Software for Reduction of Energy Capacity of Cargo Transportation by Road Transport

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Abstract. The article deals with the problem of improving the efficiency of vehicle use by reducing the consumption of fuel and energy resources of trucks during the carriage of goods. A solution is proposed, based on the development of a special software product that allows taking into account the vehicles’ adaptability of different weight categories to the mass of the transported cargo. It is offered the software to calculate the objective fuel consumption norms on cargo transportation.

1. Introduction

On September 21, 2018, the Ministry of Transport of the Russian Federation issued a decree on Amendments to the Methodological Recommendations [1] of the "norms of fuel and lubricant consumption in road transport, put into effect by order of the Ministry of Transport of the Russian Federation from March 14, 2008 r 23-r. It is known that the existing standards are complemented by new models of vehicles and correct the raising factor for the operation of vehicles in populated areas with different populations. The changes and criticism of the current system of fuel consumption rationing in these changes were not taken into account.

Improving the efficiency of vehicle use includes a number of activities. One of the most important and significant in terms of importance is the course of improving the economic efficiency of vehicles.

The basis of the economic efficiency of vehicles is the concept of fuel efficiency and operating fuel consumption. Fuel efficiency, as you know, involves the performance of a given work with minimal fuel consumption [2]. Operating fuel consumption can be divided into actual and regulatory. If the actual consumption is the amount of fuel that was used to perform a given job and can vary widely depending on the conditions in which the vehicle was operated, on its technical condition, and the honesty of the driver. The standard consumption is a fixed value, an established measure, determined for a particular vehicle when it is used under given conditions. The latter is based on the norm, which in practice is calculated according to the Methodological Recommendations using the base rate of fuel consumption.

The economic efficiency of vehicles in operation is achieved mainly due to the saving of fuel and energy resources. Savings are the benefits that come when carefully spending something. Savings, in fact, is a reduction of losses due to the use of resource-saving technologies, prudent management, high organization of labor. Consequently, to save fuel means to spend it economically, and economical operation of a vehicle is its use, which makes it possible to profit when using fuel economically.

In order to figure out how to increase economic efficiency, it is necessary to understand how, in practice, fuel economy is obtained, to identify the source of its formation. Based on the above concepts, we can conclude that in the operation of fuel economy is determined by the level of deviation of the actual operating fuel consumption from the standard. At the same time, savings are generated if the difference between the actual and standard consumption is negative, otherwise there is an overrun.

The discrepancy between the calculated and actual values leads to the fact that truck drivers have the opportunity to drain the excess fuel and sell them on the private market. Only a well-established rate of fuel consumption will avoid it. However, the exact norm can only be obtained as a result of taking into
account the influence of complex and changeable factors. Obtaining an objective standard is possible only as a result of the development and use of special software.

2. Methodology

2.1 The choice of the research object

The article proposed a method to increase the efficiency of trucks transporting goods in the city and on public roads.

Currently, a reduction in actual fuel consumption will not lead to real savings \([3,4]\). The reason is the lack of an objective, scientifically based standard. Even the use of specialized equipment - instrumental means of monitoring actual fuel consumption does not allow achieving high fuel efficiency without an objectively established limit of fuel consumption. In addition, the use of instrumental control fuel consumption currently faces a number of problems. The high cost of equipment and the need to control and analyze data are the main ones.

Thus, in order to increase economic efficiency due to real fuel economy, it is necessary, first of all, to accurately and objectively determine the standard fuel consumption for vehicles of different brands and models. After that, one should achieve high fuel efficiency by reducing actual fuel consumption.

For the development of scientifically based fuel consumption rates, it is necessary to take into account both the design features of automobiles and the conditions in which they will be used. One of the most effective ways to develop fuel consumption rates is to use a space-time approach.

The basis of the space-time approach is that for vehicles used in variable and harsh conditions, the property of adaptability is introduced. Along with reliability, it was proposed to consider adaptability as one of the most important properties in shaping the quality and efficiency of vehicles \([5]\). If reliability is manifested in time, then adaptability is in space (operating conditions). The adaptability of a vehicle depends on its design features and on the conditions in which it is used and is a property to maintain at the nominal level the values of quality and efficiency indicators when the operating conditions deviate from standard ones.

2.2 Determination of the objective rate of fuel consumption of trucks for the carriage of goods

An indicator was obtained reflecting the influence of the mass of the transported cargo on the fuel consumption of vehicles with different curb weight.

\[
K_p = \frac{q_{so} \cdot m_{cargo} \cdot (a + 10 \cdot \psi)}{H_s},
\]

(1)

where \(q_{so}\) – specific indicator fuel consumption of the engine, \(1/100\text{Nkm}\);

\(\psi\) – коэффициент сопротивления дороги в заданных условиях road resistance coefficient under specified conditions;

\(m_{cargo}\) – mass of transported cargo, kg;

\(a\) – vehicle acceleration, \(\text{m}/\text{s}^2\);

\(H_s\) – base rate of fuel consumption, \(1/100\text{km}\).

