New technology of the automated individual fuel consumption standardization for the motor vehicles

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Abstract. A new technology of individual automated control of fuel consumption for the commercially operated motor vehicles is proposed. Thus, it allows the automatic collection of data on operating conditions, operating hours and fuel consumption of the vehicle. Moreover, this technology provides for the calculation of two packages of standards for a separate assessment of the technical condition of the vehicle and the quality of the driver’s work. Norms are unique for each motor vehicle and for each combination of the operating conditions and regimes. The new technology is going to minimize usage of motor vehicles with a high level of fuel consumption and provide an objective assessment of the driver’s quality and fuel efficiency for the commercially operated transport.

1. Introduction
There are two goals of the fuel consumption standardization:
- forcing the driver to minimize fuel consumption;
- minimization of the fuel consumption by making regular checks and maintenance of the motor vehicle.

Nowadays, there are 3 types of widely used standards for motor vehicles in Russia: basic, transport and routes (Methodical recommendations “Norms of fuel and lubricant consumption in automobile transport”. Appendix to the order of the Ministry of Transport of the Russian Federation of March 14, 2008 No. AM-23-p. (as amended on April 6, 2018). M., 2008. -114 p.) All of them use average evaluations of the main influencing factors on the lifespan periods of the motor vehicles. However basic and transport standards are not applicable without adjustment as well as the standards obtained during the driving cycle [1]. Most researchers are focused on the numerical modelling of discrepancies in driving cycles rates and actual fuel consumption under different road conditions [2, 3], or on using approximated equations for modelling certain fuel consumption conditions during goods transportation [4] and public transport [5]. Besides that, the fuel consumption of the hybrid vehicles [7] and auto transport with adaptive cruise-control systems [8] is also taking into account during the modelling. One of the significant topics of the research is to seek the solution for the method objectivation in order to represent operation cycles and its influence on the fuel efficiency in a clearer way [9].

The most actual standards are the norms developed for the route transportation. However, such types of standards are only effective in the situations when the small part of the auto park is used. While during the other situations the managers of the car parks use standards that take into account only the features of the transportation itself.
Technology of the route standardization includes repetitions of the modelling flow cycle by the regression dependencies of the route factors (from 5th to 7th) and operation conditions. Then these values would be used to create a group of standards. However, each standard is correlated only with one type of motor vehicle, degree of engine wear and unique operation conditions (such as traffic volume, road conditions, temperature). Furthermore, these factors vary greatly during one shift. So, the average fuel consumption during the long period of time was the basis for the standardization. Route standards should always be modified, since types of motor vehicles changes and its resource is depleted. Moreover, the switch from one shift to another, changes in traffic conditions and periods of the year also have an influence on the norms. That, in turn, results in errors and imperfections of the standards [10].

Route standards could not be fully automated and should be revised constantly at different auto parks. Such method is labour and resource-intensive as new professionals with suitable competencies should be hired. The excessive duration of the control cycle, e.g. from days to months and in some cases even longer, reduces the efficiency. Such way of assessment provides only rough average estimations without taking into account actual operating and wear conditions. The automation system of standardization is of a great significance, especially that consider usage of the exact state of the motor vehicles and operating conditions. Such methodology has been developed, and its novelty is confirmed by the invention patents [11, 12].

2. Material and methods
A new system of the standards assessing fuel consumption and a new technology of its development and usage during the motor vehicles operating are proposed in the paper. Standardization is going to be automated and initial data would be collected during the shorter periods of time. Traffic conditions, the temperature of the environment and road conditions would not change dramatically during the control periods of time.

The proposed methods could be used for an automated search for the reasons of excessive fuel consumption and its influence on the motor vehicle conditions. The two packages of standards (“technical” and “driver”) would be used instead of transportation standards:
- to assess technical conditions of the motor vehicles (“technical” standards);
- to evaluate the quality of the driver’s work (“driver” standards).

“Technical” standards would be evaluated for the certain operating hours and taking into account different components of the operating conditions, regimes and factors that limited within narrow intervals:
- speed and interval of its increase during the acceleration;
- crankshaft speed;
- load of the motor vehicle;
- temperature of the environment;
- road conditions;
- temperature of the coolant.

The “drivers” standards would be calculated during the longer operating hours for each above mentioned component limited by the narrow intervals and operating regimes of the motor vehicles:
- average speed during the period of the data collection (TB) (route congestion indicator);
- temperature of the environment;
- motor vehicle load;
- road conditions.

Individual standardization with the use of drivers and technical norms include four stages (Figure 1).
Figure 1. Sequence of the automated preparation and application of the individual standards of the fuel consumption during motor vehicle operation.

3. Theory/calculation

Preliminary ranges of the possible changes in operational regimes (Figure 2) and conditions (Figure 3) could be divided into small steps. The number of steps (levels) depends on the parameter variability and its influence on the fuel consumption. The duration of the control cycle is also set, including a number of control periods.

