОЛОГІЧНУ СИТУАЦІЮ В УКРАЇНІ ТА ШЛЯХИ ЇЇ ПОЛІПШЕННЯ

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Резюме. *Побудовано математичну модель, яка визначає залежність кількості витрат пального за деякий період часу від терміну експлуатації загального парку транспортних засобів населення України; від співвідношення кількості різних за потужністю класів транспортних засобів цього парку; від оптимізації режимів руху транспорту на дорогах. Знайдено загальні залежності між витратою пального, споживанням повітря і викидами шкідливих речовин у результаті експлуатації всіх видів індивідуальних транспортних засобів за певний період часу.*

Ключові слова: *екологія, транспортні засоби, математична модель, алгоритм, прогнозування, пальне, шкідливі речовини.*

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