Fig. 1 shows the change in the \(K_p\) coefficient calculated by the formula (1) from the mass of the transported cargo for two vehicles with different curb weights.
Figure 1. The dependence of the $K_p$ coefficient on the mass of the transported cargo for on-board vehicles with a gasoline engine: 1 - GAZ-2705 $q_n = 1500$ kg.; 2 - ZIL-4331 ($q_n = 6000$ kg.)

Figure 1 shows that the same change in the basic operating conditions (the mass of the load) in vehicles with different weight parameters leads to a different change in the coefficient $K_p$. Thus, the $K_p$ coefficient characterizes the influence of the mass of the transported cargo on the fuel consumption of automobiles, and depends on their weight parameters.

The values of the coefficient $K_p$ for suburban and urban (with frequent stops) modes of movement of on-board vehicles and vans with different types of engines are given in Table 1. The coefficient of road resistance $\psi$ is assumed to be equal to $\sim 0.018$. The average density of gasoline is taken to be $0.74$ kg / l, diesel fuel is $0.85$ kg / l, and their lower calorific capacity is $44$ and $42.5$ MJ / kg, respectively.

Table 1. Coefficient $K_p$ values

| Type of engine | Coefficient $K_p$ during country driving | Coefficient $K_p$ in city traffic mode |
|---------------|------------------------------------------|----------------------------------------|
| gasoline      | $\frac{18.8 \cdot 10^{-4} \cdot m_{carg.o}}{H_s}$ | $\frac{10.7 \cdot 10^{-3} \cdot m_{carg.o} \cdot (a+0.18)}{H_s}$ |
| diesel        | $\frac{10.2 \cdot 10^{-4} \cdot m_{carg.o}}{H_s}$ | $\frac{6 \cdot 10^{-3} \cdot m_{carg.o} \cdot (a+0.18)}{H_s}$ |

Due to the difference between the working cycles of diesel and gasoline engines, the values of the coefficient $K_p$ for them are calculated separately. In the system of fuel consumption rationing, the features of different types of engines are taken into account and the value of fuel consumption for the performance of transport work was taken to be different. Currently, the norm is set for vehicles using diesel fuel - $1.31$ l / 100tkm and for using gasoline - $2.1$ l/100tkm.

The study of hypotheses about the form of the mathematical model of the dependence of fuel consumption on the mass of the load from the point of view of their applicability allowed us to identify a piecewise linear model of the form:

$$Q_f = Q_o + m \cdot \left( \sum_{i=0}^{n_1} S_{1i} + \sum_{i=0}^{n_2} S_{2i} + \sum_{i=n_2}^{n_3} S_{3i} \right), \quad l/100 \text{ km}$$ (2)
where \( m \) – unit of mass of the transported cargo (1 ton);
\( S_1, S_2, S_3 \) – values of sensitivity parameters in the corresponding interval of \( K_p \) values, 1/100 tkm;
\( n_1, n_2, n_3 \) – the number of full tons of cargo (trailer / semi-trailer) in the corresponding \( K_p \) value range;

The use of new patterns that characterize different adaptability of vehicles, in particular to different masses of cargo, allows them to operate with maximum efficiency. Therefore, taking into account the data obtained (Figure 1 and Table 1), it is necessary to determine the levels of adaptability to the mass of the cargo in terms of fuel consumption for vehicles with diesel and gasoline engines separately.

In accordance with the space-time concept [6,7], one of the quantitative indicators of adaptability is the coefficient of adaptability. It shows how many times the value of the indicator of quality and efficiency in these conditions differs from the base value. The use of this coefficient will allow to distribute all vehicles into groups depending on their level. The coefficient of adaptation of vehicles to the mass of the transported cargo will be determined by the ratio:

\[
A = \frac{Q_o}{Q_f}
\]

where \( Q_o \) – value of fuel consumption of an empty vehicle, 1/100km;
\( Q_f \) – the actual value of the fuel consumption of the loaded vehicle, calculated using the coefficient \( K_p \), 1/100km.

