DETERMINING OPTIMAL FREQUENCY OF TECHNICAL MAINTENANCE OF BUSES

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ABSTRACT

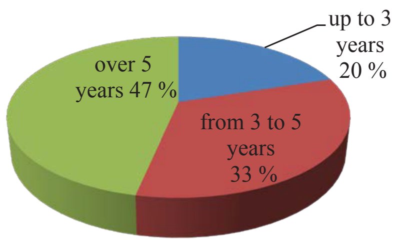
The article, using the example of LLC ATP Kama analyzes the condition of fleet of the motor transport enterprise, as well as the existing system for ensuring its operability. In particular, normative and actual technical readiness of buses is shown taking into account the terms of their operation, average daily mileage, total number of days of stay for maintenance and repair during the year. The method of adjustment of standards was chosen. Optimal periodicity of maintenance of vehicles was determined. An assessment of intensity of failures, costs for the enterprise of preventive maintenance and repair work, and calculation of economic effectiveness of the proposed solutions are suggested.

Keywords: *motor transport enterprise, economy, cost reduction, optimal periodicity of maintenance, bus operation, economic-probabilistic method, exponential distribution law.*

Background. *In market conditions, competitiveness of any motor transport enterprise depends on the coefficient of technical readiness of the fleet and the costs for maintenance (TM) and current repairs (CR). In addition, we should not forget about the increase in the cost of cars, spare parts, relatively high average age of the fleet, especially trucks and buses.*

Currently there is a tendency for disaggregation of motor transport organizations, an average enterprise now has no more than 30 units of equipment [1]. The system for maintaining working capacity of the fleet at such enterprises is ineffective and at best consists of performing maintenance with the frequency specified in the technical documentation, while most enterprises do not have their own production and technical base, they cannot keep technological discipline for maintenance and current repairs.

The main document regulating adjustment of standards depending on operating conditions, climatic conditions, average mileage of cars, quality of maintenance and current repair performance and other factors is «Regulation on technical maintenance and repair of the fleet of automobile transport» [2]. The document was developed more than 30 years ago, cars, as well as the standards, which it indicated are outdated. In addition, at present periodicity of maintenance, labor-intensive maintenance and repair are determined by the manufacturer and many enterprises adhere to these recommendations. LLC ATP Kama in Perm on the basis of which studies were conducted is not an exception. The maintenance of the enterprise fleet is carried out with the frequency specified in the technical documentation by the manufacturer, and neither the operating conditions, nor other factors, nor the specific nature of the enterprise – passenger transportation, are taken into account, all this leads to long downtime of equipment and high specific costs of operation [3–5].



Pic. 1. Age groups of rolling stock at LLC ATP Kama.

Objective. *The objective of the authors is to consider the issue of determining rational frequency of technical maintenance of buses.*

Methods. *The authors use general scientific methods, comparative analysis, evaluation approach, scientific description method.*

Results. *The said enterprise is engaged in passenger transportation, the fleet consists of MAZ and LiAZ buses. Three age groups of rolling stock are distinguished: up to 3 years, from 3 to 5 years, over 5 years (Pic. 1). And judging by the data shown, most of the bus fleet cannot be considered «young».*

The normative frequency of maintenance of MAZ buses is 10000 km (TM-1) and 30000 km (TM-2) [6], LiAZ-10000 km (TM-1) and 20000 km (TM-2) [7].

The work of the enterprise is analyzed, the main indicators for each age group are determined, they are presented in Table 1.

From Table 1 it follows that the coefficient of technical readiness of the group of buses aged from 3 to 5 years is lower than those with a service life of more than 5 years, this can be explained by random factors due to a small sample, since the studies were conducted on the basis of only one enterprise. It can also be seen that buses with a service life of up to 3 years carry out most of the transport work for transportation of passengers, however the same group has the greatest amount of time lost for maintenance and repair, which indicates non-optimal periodicity of maintenance. In addition, there is a problem of low technical readiness of buses with a service life of more than 3 years. The coefficient of technical readiness for the second and third groups is much lower than the industry average.

There are several methods for determining the optimal periodicity for maintenance of vehicles: method based on permissible level of failure-free operation, method based on permissible value and regularity of the change in the technical condition parameter, technical and economic method, economic-probabilistic, etc. [8–9].

