Investigation methods for "current repairs labour-intensiveness" factor for a vehicle

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Abstract. One of the important challenges appearing during a technical operation of vehicle is a development of methods of vehicles operating condition analysis. In the presented study a method of an operative analysis of an operative condition of vehicles is discussed considering current repairs labor-intensiveness factor. The presented method of an operative investigation of a current repairs labor-intensiveness factor allows to designate an automobile effective operation life, after which it has to be withdrawn from an operation even if its service life isn't over.

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Introduction

System of maintenance and current repairs (CR) currently existing in Russian Federation had formed mainly in 50-60 of 20th century and in that time it was an advanced system of vehicles of an operation capability maintenance. Its structure was formed basing on an obsolete level of reliability and a quality of automobiles production, operation conditions of vehicles and goals which were set for a motor transport and its subsystem – maintenance. But during the past 50 years a significant changes in a production technology and a design of automobiles occurred: significantly increased a level of reliability and quality of automobiles. Conditions of a commercial operation of vehicles, conditions and methods of freight organization etc. had also changed. Consequently, changes in a currently existing methodological basis of a technical operation of an automobile (TOA), its adaptation to a contemporary technical level and existing macroeconomic situation also have to be made [1]. One of important problems, appearing during a management of TOA is a development of methods of an automobile operation condition analysis [2].

The goal of our study is to prove that it's necessary to look for a solution to a problem of an adaptation of TOA system in modern conditions not in a direction of securing a maximal operation life, but in a direction of an achievement of a level of reliability and effectiveness of automobiles during a certain a mileage which is specified by standards and codes [3].

In the presented study the method of an operative analysis of an operating condition of an automobile is discussed in a context of a labor-intensiveness of CR. The proposed method of an operative analysis of a labor-intensiveness of a CR factor (man-hours/1000 km) allows to desingate an effective operation life of an automobile.

1. Main part.

Specifying following symbols:

i – a sequence number of an interval of a consequently made maintenance operations;

Δl – an automobile mileage corresponding to a certain maintenance interval;

l_i – a mileage of an automobile corresponding to *maintenance i*;

t_i – a labor intensiveness of a failures elimination (CR) appearing within *maintenance i,* man-hours;

t_i^c – a total labor-intensiveness of a failures elimination (CR), corresponding to mileage l_i, man-hours.

As a result of conducted experimental studies, relationships of CR labor-intensiveness changes and an automobiles mileage from a beginning of a service life were obtained which can be approximated using the linear function:

$$t_i = k \cdot l_i + b \qquad (1)$$

Where

$$k = \frac{t_{i+1} - t_i}{l_{i+1} - l_i} = \frac{t_{i+1} - t_i}{\Delta l}. \qquad (2)$$

Considering aforementioned:

$$l_i = i \cdot \Delta l. \qquad (3)$$

Then

$$t_i^c = \sum_{j=1}^{i} t_j = \sum_{j=1}^{i} (k \cdot l_j + b) = k \sum_{j=1}^{i} l_i + b \cdot i. \qquad (4)$$

Because

$$\sum_{j=1}^{i} l_j = \frac{l_1 + l_i}{2}\cdot i = \frac{\Delta l + i\cdot\Delta l}{2}\cdot i = \frac{\Delta l}{2}\cdot i\cdot(i+1),$$
(5)

Therefore

$$t_i^{\Sigma} = k\cdot\frac{\Delta l}{2}\cdot i\cdot(i+1) + b\cdot i. \quad (6)$$

Authors propose to estimate a CR labor-intensiveness factor [7] for each interval between two consequently conducted maintenances (the method of an operative determination of a CR labor-intensiveness factor) using following method:

$$T_i = \frac{t_i}{\ell_{i+1} - \ell_i} = \frac{t_i}{\Delta\ell} = \frac{k\cdot\ell_i + b}{\Delta\ell} = k\cdot\frac{\ell_i}{\Delta\ell} + \frac{b}{\Delta\ell} = k\cdot\frac{i\cdot\Delta\ell}{\Delta\ell} + \frac{b}{\Delta\ell} = k\cdot i + \frac{b}{\Delta\ell}$$
(7)

It is necessary to note, that nowadays a labor-intensiveness of current repairs is calculated using the equation:

$$T_i^c = \frac{t_i^c}{\ell_i} = \frac{\Delta\ell\cdot i\cdot(i+1)\cdot k}{2\cdot i\cdot\Delta\ell} + \frac{b\cdot i}{i\cdot\Delta\ell} = \frac{k}{2}(i+1) + \frac{b}{\Delta\ell}$$
(8)

It can be said that between values of labor-intensiveness T_i and T_i^c there is an analytical connection:

$$T_c - T_i^c = k\cdot i + \frac{l}{\Delta\ell} - \frac{k}{2}(i+1) - \frac{l}{\Delta\ell} = k\cdot i - \frac{k}{2}\cdot i - \frac{k}{2} = k\left(\frac{i-1}{2}\right) = \frac{k}{2}(i-1)$$

Then $T_i - T_i^c = \frac{k}{2}(i-1).$

Setting conditions:

1) $b = 0$
2) $T_c = T_j^c$

Then:

$$T_i = k\cdot i; \quad (9)$$

$$T_j^c = \frac{k}{2}(j+1). \quad (10)$$

Therefore,

$$k\cdot i = \frac{k}{2}(j+1) \succ 2i = j+1 \succ j = 2i-1.$$

Then $T_i = T_j^c$ in a case of $j = 2i-1$

For a determination of an automobile effective operation mileage considering a labor-intensiveness of CR factor technical and economic criteria is used [8]. For that specifying following symbols:

$S_{a/м}$ – an automobile cost, rubles.

C_{TP} – a cost of carrying out one hour of CR work, rubles.

