LIVESTOCK FARMS SERVICING PERIMETER OPTIMIZATION

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Abstract: *The system of the servicing of the machines in the livestock farms has been analyzed and the necessity of optimizing the spare parts services and the scope of the workshops for maintaining the equipment in the livestock breeding.*
Relations have been developed to optimize the area to be serviced by the workshop and its spare parts warehouse, as well as the optimal average distance to be found from where machines work.
KEY WORDS*: MACHINERY, LIVESTOCK FARMS, SERVICE, SPARE PARTS, STOCK MAINTENANCE COSTS, OPTIMIZATION, AREA.*

In the process of operation, the machines interact with the environment, and their elements interact with each other. As a result of the influence of numerous and largely unmanageable factors in the process of operation, the mutual arrangement of the parts, gaps, electrical and other dimensions changes. In livestock breeding the equipment operates in aggressive work environments and most often without an approved service system. This results in malfunctions (defects, failures and faults) that translate the machine into a malfunction, inactivity or borderline condition [1,2,3]. Given the specifics of animal breeding, it is necessary to remove them within a short time.
In this aspect, it is necessary to optimize the spare parts service and the scope of the workshops to maintain the required stand-by factor [4,5].
To determine the service maintenance perimeter, the average cost per unit time criterion is used, expressed in the following way:

$$\Phi = C_{пр} + C_з + C_{тр}, \text{ лв./h},$$

Where: $C_{пр}$ is losses due to downtime of machines waiting for spare parts BGN/ h;
$C_з$ – costs of maintaining a stock of spare parts BGN/ h;
$C_{тр}$ – transport costs related to the supply of spare parts, BGN / h.

In determining the impact of individual elements($C_{пр}$, $C_з$ и $C_{тр}$) on the cost value of the average costs, the relationship between the average distance from the workshop with a spare parts store to the farm and the area of the service area S_0 is expressed by the formula

$$L = k\varepsilon\sqrt{S_0},$$

Where: ε is the coefficient expressing the relationship between the shape of the section of land and the location of the workshop (ε=0,4-0,8);
к – the coefficient representing the distortion of the road network (к=1,3-1,5) .
There has been a detailed research on the change of the coefficient according to the geometric shape of the earth section (circle, hexagon, square and rectangle) and the location of the workshop with the spare parts warehouse (in the center of the geometry, half of the diagonal of the square and the rectangle, in the middle of the radius of the circle, of the circle itself or of a square and a rectangle). It was found to be in the range of 0,4 to 0,8 [6]. The lower limit refers to cases where it is in the center of the geometric figure, and the upper limit - when it is on one of the vertices of the square or rectangle.
Given the administrative and territorial division of our country, the value ranges from 0,4 to 0,6.
The average time for delivery of spare parts to the farm t_g to the machines is determined by the dependence

$$t_g = (k\varepsilon\sqrt{So})/\nu,$$

Where ν is the average speed of the vehicle, km / h.
Hence losses due to downtime of machines waiting for spare parts

$$C_{пр} = [(2\varepsilon k\sqrt{S0}/\nu]n\lambda C_{пр}^{|},$$

Where λ is the average number of requests of a certain element, h^{-1};
n - the number of uniform details of a given type in the machine, num.;
$C_{пр}$ are losses due to machine downtime, BGN/h.
For a full and consistent description of the flow of requests is necessary to know what is the probability that in a given time interval to eliminate the failure to do 1, 2, 3 requests.
It is assumed that the flow of failures (requests) is custom, ie. the conditions are met: the flow is ordinal, stationary and without consequences. This assumption is confirmed in [6].
The average number of requests for a spare part Λ entering the warehouse serving the area S_o, is:

$$\Lambda = S_0\lambda n g T_n,$$

where: g is the average number of machines that are located on a unit served by the warehouse area (density), pc / km2;
Tn - the period of replenishment of spare parts or the period of time for which the machinery will be provided with spare parts, h.
The required stock of X_3 spare parts in the warehouse, which will compensate for random fluctuations in the request flow, is

