The calculation program of the technical service enterprise of transport-technological machines in agriculture

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Abstract. The article deals with the issues of improving the efficiency of technical service infrastructure facilities of transport - technological machines. The article also includes methodical aspects of calculating the program of the technical service enterprise, taking into account their adaptation to fluctuations in demand for repair products. Analytical data for calculation of cost of repair of cars depending on the program of the repair enterprise were received. When analyzing data the costs of transportations of repair objects by motor transport were taken into account.

1. Introduction
The infrastructure of technical service of transport-technological machines in agriculture is a complex of objects of agricultural engineering service including enterprises with appropriate material, labor, energy, financial and information resources which carry out activities to meet the demand of owners of technics for various types of services [1]. These enterprises depend on the impact of random factors on their work, both in the course of operation of service enterprises themselves, and in the process of providing appropriate technical or technological services.

This work is aimed at solution the problems of repair and operational organization of transport and technological means in agriculture, contributes to the development of maintenance infrastructure.

2. Materials and methods
Usually, the need for repair service of machines that have lost their performance due to failures occurs accidentally and is of a probabilistic nature [2]. In these cases the probability of recovery can be found according to the probability theory from the expression [3]:

\[ P = \left( \frac{x_p}{x_c} \right)^{x_p} \]  

(1)

\( P \) – the probability of maintenance and repair; \( x_p \) – volume of realized demand for maintenance and repair; \( x_c \) – number of applications (real volume).

Hence the expected volume of services is:

\[ x_p = P \cdot x_c \]  

(2)
The probability of $P$ depends on the volume of demand and decreases in the case when the demand exceeds the production program of the enterprise $M$, as well as with an increase of the waiting service time due to the fact that some customers leave the queue.

The peculiarity of the indicator $x_p$ as an indicator of work of the enterprise is that it is advisable to use it when excess demand $x_c$ of the available capacities of the enterprise $M$: $x_c > M$, $P < 1$; otherwise $(x_c < M, P~1)$ this indicator should be supplemented with another characteristic – the level of use of production capacities:

$$\frac{M - x_c}{M}. \quad (3)$$

The relationship between the production program and the cost of maintenance and repair is determined by the formula [4,5]:

$$C = \frac{A}{M} + B \quad (4)$$

where $C$ – the indicator of the changes for payment for repairmen, spare parts and maintenance materials, and also overhead expenses; $A$ and $B$ – coefficients of the equation; $M$ – the production program of the repair enterprise in units of repair.

The costs $C$ associated with maintenance and repair of machines are most often relates to one ton of machine weight [6,7]:

- salary costs $D = \frac{C_{wC}}{Q_{avt}}$;
- costs of spare parts and repair materials $D_{spm} = \frac{C_{wspm}}{Q_{avt}}$;
- salary costs $\eta_r = \frac{H_p}{Q_{avt}}$;

$Q_{avt}$ – is the weight of cars in tons; $\eta_r$ – the coefficient of change of the overhead expenses $H_p$ per ton of the object being repaired.

The value of $D$ characterizes the complexity of repair of the machine, and the value of $D_{spm}$ – the degree of machine wear. Then, taking into account (4) the cost of machine repairing in general can be written as:

$$C_r = \left(\frac{A}{M} + B\right) \cdot D + \left(\frac{A_1}{M} + B_1\right) \cdot D_{spm} + \left(\frac{A_2}{M} + B_2\right) \cdot \eta_r \cdot Q_{avt} \quad (5)$$

From this formula, it is clear that with the increase of the program of the repair enterprise the cost of repair of the machine is reduced. However, the increase in the program of the repair enterprise causes additional costs for the transportation of repair facilities to the repair enterprise and back. These costs are proposed [1,7] to be taken into account by the coefficient of transportation of spare parts and scrap $- \eta_{tp}$ and by the coefficient of transportation of materials $- \eta_{tm}$.

Additional transport costs can be taken into account by coefficients:

$\eta_{rc}$ – region coefficient;
$\eta_{ep}$ – expeditionary procedures;
$\eta_{tb}$ – transportation of bulky goods;
$\eta_u$ – coefficient of use of single and two axle trailers.

In general the formula of transport costs taking into account the opposite traffic and additional costs will be as follows:

$$C_{CR} = a \cdot \left(1 - \eta_{tp} - \eta_{tm}\right) \cdot \left(1 + \eta_{rc} + \eta_{ep} + \eta_{tb} + \eta_u\right) \cdot R_{avt}\cdot Q$$

$a$ – the coefficient of tariffs for cargo transportation; $R_{avt}$ – average radius of transportation of repair facilities.

The coefficients which take into account additional costs in accordance with agricultural machinery and Eastern Siberia climate conditions have the following values [8]: $a = 0.34$ (up to 100 km); $a = 0.084$ (more than 100 km); $\eta_{rc} = 0.20$; $\eta_{ep} = 0.04$; $\eta_{tb} = 0.40$; $\eta_u = 0.20$. 
Hence, the formula for determining the cost of machine repairing, taking into account transport costs, will have a general form:

\[ C_r = \left[ \frac{A}{M} + B \right] \cdot D + \left( \frac{A_1}{M} + B_1 \right) \cdot D_{spm} + \left( \frac{A_2}{M} + B_2 \right) \cdot \eta_u + a \cdot \left( 1 - \eta_{tp}^+ + \eta_{tm}^+ \right) \cdot \left( 1 + \eta_{rc}^+ + \eta_{ep}^+ + \eta_{tb}^+ + \eta_u^+ \right) \cdot R_{av}^n \cdot Q_{wst} \]  \hspace{0.5cm} (6)

The optimal average distance of transportation of repair facilities is calculated from the function minimum (6) concerning \( R_c \):

\[ R_c = \frac{1}{n+2} \sqrt{\frac{2 \left( A \cdot D + A_1 \cdot D_{spm} + A_2 \cdot \eta_u \right)}{n+2 \left( 1 - \eta_{tp}^+ + \eta_{tm}^+ \right) \left( 1 + \eta_{rc}^+ + \eta_{ep}^+ + \eta_{tb}^+ + \eta_u^+ \right) N_k}} \]  \hspace{0.5cm} (7)

\( n \) - an indicator of degree of increasing in costs depending on distance of transportation;
\( N_k \) - the number of repaired machines falling on the territory under consideration.

