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# ASSESSMENT OF THE WORKLOAD OF A MOBILE WORKSHOP SERVING A GROUP OF GRAIN COMBINE HARVESTERS BASED ON QUEUEING THEORY

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**Abstract.** This paper evaluates the workload of a mobile workshop providing authorized technical service for grain combine harvesters during the harvesting season using the principles of queueing theory. The study was conducted based on eight foreign-made «Dominator-130» grain combine harvesters operating in the Dustlik district of Jizzakh region and a mobile workshop assigned to service them. Based on time-study observations, the structure of the mobile workshop's working time was determined, and the service intensity, arrival rate of service requests, average queue length, waiting time, service probability, and service capacity were calculated. The results showed that the current workload of the mobile workshop was 42.4%. It was also demonstrated that, by reducing the workshop's idle time, the number of combine harvesters served could be increased from 8 to 13. Under these conditions, the workload of the mobile workshop reaches 68%, resulting in more efficient utilization of service resources.

**Keywords:** grain combine harvester, mobile workshop, authorized technical service, queueing system, service intensity, arrival rate, workload.

**Introduction.** During the grain harvesting season, the technical readiness of combine harvesters is one of the key prerequisites for harvesting crops within the prescribed agrotechnical period. Timely elimination of technical failures reduces machine downtime and improves the operational efficiency of harvesting equipment. Therefore, improving the technical service system for grain combine harvesters is considered one of the important tasks in agricultural production [1].During the harvesting season, most maintenance operations are performed directly under field conditions. In this regard, mobile workshops play an important role in rapidly eliminating equipment failures, reducing the downtime of combine harvesters, and ensuring uninterrupted harvesting operations. Efficient utilization of the service capacity of mobile workshops requires a scientific assessment of their workload [2]. Queueing theory is widely applied to evaluate the performance of mobile service systems. This approach makes it possible to determine key performance indicators, including service intensity, arrival rate of service requests, average queue length, waiting time, service probability, and service capacity. These indicators provide a quantitative basis for assessing the operational performance of the service system and the efficiency of resource utilization [3].

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The objective of this study was to evaluate the workload of a mobile workshop serving eight «Dominator-130» grain combine harvesters operating in the Dustlik district using the principles of queueing theory and to identify opportunities for improving service efficiency.

**Research Methodology.** The study was conducted on eight «Dominator-130» grain combine harvesters operating in farms located in the Dustlik district of Jizzakh region and one mobile workshop of the regional service center providing authorized technical service to these machines. Field observations were carried out during the grain harvesting season under actual operating conditions. All activities performed by the mobile workshop during the working day were recorded using the time-study (chronometric observation) method. The recorded data included the time spent on servicing the mobile workshop itself, eliminating failures of the combine harvesters, idle time due to the absence of service requests, and time allocated for personal needs.

The collected data were analyzed using the principles of queueing theory. In the analysis, the arrival of equipment failures was assumed to follow an exponential distribution. First, the service intensity and the arrival rate of service requests were determined. Subsequently, the workload of the mobile workshop, the average queue length, the waiting time for a failed combine harvester, the service probability, and the relative and absolute service capacities of the system were calculated. Based on these results, the current workload of the mobile workshop was evaluated, and the possibility of increasing the number of combine harvesters served by reducing idle time was assessed.

**Research results and their analysis.** During the grain harvest season, the activities of one mobile workshop providing branded technical services to eight "Dominator-130" grain harvesters operating in the farms of the Dustlik district were monitored using the time-and-motion method. As a result of the observation, the structure of the mobile workshop's working day is presented in Table 1.

**Table 1. Working Time Distribution of a Mobile Workshop Serving Eight Grain Combine Harvesters**

| Working day activities | Duration, h | Share, % |
|---|---|---|
| Maintenance of the mobile workshop vehicle | 0.22 | 1.9 |
| Elimination of failures in combine harvesters | 4.60 | 40.5 |
| Idle time due to the absence of service requests | 5.82 | 51.2 |
| Personal needs | 0.72 | 6.4 |
| **Total** | **11.36** | **100.0** |

As shown in Table 1, 40.5% of the mobile workshop's working time was devoted to eliminating failures in combine harvesters, whereas 51.2% was spent in an idle state due to the absence of service requests. This indicates that the available service resources were not utilized efficiently.

The observation data were analyzed using the principles of queueing theory. In the analysis, the occurrence of failures in combine harvesters was assumed to follow an exponential distribution. The service intensity was determined using the following equation:

$$\mu = \frac{1}{t_y} = \frac{1}{4,60} = 0,217 \text{ (units/h)} \qquad (1)$$

where $\mu$ is the service intensity (units/h), and ($t_y$) is the average time required to eliminate a single failure, h.