$$X_з = U_\alpha\sqrt{\lambda n g S_0 T_n},$$

Or related to a machine unit,

$$X_3/gS_0 = U_\alpha\sqrt{\lambda n T_n / gS_0},$$

Where U_α is the quantile of normal distribution with different confidence α and for α=0,85-0,99, U_α=1,0-2,6.
Then the cost of maintaining the reserve of C3 is expressed by the dependence

$$C_3 = C_д E_н U_\alpha \sqrt{\lambda n T_n / gS_0},$$

Where $C_д$ is the cost of the element;
$E_н$- normative coefficient of efficiency of capital investments ($E_н$ = 0,15).
Transportation costs related to the supply of spare parts $C_{тр}$ are:

$$C_{тр} = 2a\varepsilon k(1-\eta)n\lambda\sqrt{S_0},$$

Where a is the value for freight transport per unit distance, BGN/km;
η - the ratio accounting for the reduction of transport costs in relation to the transport of payload (η=0÷0,5).
Hence, in order to determine the optimum level of spare stock, it is necessary to sum up the costs of maintenance of the C_3 stocks, the transport costs $C_{пр}$ and the losses due to the downtime $C_{тр}$, ie. we find the area of the area where the total costs are minimal. Depending on the optimum area of the area to be served:

$S_{opt}=C_д E_н U_\alpha \nu/2k\varepsilon[C_{пр}+(1-\eta)a\nu].\sqrt{T_n/\lambda ng}$,km^2,

And the optimal average distance L_{opt}, the place where the spare parts of the machine are to be located to where the machines are working, is

$$L_{opt}=\sqrt{\varepsilon\kappa C\partial\partial E\nu U_\alpha}/2C_{np}+a\nu(1-\eta).\sqrt{T_b}/\lambda ggn.$$

If the relationship between the number of machines N_M, their density g and the optimal area of the area served by the S^{opt}_o warehouse is used, there is a dependency on the optimal number of machines that can be serviced by the warehouse for details of a type

$$N_m^{opt}=C_д E_н \nu U_\alpha / 2k\varepsilon[C_{np}+a(1-\eta)\nu].\sqrt{gT_n/\lambda n} \text{ ,бр.}$$

So far it has been accepted that the distribution of machinery in a given area is even. Actual conditions more closely correspond to a poisson field model with randomly spaced points.

What is interesting is the extent to which the average radius of service and delivery of spare parts to machines with a uniform distribution of machinery differs from the average radius obtained by accidentally distributing machines in a given territory.

Therefore, the law on the distribution of distances will be used r_n from any point of the field to the n-th point [6].

The distribution function $F_1(r)$ of the distance r_1 from any point of the field to the nearest adjacent point is written with the equation

$$F_1(r)=1-\exp\{\pi r^2\gamma\}.$$

The physics meaning of F_1 (r) is to determine the probability that a circle with a radius r falls at least one point apart from the one that is the center of the circle. The probability of this event does not depend on whether this point is at the center of the circle or not.

The distribution density function is $f_1(r)=\alpha F_1(r)/(dr)=-\pi r\gamma\exp\{-\pi r^2\gamma\}$. The mathematical expectation of the average distance between two adjacent points respectively

$$r_1=\int_0^\infty \gamma\, 2\pi r\gamma\exp\{-\gamma\pi r^2\}dr=1/(2\sqrt{\gamma}).$$

The distribution function $F_2(r)=P(r_2<r)$ reflects the probability that in a circle with radius r fall not less than two points and $F_2(r)=1-\exp\{-\pi r^2\gamma\}-\pi r^2\gamma\exp\{-\pi r^2\gamma\}$.

An analogous function corresponding to the likelihood of falling

n points in the circle is

$$F_n(r)=P(r_n<r)=1-\sum_{k=0}^{n-1}(a^k/k!)\,e^{-a},$$

where $a=\pi r^2\gamma$.

The density F_n (r) is determined by differentiating the distribution function F_n (r) by r:

$$f_n(r)=dF_n(r)/(da/dr)=[-\sum_{k=0}^{n-1}k\,(a^{k-1}/k!)\,e^{-a}+\sum_{k=0}^{n-1}(a^k/k!)e^{-a}]\,2\pi r\gamma=a^{n-1}/(n-1)!\,e^{-a}.2\pi r\gamma.$$

The mathematical expectation is:

$$r_n=\int_0^\infty r\,(\pi r^2\gamma)^{n-1}/(n-1)!\,\exp\{-\pi r^2\gamma\}.2\pi r\gamma dr.$$

After conversion we get

$$r=\Gamma(n+1/2)/(n-1)!\sqrt{n\gamma},$$

where: $\Gamma(n + ½)$ is a gamma function [7].

