The algorithm for vehicle fleet creation

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Abstract. The article deals with the problem of creating the structure of a vehicle fleet. Today when specialists solve this problem, they rather use their experience and intuition, based on one criterion, which is the most important in their opinion. The most usual criterion, in this case, is the cost of a vehicle and the level of vehicle safety is often neglected. Meanwhile, the increase in this level is one of the World Health Organization’s activities aimed at decreasing the number of road traffic injuries within the Decade of Action for Road Safety. This article analyzes different quality indicators of goods transportation by automobile transport. As a result, it establishes a list of indicators that can be important when solving the task of creating a rational vehicle fleet to satisfy the requirements for goods transportation in the mineral resources sector. The article also describes the validation scheme for weighting factors used for the indicators in the list. As a consequence, the algorithm for vehicle fleet creation is developed.

1. Introduction
The system of utility vehicles significantly influences the functioning of enterprises in the mineral resources sector. The performance of vehicles directly impacts the primary cost of the final product.

At the same time, the model ranges of similar type vehicles have been expanding recently which can complicate the creation of a rational vehicle fleet for the specialists of vehicle fleet operators. In these conditions taking a clear solution could be almost impossible.

In reality, the specialists of vehicle fleet operators manage the structure of a fleet without any scientifically approved methods. Their decisions are usually based only on the criterion of a vehicle cost. Other factors often neglected.

However, when creating a rational fleet, it is not appropriate to choose the model of a vehicle based on one criterion as suggested by some methods. A specialist needs to consider a broad range of quality indicators.

There are several problems in the transportation sphere, including the safety problem, the problem of saving resources [1] and the problem of increasing the profits of a fleet operator [2]. Moreover, the proliferation of cars brings forward the problem of environment safety [3–5]. Every vehicle should have a high level of design safety as this plays a critical role in accident prevention and decreasing the number of road traffic injuries. Besides vehicles should be economically efficient. Clearly, the stability and efficiency of a transportation system are influenced by a broad range of factors [6], including the qualification of employees who manage and service vehicles [7]. However, in terms of this task, it is interesting to study those factors directly connected with a vehicle pool. Thus, this research implies solving a multi-criteria task which preserves some uncertainty connected with contrasting evaluations by different criteria.

The current practice needs modern instruments to solve the task of creating a rational vehicle fleet.
2. Creating the list of quality indicators
The quality of vehicle transport means the combination of vehicles characteristics which make them suitable to perform necessary tasks and satisfy the requirements of transportation in set operating conditions. The quality of the object in study (a vehicle) is defined by its properties i.e. characteristics. Thus, it is important to identify the list of factors that have the most influence on the outcome of object operation, the demand on it, etc. A vehicle is a repairable product which is characterized by reliability, durability, usability, standard design and unification as well as repairability, transportability, aesthetic and patent and law indicators. There is an integrated index of a vehicle quality which is the sum of products of such indicators as dynamics, comfort, safety, fuel expenditures, maintenance, reliability, and their weighting factors.

GOST 4.401-88. The system of the product quality indicators. Trucks. There is a broad list of quality indicators reflecting the following characteristics of vehicles:

- purpose indicators (vehicle type, axial configuration, engine type, the number and arrangement of cylinders, mass, number of seats in a cab, vehicle size, wheelbase, the internal size of the body, floor level, external minimal turning radius between walls, maximum climbing angle, deadweight coefficient, power-to-weight ratios of a vehicle and a haul train, maximum speed, minimum stable speed, fuel distance);
- reliability indicators (overhaul life, no-failure operating time, mean time to failure, warranty operating life);
- the indicators of efficient use of resources, materials, fuel, energy, and labor (specific weight, specific fuel consumption at the speed of 60 km/h);
- usability indicators (in-car noise level, maximum effort applied to control gears);
- performance indicators (specific labor inputs, maintenance rate);
- environmental indicators (the content of harmful substances in combustion gases of gasoline engines, smoking at the exhaust of diesel engines, ambient noise level);
- safety indicators (breaking path using a service brake system during usual efficiency trials, breaking path using an emergency brake system during usual efficiency trials).

Standard list include those main quality indicators that are established by the state CTR (common technical requirements) standard with perspective requirements: overhaul life, no-failure operating time, mean time to failure, specific weight, specific fuel consumption at the speed of 60 km/h, in-car noise level, specific labour inputs for maintenance and repairs, maintenance rate (first/second maintenance), the content of harmful substances in combustion gases of gasoline engines, smoking at the exhaust of diesel engines.

Since a big number of vehicles is used in Russia where Euro 1 standard emissions are still common [8, 9], the consideration of ecological indicators is especially important.

When creating a rational vehicle fleet, it is necessary to remember about economic components i.e. the cost of a vehicle itself and its use. Besides the fuel consumption and the cost of a vehicle, the expenditures on maintenance and insurance must be taken into account.

The final list of indicators depends on the required type of a vehicle, the nature of work performed, the operation conditions, etc. However, it is clear that different indicators are not equal and can influence the choice of vehicles differently. To determine the importance factors, it is necessary to evaluate indicators experimentally.

