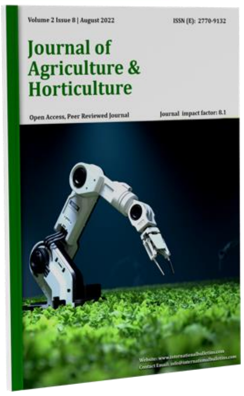

DETERMINATION OF THE NUMBER OF MOBILE WORKSHOP EXECUTIVES PROVIDING SERVICE TO THE GROUP OF GRAIN COMBINEERS

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ABSTRACT. The article presents the results of research on determining the number of mobile workshop workers serving a group of grain harvesters during the harvest for grain-growing clusters. According to calculations, when the service intensity of the mobile workshop is equal to $\lambda = 0,23$ (pieces/day), it was found that a mobile workshop consisting of 2 specialists can provide full technical service to a group of 8 grain harvesters.

KEYWORDS: grain clusters, grain combines, mobile workshop, technical service.

INTRODUCTION. It is known that in the process of using grain harvesters, it is necessary to provide them with shift and periodical maintenance, to eliminate sudden malfunctions in the field. The flow of requests for shift maintenance can be considered as constant with the frequency of arrival at the service center, since the shift service is carried out once a day on one combine [1]. For the remaining types of services, demand flows are subject to the Poisson law with proportional probability $q(\chi^2) = 0,06 - 0,41$ [2]. The probability of occurrence of demand *K* in the interval *t* [3]:

$$q_K = \frac{(\lambda_i t)^K}{K!} e^{-\lambda_i t}, \qquad (1)$$

where λ_i – the intensity (density) of the flow of requests for i type of service in one unit of time, pieces/day.

MATERIALS AND METHODS.

The values of the λ parameter determined on the basis of chronometric observations for a group of 8 "Keys-2366" grain harvesters operating in the conditions of Syrdarya region are presented in the following table.

The duration of maintenance of combines is subject to an exponential law with proportional probability:

$$q(t) = \mu_i \exp(-\mu_i \frac{t - t_{oi}}{h_i}), \qquad (2)$$

where $q(t)$ – the distribution density or differential function of the values of the time interval *t* when *K* requirements occur in the poisson flow;

$\mu_i = 1/t_{yi}$ – the intensity of service performance of type *i* or the number of

Table
Statistical parameters of failures and corrections in "Case-2366" combines

Type of service	λ_i, **units/day**	t_{yi}, **hour**	μ_i, **demand/ hour**	t_{oi}, **hour**	h_i, **hour**
Technical service during the shift	1,00	1,02	0,98	0,17	0,67
First maintenance	0,07	1,75	0,57	0,50	0,67
Debugging leftovers from the previous business day	0,06	0,68	1,45	0,10	0,30
Fixing malfunctions that occurred in working combines	0,23	0,53	1,87	0,10	0,20

serviced (satisfied) requirements (corrections) in one unit of time, demand/hour;

t_{yi} and t_{oi} – the average and current time spent on i type of service, hour;

h – the accepted distribution step of service duration of type i, hours.

The values of μ_i, t_{oi}, h_i determined as a result of statistical studies are also included in the table above.

Since the flow of requirements for all types of technical maintenance of combines is subject to the Poisson law, and their execution times are represented by the exponential distribution law, the service process can be studied using the mass service theory. We adopt and consider a turn-by-turn closed system, taking into account that serviced harvesters will again become a source of potential demand over time. In such a system, the probability of all mobile workshop performers being free [4]:

$$q_o = \left[\sum_{K=0}^{n} \frac{m!}{K!(m-K)!} \left(\frac{\lambda_i}{\mu_i}\right)^K + \sum_{K=n+1}^{m} \frac{m!}{n^{K-n} n!(m-K)!} \left(\frac{\lambda_i}{\mu_i}\right)^K \right]^{-1}, \qquad (3)$$

where m – the number of serviced combines or the largest number of concurrent requests in the service system;

n – the number of specialists (executives) in the mobile workshop.