$S(T_i)$ – expenses for CR in a case of an implementation of a proposed method, rubles/1000 km.

$S(T_i^c)$ – expenses for CR in a case of an implementation of a traditional method, rubles/1000 km.

$S_{(1)i}$ – total expenses for an automobiles operation in a case of implementing a proposed method, rubles/1000 km;

$S_{(2)i}$ – total expenses for an automobiles operation in a case of implementing a traditional method, rubles/1000 km [9].

$$S_{(1)i} = \frac{S_{a/м}}{\ell_i} + S(T_i) = \frac{S_{a/м}}{i\cdot\Delta\ell} + kC_{TP}\cdot i = \frac{S_{a/м} + k\cdot\Delta\ell\cdot C_{TP\cdot i^2}}{i\cdot\Delta\ell}$$
, (11)

$$S_{(2)i} = \frac{S_{a/м}}{\ell_i} + S(T_i^c) = \frac{S_{a/м}}{i\Delta\ell} + \frac{k}{2}C_{TP}\cdot(i+1)$$
. (12)

Calculating a derivative of aforementioned relationships by a mileage in order to find an extreme (min) of a function:

$$(S_{(1)i})' = -\frac{S_{a/м}}{i^2\Delta\ell} + k\cdot C_{TP} = 0,$$
(13)

$$(S_{(2)i})' = -\frac{S_{a/м}}{i^2\Delta\ell} + kC_{TP} = 0 \quad ,$$
(14)

Therefore

$$i_1 = \sqrt{\frac{S_{a/м}}{k\cdot\Delta\ell\cdot C_{TP}}}, \quad (15)$$

$$i_2 = \sqrt{\frac{2\cdot S_{a/м}}{k\cdot\Delta\ell\cdot C_{TP}}}, \quad (16)$$

Thus, intervals of mileage, which correspond to min of total normalized expenses in a case of different methods of an estimation of a labor-intensiveness of CR [10] are calculated using equations (15) and (16). A comparison of those equations shows that they have a following connection:

$$i_2 = i_1\cdot\sqrt{2} \quad (17)$$

Exemplifying the method described above. The raw data is presented in table 1.

Table 1. The raw data for a calculation of an automobile effective operation mileage

Parameter, unit of measurement	Parameter's value									
i, pcs.	1	2	3	4	5	6	7	8	9	10
ℓ_i, thousand km	20	40	60	80	100	120	140	160	180	200
t_i, man-hour	2	4	6	8	10	12	14	16	18	20

Solution:

$$k = \frac{4-2}{40-20} = 0,1$$

$$k = 0,1;\ b = 0;\ \Delta\ell = 20$$

$$t_i = 0,1 \cdot \ell_i = 0,1 \cdot 20 \cdot i = 2 \cdot i$$

$$t_i = 2 \cdot i$$

$$t_i^c = i \cdot (i+1)$$

$$T_i = 0,1 \cdot i$$

$$T_i^c = 0,05 \cdot (i+1)$$

For a calculation of min of total normalized expenses accepting that:

1. A cost of an automobiles, $S_{a/м} = 3000 \cdot 10^3$ rubles;
2. A cost of CR conduction, $C_{TP} = 100$ rubles/man-hour.

Thus,

$$i_1 = \sqrt{\frac{3000 \cdot 10^3}{0,1 \cdot 100 \cdot 20 \cdot 10^3}} = \sqrt{15} \approx 3,87 \approx 4$$

$$i_2 = \sqrt{\frac{2 \cdot 3000 \cdot 10^3}{0,1 \cdot 100 \cdot 20 \cdot 10^3}} = \sqrt{30} \approx 5,48 \approx 5,5$$

Inference. Thus, in our case:

1. In the first case (the method of an operative determination of a CR labor-intensiveness), a minimum of an automobile cost ratio and CR expenses ratios is achieved at 4[th] interval of the mileage, i.e. with work of $\ell = 80 \cdot 10^3$ km and is equal to $77,5 \cdot 10^3$ rubles.
2. In the second case, minimum is achieved at 6[th] interval of the mileage, i.e. with the mileage of $\approx 110 \cdot 10^3$ km and is equal to $\approx 60 \cdot 10^3$ rubles.
3.

The full list of the raw data and results of the calculation is presented in table 2.

Table 2. The raw data and results of the calculation of an automobile effective operation mileage

i	ℓ_i	t_i	t_i^c	T_i	T_i^c	$S(T_i)$	$S(T_i^c)$	$S_{a/м}$	$S_{(1)}$	$S_{(2)}$
1	20	2	2	0.1	0.10	10	10	150	160	160
2	40	4	6	0.2	0.15	20	15	75	95	90
3	60	6	12	0.3	0.20	30	20	50	80	70
4	80	8	20	0.4	0.25	40	25	37.5	77.5	62.5
5	100	10	30	0.5	0.30	50	30	30	80	60
6	120	12	42	0.6	0.35	60	35	25	85	60
7	140	14	56	0.7	0.40	70	40	21.4	91.4	61.4
8	160	16	72	0.8	0.45	80	45	18.7	98.7	63.7
9	180	18	90	0.9	0.50	90	50	16.7	106.7	66.7
10	200	20	110	1.0	0.55	10	55	15	115	70

Conclusions

The first case (the method of an operative investigation of current repairs labor-intensiveness factor) allows to determine when it is rational to withdraw an automobile from an operation considering economic factors even if its operation life isn't over.

The second method presumes a use of an automobile until the end of its operation life which frequently harms an effectiveness of its work.

The proposed method of an operative investigation of current repairs labor-intensiveness factor allows to specify an effective operation life of an automobile, on reaching which it has to be withdrawn from an operation even if its operation life isn't over.

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