In accordance with formula (2), vehicles are divided into three levels of adaptability: high, medium, low. Table 2 and Table 3 show an example of the division of vehicles into groups, depending on the level of adaptability.

| Table 2. The adaptability levels of vehicles with gasoline engines to the mass of transported cargo |
| --- |
| Name of adaptability range | Curb weight, characteristic for a given range of adaptability, t. | Vehicles | Full weight class |
| High | 6000 and more | URAL-377H | 5 – 7 |
| Medium | 3500 | ZIL-431410 | 3 – 4 |
| Low | 2000 and less | YerAz -762A | 1 – 2 |

| Table 3. The adaptability levels of vehicles with diesel engines to the mass of transported cargo |
| --- |
| Name adaptability range of | Curb weight, characteristic for a given range of adaptability, t. | Vehicles | Full weight class |
| High | 9000 and more | MAZ-6303 | 6 – 7 |
| Medium | 6500 | ZIL-534330 | 4 – 5 |
| Low | 4000 and less | ZIL-5301BE | 1 – 3 |

The values of the coefficient of adaptability to the mass of the transported cargo in terms of fuel consumption were obtained analytically. When calculating using ratios (1), (3), \( q_{so} \) values were used, which, depending on the type of engine installed on the vehicle, take values from \( 5.4 \times 10^{-3} \) to \( 11.6 \times 10^{-3} \) l/100 Nkm, as well as flow values fuel of vehicles in the empty state. The presented results were obtained for the case of transportation of 1 ton of cargo. The result of statistical analysis showed that the density function of the distribution of values of the coefficient of adaptability corresponds to the normal law (Fig. 2).
Figure 2. Histogram and distribution curve of the values of the adaptability coefficient for vehicles with a diesel (left) and gasoline engine (right)

To assign a particular vehicle to a particular range of adaptability, it is enough to determine what type of engine is installed in the vehicle and then find out what class the vehicle is in full weight. Figure 2 shows the dependence of the adaptability coefficient \( A \) on the mass of the transported cargo for vehicles with petrol and diesel engines, which belong to different classes according to the total weight.

3. Results and analysis
To determine the amount of fuel consumption during a cargo transportation, an experiment was performed using the data of the on-board computer and the method of topping up the tank to full. The cargo mass was measured by floor scales MP 60 MDA-7 p / d-10 "Guliver". Figure 3 illustrates the results of the experiment for three vehicles: Volvo FM12, MAZ-437040, GAZ-3302.

Figure 3 shows that vehicles with different gross weights have different dependences of the adaptability coefficient on the mass of the load. That is, vehicles with excellent weight characteristics react differently by changing fuel consumption by the same weight of cargo. This means that they have different adaptability. In this regard, the size of the fuel consumption rate for the performance of transport work must be appointed differentially.

Based on the obtained S values, a table of the values of the fuel consumption rate for the performance of transport work was compiled. The work was differentiated depending on the adaptability levels of vehicles of different brands and models, for different severity intervals (Tables 4 - 4).

The use of objective differentiated standards will save fuel, primarily due to the elimination of the possible causes of its overspending: theft, poor technical condition of the vehicle, unskilled driving [8].
Figure 3. The dependence of fuel consumption of vehicles on the mass of the cargo

| Level of vehicle adaptability | The value of the fuel consumption rate for the transport of 1 ton of cargo for the severity intervals, 1/100 tkm |
|-------------------------------|--------------------------------------------------------------------------------------------------------|
|                              | Temperate | Moderately severe | Severe          |
| High                          | 0.78      | 0.92              | 1               |
| Medium                        | 0.91      | 1.03              | 1.12            |
| Low                           | 1.02      | 1.14              | 1.23            |

| Level of vehicle adaptability | The value of the fuel consumption rate for the transport of 1 ton of cargo for the severity intervals, 1/100 tkm |
|-------------------------------|--------------------------------------------------------------------------------------------------------|
|                              | Temperate | Moderately severe | Severe          |
| High                          | 1.56      | 1.74              | 1.82            |
| Medium                        | 1.64      | 1.8               | 1.9             |
| Low                           | 1.73      | 1.88              | 1.97            |

For ease of use in any enterprise that uses automobile transport and rationing the fuel consumption of automobiles, a software implementation of this Methodology has been proposed. The program is created in C++, has an intuitive interface and allows you to get the value of the fuel consumption of a particular vehicle to perform a given transport work (figure 4).
3. Conclusion

Thus, we can conclude that for vehicles with gasoline and diesel engines belonging to different weight groups, the ranges of fitness are defined. At the same time, there is no need to make calculations for assigning a vehicle to one group or another. In practice, it will improve the efficiency of the use of vehicles mainly due to the use of the most suitable rolling stock for the transportation of a given mass of cargo, and as a result of the establishment of a differentiated rate of fuel consumption for transport work.

The economic effect obtained through the use of software created on the basis of objective rationing, taking into account the various levels of fitness of vehicles, in comparison with the current standards for the studied vehicles ranges from 3.7 to 8 rubles / 100 km per vehicle (prices in March 2019) when transporting one ton of cargo.

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