The probability of receiving *K* requests into the system, satisfying *n* pieces of them, and waiting (*K* – *n*) pieces in the queue q_K is determined using the following expression:

$$q_K = \frac{m!}{n^{K-n} n!(m-K)!} \left(\frac{\lambda_i}{\mu_i}\right)^K q_o. \qquad (4)$$

$$n \le K \le m.$$

Using the values of the probabilities q_o and q_K, the following parameters can be determined:

average number of harvesters waiting to be serviced or average queue length caused by failed harvesters

$$L_q = \sum_{K=n+1}^{m} \frac{(K-n)m!}{n^{K-n} n!(m-K)!} \left(\frac{\lambda_i}{\mu_i}\right)^K q_o; \qquad (5)$$

average number of serviced combines (demands).

$$L = L_q + \sum_{K=1}^{n} \frac{m!}{K!(m-K)!} \left(\frac{\lambda_i}{\mu_i} \right)^K q_o ; \qquad (6)$$

the average number of mobile workshop workers who are free from service work

$$N_o = \sum_{K=0}^{n-1} (n-K) q_K ; \qquad (7)$$

idle ratio of harvesters waiting for service

$$K_T = \frac{L_q}{m} ; \qquad (8)$$

executive vacancy rate

$$K_\delta = \frac{N_o}{n} . \qquad (9)$$

When determining the optimal composition of a mobile workshop for a specific area (agrocluster, group or association of farmers, alternative machine-tractor parks), the number of performers (*n*) is changed in different options, and the values of system parameters are found using formulas (3)-(9). Then each calculation option is evaluated according to the minimum of the total loss caused by the stoppages of the combine harvesters and the mobile workshop:

$$З_K L + З_{KУ} N_o \rightarrow \min , \qquad (10)$$

where $З_K$ and $З_{KУ}$ – the values of losses caused by the stoppages of combine harvesters and mobile workshops in one unit of time, soums.

In the variant of the mobile workshop that satisfies criterion (10), the composition of performers is optimal.

For now, we limit ourselves to determining the average number of employees of the mobile workshop who are free from service work using a statistical method.

As a result of our chronometric studies, it became known that the flow of *K* requests (disruptions) occurring in grain harvesters participating in harvesting is distributed by an exponential law [4]:

$$q(K) \approx \frac{\lambda^K}{K!} e^{-\lambda} . \qquad (11)$$

We equate the value of λ, which is the only parameter of such a law, to the value of $\lambda_i = 0,23$ (pieces/day), that is, $\lambda = \lambda_i = 0,23$ (pieces/day), corresponding to the service type "Repairing malfunctions in working combines" of the table above.

Using (11), we find the probabilities of no breakdowns (*K*=0), one (*K*=1), two (*K*=2), three (*K*=3) breakdowns in the harvesters in a short time:

$$q(0) = e^{-\lambda};\ q(1) = \lambda e^{-\lambda};\ q(2) = \frac{\lambda^2}{2!} e^{-\lambda}; q(3) = \frac{\lambda^3}{3!} e^{-\lambda} . \qquad (12)$$

When $\lambda = 0,23$ is (pieces/day), (12) takes the following form:

$$q(0)=e^{-0,23};\ q(1)=0,23e^{-0,23};$$

$$q(2)=\frac{0,23^2}{1\cdot 2}e^{-0,23};q(3)=\frac{0,23^3}{1\cdot 2\cdot 3}e^{-0,23}$$

or

$$q(0)=e^{-0,23};\ q(1)=0,23e^{-0,23};$$

$$q(2)=0,0264e^{-0,23};q(3)=0,0020e^{-0,23}. \qquad (13)$$

[5] we find the value of $e^{-0,23}=0,795$ from the literature and put it in (13) and continue the calculation:

