Methodology for estimating appropriate work parameters of motor vehicle and tractor maintenance and troubleshooting stations in farms of Kostanay Region Kazakhstan

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Abstract. This paper presents a methodology for estimating an optimal zone of motor vehicle and tractor maintenance as well as an approach to calculate total discounted costs for maintenance and troubleshooting of motor vehicles and tractors in a production department. The proposed methodology allows substantiating an appropriate use of company motor vehicles and tractors for implementing mechanized operations in crop farming.

1. Introduction
This study represents a summary and a next step forward in the methodology to estimate optimal parameters of using facilities to maintain agricultural machinery, which we proposed in a series of works published from 2015 to 2018 [1,2,3,4].

A nine year research experience in estimating and substantiating optimal parameters for centers and stations has demonstrated it is necessary to precise optimization criteria and replace a hypothetical calculation unit of labor intensity – “a maintenance cycle” by a less complex unit “man-hour”.

2. Materials and Methods
The developed maintenance and troubleshooting types and complexes for motor vehicles and tractors (stationary maintenance centers, mobile mechanized units, and tractor maintenance stations) are core elements of agricultural facilities and equipment. In most cases, maintenance operations are carried out by employees of production companies themselves with the help of mobile maintenance units at stationary maintenance centers or immediately where a machine is operated. Maintenance repair works of machines are pre-planned and carried out by employees of a production company and with certain equipment. The overhaul maintenance is implemented at specialized repair plants. When in service failures are possible because of faulty usage of equipment, poor quality of maintenance and repair, and aging of machine parts. As a rule, to eliminate failures of the 1st and 2nd complexity groups repair works are performed directly at a place where a machine is operated, either by a machine operator or with specialized units. Faults of the 3rd complexity group are rectified in a repair shop. An element in the preventive maintenance and repair system is troubleshooting carried out in both processes. There are certain types of troubleshooting, such as operational, production, complete, partial, planned, unplanned, specialized and combined ones. In operating conditions, machines are transported to places of work, maintenance and repair. They can move in self-propelled mode or are towed, transported on heavy-duty trailers, by rail and water transport. When in service a variety of factors interacting with each other affect a machine.

The specifics of motor vehicles operation in land reclamation and construction production companies can be represented as a counteraction of factors making a reliability assurance system less efficient (machine loading, machine aging, adverse environmental factors, etc.) and factors that improve the system functioning (incorrect operation of a motor vehicle and tractor facilities, organizational measures, etc.). Proper maintenance and troubleshooting of motor vehicle and tractor facilities and their functioning are related to certain
challenges, such an efficiency analysis of a state-of-the-art motor vehicle and tractor maintenance station by available stationary and mobile means, developing a net of maintenance stations for machines, with production conditions are taken into consideration. To resolve these problems it is necessary to determine appropriate basic work parameters of motor vehicle and tractor maintenance stations.

These parameters include the following:
1. an optimal zone of motor vehicle and tractor maintenance, characterized either by a correct average distance needed for tractors to be transported to maintaining or an optimal average distance of moving mechanized maintenance vehicles to tractors operating in fields (Lavopt.);
2. an optimal throughput of stationary maintenance centers, mobile vehicles, etc.,
3. optimal aggregate reduced costs for motor vehicle and tractor troubleshooting in a production subdivision.

In contrast to available methods for calculating a maintenance station, the proposed methodology is based on a more progressive criterion to conduct an economic assessment of agricultural processes – total reduced cost [5]. This criterion takes into account a deficit of capital investments and labor resources, allowing, therefore, a solution to the problems of interest from the standpoint of national economic efficiency.

3. Results and Discussion
In this regard, the function of specific aggregate reduced costs for maintaining and troubleshooting machinery used in a production subdivision, a mentioned above criterion taken into consideration, is written as follows:

\[
C = \frac{B_b \cdot (A_{rep.b} \cdot (+E_n)) + B_e \cdot (A_{rep.e} \cdot (+E_n))}{N_Y} + \frac{F_y \cdot E_l \cdot C_f}{N_Y} + \frac{2a_{av} \cdot M \cdot Lav}{N_Y} + \frac{E_l \cdot Mw-a \cdot \gamma w-a}{Nl \cdot Lav} + \frac{\alpha_{av} \cdot \gamma w-a}{Nl \cdot Lav}
\]

where \(B_b\) – a balance price (cost) of a stationary maintenance center or tractor maintenance workshop, ruble; \(B_e\) is a balance price (cost) of technological equipment used in a tractor maintenance center, ruble; \(A_{rep.b}\), \(A_{rep.e}\) – a coefficient of annual expenditures on renovating buildings, repairing equipment, 1/year; \(E_n\) – a standard coefficient of capital investments efficiency, 1/year. \(E_n = 0.15\) 1/year;
\(NL\) – a linear maintenance density (specific labor intensity of maintenance, per 1 square meter of an actual average distance tractors overcome for maintenance, man.h./year.km;
\(Lav\) – an average distance of tractors overcome for maintenance (a “radius” of a maintenance zone), km;
\(F_y\) - an annual time for motor vehicle and tractor maintenance in a particular subdivision, h/year;
\(E_l\) - a sum of standard specific elements in operating costs for motor vehicle and tractor maintenance in the subdivision, this amount includes an hourly tariff rate (with charges) of an adjusting worker, standards of hourly costs for repairing and maintaining buildings, equipment, for fuels and greases, materials for cleaning and other operations, fuel for flushing and technological needs in maintaining tractors and agricultural machines, as well as hourly costs for heating and electricity of mobile mechanized units or tractor maintenance stations, ruble/hour;
\(N_Y\) – an annual labor input of maintaining 1GGP unit, man.h/year;
\(\alpha_{av}\) - transport aggregate reduced costs for idle driving of tractors for maintaining, ruble/km;
\(m\) is a number of trips per year of all tractors for maintenance in the subdivision 1/year;
\(Vav.tr\) – an average speed of tractors during an idle run for maintaining, km/h;
\(E_l\) is an efficiency coefficient of using labor resources, ruble/person per year.
\(E_l = 1500\) ruble/person year [7];
\(Mw-a\) – adjusting workers and their assistants (mechanics), people;
\(\gamma w\) is a coefficient of using adjusting workers at a mobile mechanized unit, stationary tractor maintenance center (a share of annual working time adjusting workers need for their direct work in a mobile mechanized unit, stationary tractor maintenance station);
\(dav\) – average losses for idle hours of tractors, ruble/hour.