If \( n = 1 \) in formula (7) the root degree will be equal 3. The formula for determining the rational capacity of the repair enterprise will take the following form:

\[ M_p = \frac{1.352 \left( A \cdot D + A_1 \cdot D_{spm} + A_2 \cdot \eta_u \right) N_k^{0.352}}{0.352 \left( 1 - \eta_{tp}^+ + \eta_{tm}^+ \right) \left( 1 + \eta_{rc}^+ + \eta_{ep}^+ + \eta_{tb}^+ + \eta_u^+ \right)} \]  \hspace{0.5cm} (8)

If rational average distance of transportation of repair objects is known, then the optimal program of the repair enterprise can be also defined by the formula (7):

\[ M_p = R_{av}^2 \cdot N_k \]  \hspace{0.5cm} (9)

The optimal average distance of transportation of the repaired objects taking into account the coefficients of the layout of the territory of \( \eta_t \) and length of roads \( \eta_{lr} \), will be defined by expression:

\[ R_{cpn} = \frac{R_{av}}{\eta_t \cdot \eta_{lr}} \]  \hspace{0.5cm} (10)

Then the accepted program of the repair enterprise will be equal to:

\[ M_{rp} = \left( \frac{R_{av}}{\eta_t \cdot \eta_{lr}} \right) \cdot N_k \]  \hspace{0.5cm} (11)

or

\[ M_{rp} = \frac{W_p}{\eta_t \cdot \eta_{lr}} \]  \hspace{0.5cm} (12)

The number of repair enterprises will be equal to:

\[ N_{rp} = \frac{N_m}{M_{rp}} \]  \hspace{0.5cm} (13)

\( N_m \) – the expected number of machine repairs.

The cost of repair of the machine at the enterprise with the optimal program of repair can be determined by the formula:

\[ C_p = \left[ \frac{A}{M} + B \right] \cdot D + \left( \frac{A_1}{M_{rpm}} + B_1 \right) \cdot D_{spr} + \left( \frac{A_2}{M_{rpm}} + B_2 \right) \cdot \eta_u + a \cdot \left( 1 - \eta_{tp}^+ + \eta_{tm}^+ \right) \cdot \left( 1 + \eta_{rc}^+ + \eta_{ep}^+ + \eta_{tb}^+ + \eta_u^+ \right) \cdot R_{av}^n \cdot Q_{wst} \]  \hspace{0.5cm} (14)

When determining the total cost of repair of machines according to the formula (14), the weight of all repaired machines \( \sum Q = \sum N_m \cdot Q_{wst} \) should be substituted instead of \( Q_{wst} \).

The values of \( D, D_{spr}, \eta_u, \eta_{tp} \) and \( \eta_{tm} \) when repairing tractors with reference to the Eastern Siberia climate conditions [1] are given in the table.
Table 1. Relative costs and coefficients of transportation of spare parts and materials while repairing tractors

| Name and brand of repaired tractors | Costs related to 1 ton of machine weight, thousand rubles. | Coefficient value |
|-----------------------------------|----------------------------------------------------------|------------------|
|                                   | D  | $\eta_u$ | $D_{opr}$ | $\eta_{spr}$ | $\eta_{str}$ |
| MTZ-80/82                        | 2.5 | 5.2      | 8.0       | 0.188       | 0.081       |
| MTZ-1221                         | 4.5 | 5.2      | 8.0       | 0.216       | 0.087       |
| K-701                             | 5.7 | 6.0      | 8.7       | 0.086       | 0.121       |
| K-744                             | 7.7 | 7.2      | 9.0       | 0.076       | 0.103       |

Coefficient $\eta_{lr}$ taking into account the nature and length of roads for areas and the region, is determined by the formula (7):

$$\eta_{lr} = \frac{\sum L_f}{L_d}$$  \hspace{1cm} (15)

where $L_f$ – the actual distance of roads from the center of the zone to large settlements, where the tractors is concentrated, in km;

$L_d$ - distance from the center of the zone to the same settlements in a straight line on the map, in km.

The calculated values of the coefficient $\eta_{lr}$ for agricultural areas of the region lie within 1.19-1.45, for the region – $\eta_{lr} = 1.29$.

The number of enterprises to meet real demand for agricultural engineering services [3]:

$$m = \frac{z_c}{M_S}$$  \hspace{1cm} (16)

Density of enterprises in the service area of the technical service system:

$$N_{de} = \frac{N_{de}}{S_{sa}}$$

$S_{sa}$ – the area of the operated zone (service aria); $N_{de}$ – density of enterprises in the service area.

3. Conclusion

The analyzed issues can contribute: firstly, to the solution of the problems of repair and maintenance organization of transport-technological means in agriculture; secondly, to the development of infrastructure of technical service, and also to design and placement of agrotechnical service objects for large agricultural enterprises and district municipalities.

References

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