$$q(0)=0,795;$$

$$q(1)=0,23\cdot 0,795=0,1828;$$

$$q(2)=0,0264\cdot 0,795=0,0209;$$

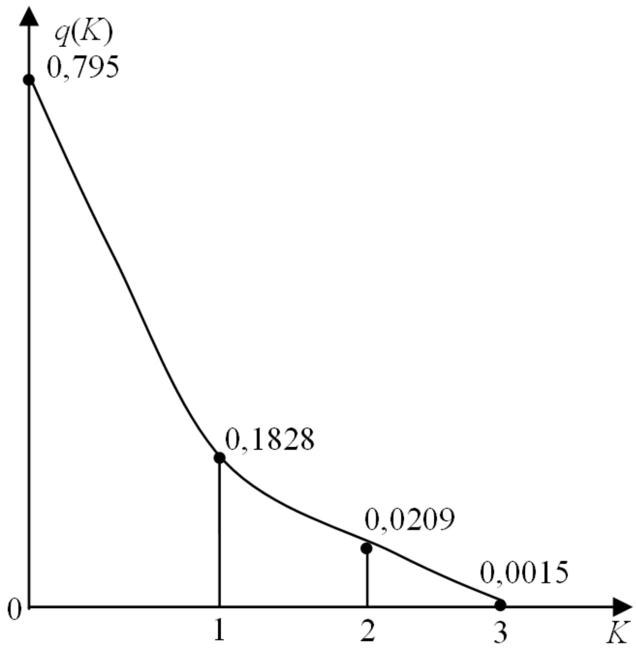
$$q(3)=0,0020\cdot 0,795=0,0015.$$

It is easier to understand if these numbers are expressed as percentages: $q(0)=79,5\%;\ q(1)=18,28\%;\ q(2)=2,09\%;\ q(3)=0,15\%.$

The obtained numbers indicate that the probability of more than one failure of a grain harvester in a short period of time is negligible ($q(2)=0.0209$ or 2.09%; $q(3)=0.0015$ or 0.15%), even if the probability of a single failure is $q(1)=0,1828$ or 18.28 percent.

This case proves that during small time the disturbances in the combine or the flow of demands have the property of ordinariness.

A graph of $q(K)$ probabilities is shown in the figure below.



Picture. A plot of the probability of occurrence of *K* failures in 8 grain harvesters during a small period of time

DISCUSSION. In the course of eliminating *K*=1, *K*=2 and *K*=3 breakdowns that occurred in the combines with the help of a mobile workshop consisting of specialists $n=2$, $n=3$ and $n=4$, the part of the mobile workshop specialists that will remain free was calculated using formula (7).

When there is a person $n=2$:

$$N_0=\sum_{K=0}^{2-1}(2-K)q(K)=\sum_{K=0}^{1}(2-K)q(K)=(2-0)q(0)+(2-1)q(1)=$$

$$=2q(0)+q(1)=2\cdot 0,795+0,1828=1,59+0,1828=1,7728\approx 2 \text{ person}$$

When there is a person $n=3$:

$$N_0=\sum_{K=0}^{3-1}(3-K)q(K)=\sum_{K=0}^{2}(3-K)q(K)=(3-0)q(0)+(3-1)q(1)+$$

$$+(3-2)q(2)=3q_0+2q(1)+q(2)=3\cdot 0,795+2\cdot 0,1828+$$

$$+0,0209=2,385+0,3656+0,0209=2,7715\approx 3 \text{ person}$$

When there is a person $n=4$:

$$N_0=\sum_{K=0}^{4-1}(4-K)q(K)=\sum_{K=0}^{3}(4-K)q(K)=(4-0)q(0)+(4-1)q(1)+$$

$$+(4-2)q(2)+(4-3)q(3)=4q(0)+3q(1)+2q(2)+1\cdot q(3)=$$

$$=4\cdot 0,795+3\cdot 0,1828+2\cdot 0,0209+0,0015=3,18+0,5484+$$

$$+0,0418+0,0015=3,7717\approx 4 \text{ person}$$

It can be seen that when the service intensity of the mobile workshop is $\lambda=0,23$ (pieces/day), $N_0=2$ or all of the given $n=2$ employees, $N_0=3$ out of $n=3$, $N_0=4$ out of $n=4$, or 100 percent remain idle (unemployed).

Thus, when the service intensity of the mobile workshop is equal to 8 (pieces/day), a workshop consisting of 2 specialists can provide full technical service to a group of $\lambda=0,23$ grain harvesters.

CONCLUSION

For grain clusters, a mobile workshop serving a group of combine harvesters during the harvest period is capable of providing full technical service to a group of 8 combine harvesters with 2 specialists when the workshop's service intensity is equal to $\lambda=0,23$ (pieces/day).

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