This criterion can also be expressed in larger measurement units (rubles) per cycle (rub/cycle) via dividing annual labor intensity of maintaining tractor at the subdivision to labor intensity of maintaining any conventional tractor [6] and [7].

Taking a first derivative to \(Lav\), from expression (1) and equating it to zero, we obtain a formula for estimating an optimal average distance of tractors driving to a stationary maintenance station, station of tractor maintenance:
When using mobile means (mobile mechanized maintenance units), maintenance of tractors is carried out in the field. At the same time, a unit moves to tractor, and for a tractor $V_{av.tr.} = 0$. Therefore, using only first elements of function (1), similarly to expression (2), we obtain a formula for determining an optimal average distance of crossings (optimal service zone) of mobile mechanized maintenance equipment:

$$L_{av.\text{opt}} = \left( \frac{Ny \cdot \{Bb \cdot (A rep.b. + En) + Be \cdot (A rep.e. + En)\} + Em \cdot Mw \cdot \gamma w}{2Ni \cdot m \cdot \frac{av\text{. }\gamma w}{av\text{. }F}} \right)^{1/2} \quad (2)$$

If we know $L_{av.\text{opt}}$ we can determine an optimal (annual) throughput of stationary and mobile maintenance units (man.h/year).

$$W_{y,\text{opt}} = NI \cdot L_{av.\text{opt}}$$ \quad (4)

An optimal throughput complies with a minimum value of specific aggregate, reduced costs for maintaining motor vehicle and tractor facilities of a production unit, which is determined by equation (1) with $L_{av.\text{opt}} = L_{av.\text{opt}}$ in (av.c) (ruble/man.h):

$$C_{st.(c)} = \frac{Bb \cdot (A rep.b. + En) + Be \cdot (A rep.e. + En) + Fy \cdot \Sigma \mathcal{C}_f + \frac{2av\text{. }m \cdot L_{av.\text{opt}}}{Ny}}{Ny} + \frac{2av\text{. }m \cdot L_{av.\text{opt}}}{Vav\text{. }\gamma w} \quad (5)$$

To use formulas (2), (3), (4), (5) in calculations, it is necessary to determine a number of initial values in the following order:

1. A number of maintenance works (M-1, M-2, M-3 and seasonal maintenance) per year for a given set of tractors in a subdivision is determined according to a well-known method and is calculated as a number of maintenance trips (m) per year of all tractors in the subdivision.
2. According to labor intensity standards for different maintenance operations annual the labor intensity of tractor maintenance in the subdivision ($Ny$) is estimated \[8\].
3. An annual time and a number of workers required are calculated according to the formula (people):

$$M_w = \frac{Ny}{Fy} \quad (6)$$

where $N_{y}$ - labor intensity of maintaining tractors in the subdivision, man.h/year.

4. An actual average driving distance of a tractor for maintenance is determined by the formula (km):

$$L_{av.} = 0.1 \cdot \varepsilon \cdot K_{c} \cdot F^{1/2} \quad (7)$$

where $F$ is a coefficient depending on the subdivision territory configuration (values given in \[5\]);

5. The linear density of the maintenance labor intensity is calculated (man.h / year.km):

$$NI = \frac{Ny}{L_{av.}} \quad (8)$$

When analyzing the existing maintenance organization, optimal parameters obtained as proposed above are compared with those actually available in this department. Designing a future maintenance station, the calculation of optimal parameters allows a reasonable choice of standard projects for stationary maintenance facilities, (stationary maintenance stations, and stationary tractor maintenance stations).

We carried out an analysis and found that every 10 years (since 1980) an average wholesale price of one domestically produced machine increased by 1.37-1.45 times, whereas its average capacity only by 1.1-1.4 times. Consequently, an average price of a machine increases faster than its use effect. Undoubtedly, some parameters of machines are improved: a degree of their automation and reliability increase.
The above methodology for estimating optimal parameters related to the work of maintaining and troubleshooting station of motor vehicles and tractors is simple in application for calculations and analysis. In 2010-2019 it was tested theoretically and practically at Faculty of Agricultural Engineering, Russian State Agrarian University – Moscow Agricultural Academy named after V. K.A. Timiryazev and in the farms of Kostanay Region, Kazakhstan.

4. Conclusion
The proposed methodology furthers resolving a wide range of problems related to optimal design of agricultural production operations and processes.

The method considered can be used in diverse agricultural production processes and individual operations. It allows substantiating an optimal use of motor vehicle and tractor facilities of an enterprise, grain cleaning and drying stations of post-harvest grain processing and can be successfully applied for optimization production complexes in crop production and similar optimization calculations.

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