A large number of scientific publications have been devoted to the search for optimal periodicity of maintenance [10–17]. As a rule, their authors understand under optimum periodicity such a service life at which the costs for maintenance and current repair, referred to the unit of work, are minimal [10]. For our study, the most interesting is the economic-

Table 1

Main performance indicators of rolling stock

No.	Service life	Coefficient of technical readiness		Fleet utilization coefficient	Average daily mileage, km	Average number of days in maintenance and repair per year (per unit)
		actual	normative			
1	Up to 3 years	0,89	0,85	0,77	153	43
2	From 3 to 5 years	0,63	0,85	0,58	66	20
3	Over 5 years	0,70	0,85	0,63	85	27

Table 2

Costs of the enterprise for maintenance and current repair

No.	Service life	Periodicity of TM-1, km	Periodicity of TM-2, km	Specific costs for TM and CR, rub./km	Total annual costs for TM and CR, thous. rub.
1	Up to 3 years	10000	40000	1,40	234,11
2	From 3 to 5 years	8000	32000	2,70	328,16
3	Over 5 years	6000	24000	3,78	825,76
	Total				1387,92

probabilistic method, because it allows us to estimate not only costs, but also failure-free operation at a given risk and a reasonable amount of input data and laborious calculations.

Specifics of the enterprise is passenger transportation, therefore, in order to maintain the fleet of buses in working condition, a preventive maintenance system is used. Periodicity of maintenance and costs of the enterprise for maintenance and current repair for 2016 are presented in Table 2.

One of the optimization criteria is reduction of operating costs, therefore, the specific costs per kilometer of mileage were determined in the calculations.

Specific costs when applying a preventive strategy can be interpreted as a ratio of weighted average cost of one operation to weighted average service hours, taking into account failure of a part of the structural elements of a bus according to the formula [8]:

$$U_1 = C_1 = \frac{cF + dR}{l_p^{'}F + l_pR}, \quad (1)$$

where d – cost of maintenance operation, rub.;

R – probability of failure-free operation;

F – probability of a failure during performance of maintenance with periodicity l_p and probability of performing a repair operation (elimination of a failure);

c – cost of a failure elimination operation, rub.;

l'_p – average service hours of a failed element with probability F, km;

l_p – periodicity of technical maintenance, km.

The probability of failure-free operation under the exponential law is expressed by the formula [8]:

$$R(x) = \exp^{-\lambda x}, \quad (2)$$

where λ – failure intensity.

The use of the exponential law in calculations is due to greater accuracy in comparison with the normal distribution law. The exponential law describes reliability of a product in the period of its normal operation, when gradual failures are not yet manifested and reliability is characterized only by sudden failures.

The failure intensity is a constant value and is determined by the formula [8]:

$$\lambda = \frac{1}{T_0}, \quad (3)$$

where T_0 – average service hours to a failure, km.

Probability of a failure during maintenance [8]:

$$F = 1 - R. \quad (4)$$

The results of the calculations are shown in Pic. 2–4.

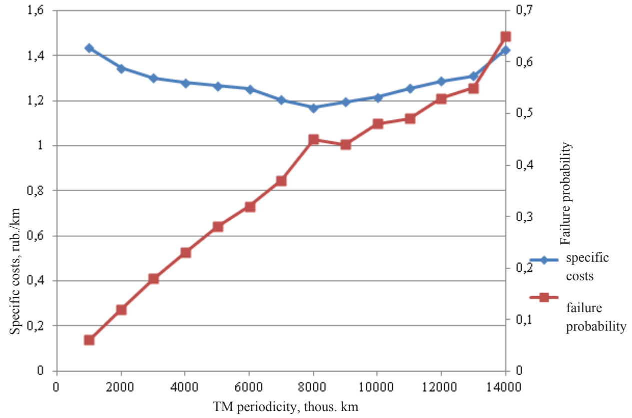
The type of graphs can be explained as follows: maintenance costs depend little on the mileage and it can be assumed that they are a fixed value. The more frequent is maintenance, the higher is the unit cost of maintenance and the less are repair costs, since the probability of failure is reduced. If maintenance is carried out rarely, then the unit costs for repairs increase.

All the obtained graphs have minima that correspond to the optimum values of TM periodicity, but these values are substantially less than the values of the normative periodicity of maintenance of MAZ and LiAZ buses given above. It is advisable to adjust the obtained optimum values of the periodicity of TM to reduce the probability of failures.

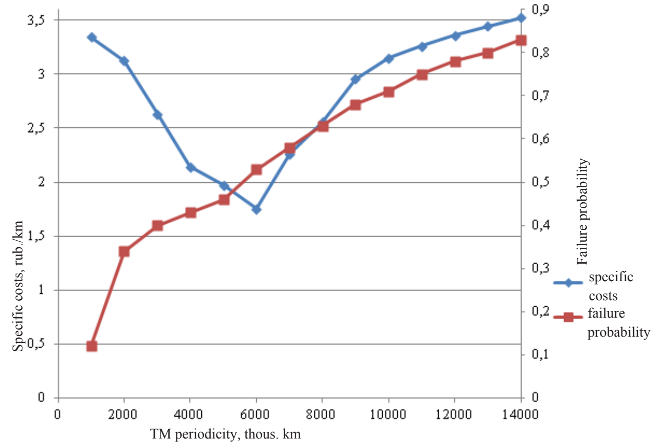
Thus, for transport with a service life of up to 3 years it is recommended to carry out TM-1 with a periodicity of 8000 km, the specific costs will be minimal and amount to 1170 rub./km, with the probability of failure – 0,45. Given the specifics of the enterprise – passenger transportation, the periodicity will be optimal not with minimal costs, but with a lower probability of failures at rational costs. Therefore it is reasonable to carry out maintenance with a frequency of 5000 km, the costs will increase to 1,265 rub./km, i. e. by 8 %, while the probability of a failure will decrease to 0,23 or almost by 2 times.