3. The methodology of determining the weighting factors of indicators when choosing a vehicle by the importance priority
Weighting factors are determined in several phases: preliminary ranking, expert competency assessment, the second ranking which takes expert competency in the account.

However, assessing competency may be difficult as the dimension of agreement can’t be its only measure. There can be inverse logic arising from the polarization of opinions. It means that specialists doing research in one sphere but having different specializations can evaluate one criterion differently, which doesn’t mean these specialists are incompetent. Thus, it is possible to conduct an expert
assessment in a group of experts. Each expert individually ranks indicators, starting from the most important in his opinion. Ranking criteria in terms of importance is an elementary operation of information processing. It is treated by specialists as acceptable because it can be done with minor contradictions by a decision-maker. The average rank value based on the expert group data is calculated via the formula:

$$z_i = \frac{1}{m} \sum_{j=1}^{m} c_{ij},$$

(1)

where $c_{ij}$ is a rank of $i$ indicator set by a $j$ expert; $m$ is a number of experts.

The mean square deviation of ranks of the $i$ indicator from its average value is calculated in the following way:

$$\delta_i = \sqrt{\frac{1}{m(m-1)} \sum_{j=1}^{m} (c_{ij} - z_i)^2}.$$  

(2)

Next, the rounding of mean observation is used to define preliminary ranks based on all indicators and using the following algorithm:

- the lowest $z_i$ rank is given the rank $r_i = 1$;
- the next lowest rank $z_k$, ($k \neq i$) is given the preliminary rank 2;
- then, the next preliminary rank is given to the next lowest rank.

If some mean observations of indicators of place $z_u$ and $z_v$ ($u \neq v$) do not vary more than $\Delta_z$, where

$$\Delta_z = |z_u - z_v| \leq 0.1 \times \left( \frac{n^2}{m-1} \right)^{0.25},$$

(3)

then preliminary ranks are given as a mean based on the number of their possible sequential places.

The correctness of preliminary ranks given can be validated based on their sum which must be equal to $0.5n(n+1)$.

The group expert competency can be determined by the coefficient of rank correlation. It is calculated using Spearman formula:

$$\rho_j = 1 - \frac{6 \sum_{i=1}^{n} d_i^2}{n^3 - n},$$

(4)

where $d_i^2$ is a square of the difference between ranks.

The competency coefficient is determined based on the formula

$$\alpha_j = \frac{1 + \rho_j}{m + \sum_{j=1}^{m} \rho_j}.$$  

(5)

During the next phase, it is necessary to carry out the second ranking of indicators taking into account the competence of experts. The mean observation of ranks is calculated based on the formula:

$$z_i^* = \sum_{j=1}^{m} \alpha_j \cdot c_{ij}.$$  

(6)

The mean square deviation of ranks is calculated based on the formula:

$$\delta_i^* = \sqrt{\frac{1}{m(m-1)} \sum_{j=1}^{m} \alpha_j (c_{ij} - z_i^*)^2}.$$  

(7)
The expert consistency is assessed based on the Nikolaev–Temnov method. Let’s build the probability matrix based on the formula:

\[ P_{ik} = \frac{m_{ik}}{m}, \]  

(8)

where \( m_{ik} \) is a number of experts that gave the \( k \) place to the \( i \) indicator. The agreement of experts is determined based on the formula:

\[ W_H = 1 - \frac{H}{n \log n}, \]  

(9)

where \( H = - \sum_{i,k} P_{ik} \log P_{ik} \).

If value \( W_H \geq 0.55 \), it is possible to say that expert assessment was successful and there is no need in the second ranking.

As a rule, the determination of importance factors for private indicators is done based on the formula:

\[ \gamma_i = \frac{1/r_i^*}{\sum_{i=1}^{n} 1/r_i^*}, \]  

(10)

where \( r_i^* \) is the final rank of \( i \) indicator.

However, this approach gives only approximate result due to the rigid system of ranks given to indicators. For example, if there four indicators were given approximate ranks of 1…4, we will get a set of possible weighting coefficients of 0.48; 0.24; 0.16 and 0.12. This can’t be true as different private indicators can influence differently on the generalized indicator of a decision efficiency. That’s why when calculating the importance factors of private indicators, it is suggested to base not on the value of the final ranking \( r_i^* \), but the mean value of the ranking \( z_i^* \), reflecting the opinions of all experts and taking into consideration the assessment of their competency. Thus, the formal used to evaluate the importance factors of private indicators is the following:

\[ \gamma_i' = \frac{1/z_i^*}{\sum_{i=1}^{n} 1/z_i^*}. \]  

(11)

The weighting factors obtained as a result of this experimental calculations can be considered as well-grounded and used for solving the task of creating the rational vehicle fleet.

4. Conclusion

The algorithm for creating a rational vehicle fleet, offered in this paper, is used to determine the most important factors to solve the actual transportation task and the system of grounded weighting factors for them.

Apart from the above, it is interesting to find other tools to increase the competitiveness of vehicle fleet operators as well as the safety of transportation.

The obtained results create the preconditions for the increase in safety and efficiency of vehicle fleets by means of forming their rational structure. They can be useful for managers and specialists of vehicle fleet operators as well as scientists working on the rational structure of vehicle pools and solving the problem of increasing the quality of transportation services.

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