The average distance of space of dots from the center of the circle is defined as the average value of the mathematical expectation of the radius of distance of a point on:

$$r=\sum_{n=1}^{n_a-1} r_n/n_a.$$

The average radius of service and delivery of spare parts to the machines corresponding to the even distribution, taking into account the road network, is determined by the formula $r_{cp}=kr$.

For the practical use of the theoretical results obtained, it is necessary to introduce a correction coefficient η_c, taking into account the random distribution of the machines in a given area:

$$\eta_c=2/3\sum_{n=1}^{n_a-1} r_n/(n_a\sqrt{na/\pi\gamma}).$$

And we get:

$$\eta_c=3/2\,n_a^{-3/2}\sum_{n=1}^{n-1}\Gamma(n+1/2)/(n-1)!\,.$$

From the formula we can conclude that that the random allocation coefficient of the machines is a function of the number of machines and does not depend on the density of their distribution in a given territory (area).

The graphic change of η_c, depending on the number of machines, is given in Figure 1. Therefore, on the basis of a deflection of the correction factor accounting for the random distribution of machinery, it is sufficient for the area to have more than 25 machines of a given type, to assume that the random distribution of machinery can be replaced by a uniform distribution,i.e. this proves that the deduced dependencies are practical.

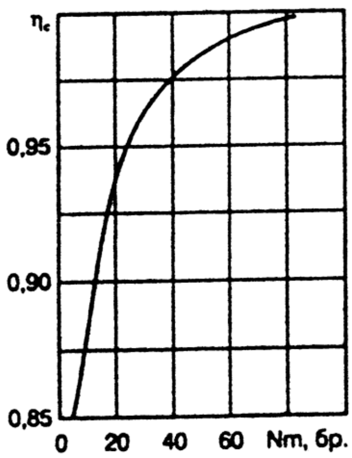

Fig. *Change in the coefficient accounting for the random distribution of machinery in the area.*

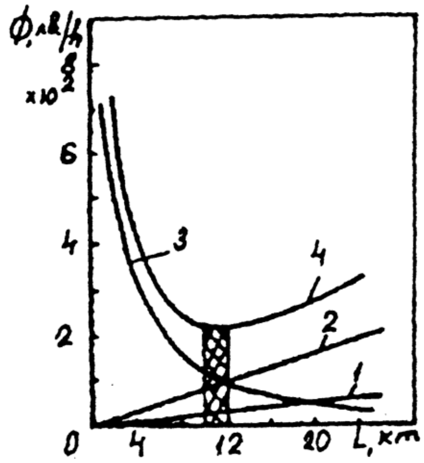

Fig.2. *Modification of total costs 4, maintenance costs of spare parts 3, downtime losses 1 and transport costs 2 depending on the distance between the location of the spare parts of the machinery to the workplace of the machinery.*

Fig. 2 shows the change in the total costs Ф, the cost of maintaining the reserve of spare parts C_3, the transport costs $C_{тр}$ and the losses due to the staying of the machines. When taking management decisions that are often not optimal and close to them, it is better to analyze and take into account the impact of individual factors on the optimum area of the area to be served by the workshop and the spare parts warehouse (S^{opt}_0), the optimal average distance (L_{opt}) where the spare part should be to the place where the machines work, which can be serviced by the spare parts warehouse (N^{opt}_m).

Conclusions:

1. Dependencies have been developed to optimize the area to be serviced by the workshop and the spare parts store, the optimal average distance they need to be located from the machine's location and to optimize the number of machines that can to be served by the spare parts store.
2. It has been found that in order to replace the random distribution of machines in a given area with a uniformity, it is sufficient that the number of machines is more than 25-30 and the analytical dependencies to optimize the perimeter of the maintenance service and that with spare parts are practical.
3. The high cost of spare parts, the periodicity of warehouse stocking and the high speed of transport are factors that allow stocks to be concentrated in a small number of large warehouses.

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