For a group with a service life from 3 to 5 years, the minimum costs will be at a maintenance period of 6000 km and will be 1,754 rub./km, with a probability of failure – 0,53. However, if the maintenance is carried out at a frequency of 4000 km, the costs will increase to 2,143 rub./km, i. e. by 22 %, while the probability of a failure will decrease to 0,30 or 43,4 %.

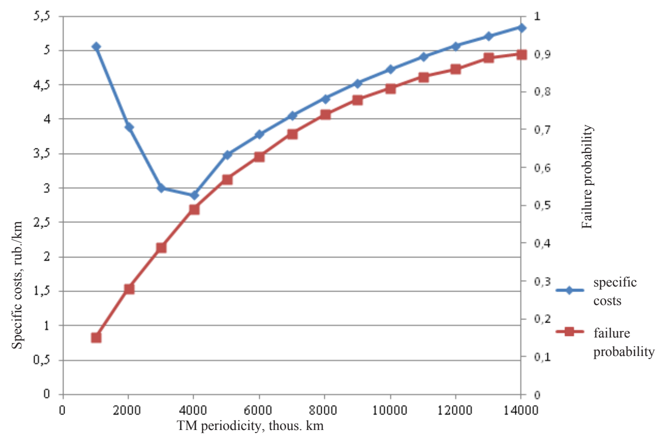
For a group with a service life of more than 5 years, the minimum costs will be at a maintenance period of 4000 km and will be 2,898 rub./km, with a probability of a failure – 0,49. However, if the maintenance is



Pic. 2. Specific costs for maintenance and repair and the probability of failure of buses with the service life of up to 3 years at different intervals of maintenance.



Pic. 3. Specific costs for maintenance and repair and the probability of failure of buses with the service life from 3 to 5 years at different intervals of maintenance.



Pic. 4. Specific costs for maintenance and repair and the probability of failure of buses with the service life of more than 5 years at different intervals of maintenance.

carried out at a frequency of 3000 km, the costs will increase to 3,002 rub./km, i. e. by 3,5 %, while the probability of a failure will decrease to 0,39 or 25,6 %.

Adjustment of standards for maintenance intervals focusing on their reduction will lead to an increase in specific costs for maintenance, but at the same time, the probability of a failure will significantly decrease, and as a consequence, the specific costs for repair will decrease, thereby achieving economic benefits. Of course, it is difficult to call the accepted probability of failures from 0,23 to 0,39 satisfactory, nevertheless maintaining the probability of a failure at the level of 0,1–0,15 (which corresponds to the coefficient of technical readiness at the level of the industry average) will lead to an increase in specific costs by approximately 2 times, and the optimal frequency will be 2000–2500 km.

Table 3 shows the results of calculations at the new optimum values of maintenance intervals. The total annual costs of the enterprise for maintenance and current repair will decrease in this case by 259,58 thousand rubles or by 18,7 %.

Conclusions.

1. The task of finding an optimal value of periodicity of carrying out maintenance and current repair of rolling stock is topical and multifactorial.

2. The optimal periodicity of maintenance for the fleet of the motor transport enterprise was determined. For buses of the first group it will be 8000 km, for the second group – 6000 km, for the third one – 4000 km. The obtained values of periodicity can significantly

Table 3

Costs of the enterprise for maintenance and current repair at the optimum periodicity of maintenance

No.	Service life	Optimal periodicity of TM-1, km	Optimal periodicity of TM-2, km	Specific costs for TM and CR, rub./km	Total annual costs for TM and CR, thous. rub.
1	Up to 3 years	8000	32000	1,265	234,11
2	From 3 to 5 years	6000	24000	2,143	328,16
3	Over 5 years	4000	16000	3,002	825,76
	Total				1128,34

reduce the probability of failure, which is very important for transportation of passengers, with a slight increase in specific costs for maintenance and current repair.

3. Using the proposed methodology will increase the coefficient of technical readiness at the enterprise and reduce the total annual costs for maintenance and current repair by 259,58 thousand rubles or by 18,7 %.

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