Figure 2. Schematic graphs of simultaneous changes in the operation parameters, e.g. the speed (V) and engine crankshaft speed (n).
The interval standards ($q_i$) are automatically set before the start of the experiment on each motor vehicle operated by the ideal driver. The operational conditions (load, traffic conditions, temperature, temperature of the coolant) are wrote down as well as working regimes (speed and crankshaft speed), and fuel consumption (Figure 4). The steps for each parameter are calculated automatically. Running hours and fuel consumption during the $s$-th period with the same $i$-th factors are summarized. Later the group of the “drivers” standards $\{q_i\}$ for the fuel consumption is calculated using the following equation (1):

$$ q_i = \frac{\sum_{s=1}^{M} h_{is}}{\sum_{s=1}^{M} l_{is}} \cdot Z = \sum_{s=1}^{M} t_{s} \cdot S = 1, 2, ..., M; I = 1, 2, ..., N, $$

where $h_{is}$ and $l_{is}$ – fuel consumption and mileage of the motor vehicle during the $s$-th running hour with the $t_i$ duration and with the $i$-th combination of the operational regimes and conditions.

$Z$ – set control system time;

$M$ – number of monitoring periods required to accumulate mileage data for the $l_{is}$ mileage and fuel consumption $h_{is}$ in order to calculate $i$-th standard $q_i$. 

**Figure 3.** Schematic graphs of simultaneous changes in the operation parameters, e.g. temperature (T) and weight load of the motor vehicle (G).

**Figure 4.** Schematic graphs of the instant fuel consumption (h).
The norm \( (q_i) \) is only suitable with the i-th combinations of the operational conditions and regimes and its total total number \((N)\).

The standard of the fuel consumption \( (Q_B) \) for each control cycle with the Z duration is calculated automatically as a ratio of the running hours to the interval rate \( q_i \) with the i-th combination of the operational conditions and regimes, that took place only in R periods of different durations \( (t_i) \), to the total mileage during the control cycle:

\[
Q_B = \frac{\sum_{i=1}^{N} q_i t_i}{\sum_{i=1}^{N} l_i}, \quad l_i = \sum_{s=1}^{R} l_{is}, \quad t_i = \sum_{s=1}^{R} t_{is}, \quad R \leq M
\]  

(2)

where \( q_i \) – interval norm of the fuel consumption for the i-th combinations of operational conditions and regimes operated by the excellent driver;

\( t_i \) and \( l_i \) – total values of the mileage and registration durations observed during the control cycle Z with the i-th combinations of the above mentioned parameters;

\( l_{is} \) – mileage of the motor vehicle during the s-th control period with the \( t_s \) duration and with the i-th combinations of the operational conditions and regimes;

\( R \) – number of control periods within the control cycle with the Z duration, taking into account the i-th combination of the above mentioned operational factors.

Consider to calculate the standard \( (Q_B) \) of the fuel consumption during the control cycle \( (Z) \) at the end of the period. The evaluation takes into account actual mileage \( (l_i) \) and group of interval standards \( (q_i) \) for the total number \((N)\) of possible combinations of operational conditions and regimes.

Then the calculated standards \( (Q_B) \) for each control cycle are compared with the actual fuel consumption \((H_v)\) measured in l/km mileage:

\[
H_v = \frac{\sum_{i=1}^{N} f_i}{\sum_{i=1}^{N} l_i}, \quad f_i = \sum_{s=1}^{U} f_{is}, \quad U \leq M
\]  

(3)

where \( f_i \) and \( f_{is} \) – actual fuel consumption with the i-th combination of the operational factors during the s-th and t-th control cycle respectively;

\( U \) – the number of the control periods within the cycle Z, where the i-th combination of the operational conditions and regimes was noticed.

Operating time \( (t_i) \) could be calculated by the following equation (4), using more than one interval \( (t_{is}) \) of the continuous work of the motor vehicle with the i-th combinations of the factors:

\[
t_i = \sum_{s=1}^{M} t_{is}, \quad s = 1, 2, \ldots, M
\]  

(4)

where \( t_{is} \) – duration of the s-th period of the continuous work of the motor vehicle with the i-th combination of the operational factors and conditions.

Automated control of the motor vehicle technical conditions and its fuel consumption allows preliminary selection of the commonly used factors and operational regimes (e.g. speed, crankshaft speed). Moreover, the dividing of the possible parameter for smaller steps could be also done automatically.

During the standardization the combinations of the operational factors and conditions automatically identified and during each of them the fuel consumption is detected. These steps are cyclically repeated in the same combinations of operating conditions and work intensity of the motor vehicles used for the commercial transportation. Than the fuel consumption data is summarized. The norms of the specific fuel consumption are evaluated for each combination and during the small steps with the constant speed
and during the acceleration with the highest fuel supply. Continuing assessment the accidental values that could fall into the same control periods are also taking into account, and actual fuel consumption is detected.

The control cycle for the “technical” standards is selected based on the errors’ accessibility. Initial data for each standard \( q_j \) could be recorded during more than one operational period (mileage \( l_i \) or duration \( t_i \)). Each standard \( q_j \) is calculated by the summarizing of the fuel consumption values during the several operational hours \( t_{jr} \), for the \( l_j \) mileage and taking into account the \( j \)-th combination of the operational factors. The group of standards \( Q_T \) is calculated for the total number \( K \) consisting of the range of standards \( \{q_j\} \) figured out for the «technical» consumption.

Interval standard of the “technical” fuel consumption \( q_{jr} \) is calculated by the summarizing fuel consumption \( h_{jr} \) during the \( r \)-th periods with \( B \) number and characterized by the same \( j \)-th combination of the before mentioned conditions:

\[
q_j = \frac{\sum_{r=1}^{B} h_{jr}}{\sum_{r=1}^{B} l_{jr}}, \quad j = 1, 2, ..., K
\]

\[
And \quad t_j = \sum_{r=1}^{B} t_{jr} \quad l_j = \sum_{r=1}^{B} l_{jr}, \quad r = 1, 2, ..., B.
\]

where \( h_{jr} \) – fuel consumption in the \( r \)-th period of time with the \( j \)-th combination of the operation conditions;
\( l_{jr} \) and \( l_j \) – mileage during the \( r \)-th control period with the \( t_r \) duration and the total mileage with the \( j \)-th combination of the operation conditions and regimes during the control stage with the \( Z \) duration accordingly;
\( B \) – number of the control stages during which the information about mileage \( l_r \) and fuel consumption \( h_r \) were collected and the \( j \)-th interval standard \( q_{jr} \) was calculated
\( t_{jr} \) and \( t_j \) – duration of work \( (t_{jr}) \) during the \( r \)-th period and the minimal period of time required for standardization \( (t_j) \) with the \( j \)-th combination of the operational factors and conditions.

Calculated standards of the \( q_j \) for the \( K \) combinations of the operation conditions and regimes indicators are combined in a package \( \{q_j\} \) and not cumulative.

Values of the actual specific fuel consumption \( (H_t, l/km) \) are compared with the calculated for the same combinations \( \{K\} \) with the standards \( \{q_j\} \):

\[
H_t = \frac{\sum_{k=1}^{D} f_k}{\sum_{k=1}^{D} l_k}, \quad k = 1, 2, ..., D, \quad D \leq M,
\]

where \( f_k \) – actual fuel consumption during the \( k \)-th control period with the \( j \)-th combination of the operation conditions and regimes values;
\( l_k \) – mileage of the motor vehicle at the \( k \)-th control stage with the \( t_k \) duration and with the \( j \)-th combination of the operation conditions and regimes indicators;
\( D \) – number of the control stages among the cycle with the \( Z \) duration, in which the \( j \)-th combination of the operation conditions and regimes was recorded.

4. Discussion

Technology of individual standardization includes the cyclical process of the standards verification and determination. First the values are set during the start of the operation and then values are refinement each 150, 300 thousand km. and after each engine replacement. The operational hours, mileage and fuel consumption data is recorded during the operation period. The information is transferred via the GSM
network or GLONASS system to the IT systems of the organization. Thus the “driver” and “technical” standards are calculated for each period and compared with the actual fuel consumption values. The fuel overspending during individual control cycles is analyzed by the software to find the reasons of fuel losses and its correlation with the operational conditions and regimes; to detect similarities of the fuel consumption by the motor vehicles working at the comparable conditions (Figure 5).

**Figure 5.** Automatic data analysis procedures for the high fuel consumption reasons identification.

The implementation of the proposed technology is required software development that would be a part of the it-system for analysis and planning of the fuel consumption in the transportation companies. The part of the hardware component of the new technology is the widespread use of the smart sensors controlling fuel consumption. Moreover, the sensors allow to control operating hours in mileage and time, check the temperature of the environment from the onboard sensors, evaluate road conditions (e.g. saturation, presence of water and ice) and show values of the engine speed and coolant temperature. The load of the motor vehicle could be controlled by the tire pressure and the road conditions by the work of ABS during the deceleration of the motor vehicle. In addition, the information about the environment could be received from the “rain sensors” on the windshield and the luster of the surface in front of the motor vehicle.

The proposed technology would help to minimize the fuel consumption by the reduction of the operation hours of the motor vehicles with the higher fuel consumption in the commercial transportation. Thus, it could result in more efficient and unique assessment of the drivers’ work and fuel consumption.

5. **Conclusions**

The proposed method of the fuel consumption analysis could be used for modern motor vehicles equipped with the smart sensors of the fuel consumption, means of data transmission via GSM or GLONASS and local web that integrated in the IT-systems of the transportation companies. Thus, the new technology is going to eliminate the outdated and time consuming process of the assessment. It allows collecting data automatically and in a more efficient way. The developed standards are more accurate and adequate to the new operating conditions, working regimes, motor vehicle loads and the temperature of the environment as well as to the traffic and road conditions. The application of the standards does not require to use the additional labor and could be done in a fully automated regime.
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