The workload of the mobile workshop was determined to be 42.4%. Based on this value, the

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arrival rate of service requests was calculated as follows:

$$\lambda = \frac{\psi}{t_y} = \frac{0,424}{4,60} = 0,092 \text{ (requests/h)} \qquad (2)$$

where λ is the arrival rate of service requests (requests/h), and ψ is the workload of the mobile workshop.

Based on the parameters of the arrival process, the average queue length and the average waiting time of a failed combine harvester were calculated as follows:

$$L_q = \frac{\psi^2}{1-\psi} = \frac{0,424^2}{1-0,424} = 0,310 \text{ (units)} \qquad (3)$$

and

$$T_\lambda = \frac{L_q}{\lambda} = \frac{0,310}{0,092} = 3,37 \text{ (h);} \qquad (4)$$

qiymatlarga ega bo‘ldi. Bu yerda $L_q$ – navbatning o‘rtacha uzunligi, dona; $T_\lambda$ – bitta nosoz kombaynning xizmat ko‘rsatilishini kutish vaqti, soat.

Hisoblashlar natijasida ko‘chma ustaxonaning bo‘sh bo‘lish ehtimoli 0,702 xizmat ko‘rsatish bilan band bo‘lish ehtimoli 0,298 talablarni qondirish ehtimoli 0,702 nisbiy xizmat ko‘rsatish qobiliyati 0,702 absolyut xizmat ko‘rsatish qobiliyati esa 0,064 talab/soat ni tashkil etdi. Ushbu natijalar mavjud servis tizimi barqaror ishlayotganini, biroq ko‘chma ustaxona ishlab chiqarish imkoniyatlaridan to‘liq foydalanilmayotganini ko‘rsatadi.

Hisoblangan nisbiy va absolyut xizmat ko‘rsatish qobiliyatlarining o‘zgarish qonuniyatlari 1-rasm va 2-rasmlarda keltirilgan. Grafiklardan ko‘rinadiki, xizmat ko‘rsatish intensivligi ortishi bilan servis tizimining xizmat ko‘rsatish qobiliyati ham ortadi, biroq ma'lum qiymatdan keyin o‘sish sur'ati kamayadi. Bu holat ko‘chma ustaxona yuklanishini maqbullashtirish zarurligini ko‘rsatadi.

where $L_q$ is the average queue length (combine harvesters), and $T_\lambda$ is the average waiting time for a failed combine harvester to receive service (h).

The calculation results showed that the probability of the mobile workshop being idle was 0.702, the probability of being occupied with servicing a failed combine harvester was 0.298, the probability of satisfying service requests was 0.702, the relative service capacity was 0.702, and the absolute service capacity was 0.064 requests/h**. These results indicate that the service system operates steadily; however, the capacity of the mobile workshop is not fully utilized.

The variations in the relative and absolute service capacities are presented in Figures 1 and 2. As shown in the figures, the service capacity of the system increases with increasing service intensity. However, beyond a certain level, the rate of increase gradually decreases, indicating the need to optimize the workload of the mobile workshop.

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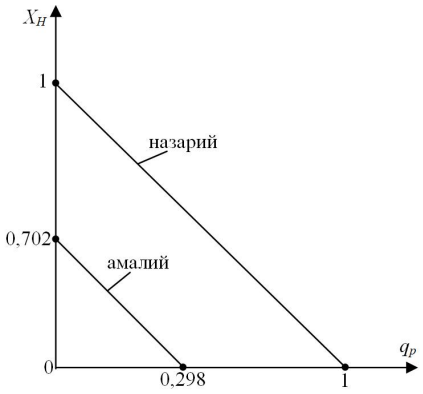



**Figure 1. Variation in the Relative Service Capacity of the Mobile Workshop**

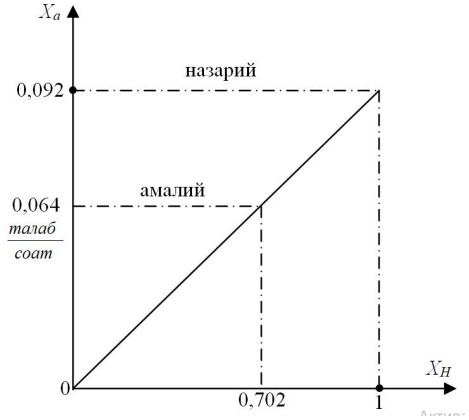



**Figure 2. Variation in the Absolute Service Capacity of the Mobile Workshop ($\lambda$ = 0,092 requests/h = const)**

To evaluate the potential for improving the operational efficiency of the mobile workshop, a scenario involving a 50% reduction in idle time caused by the absence of service requests was considered. According to the observation results, the idle time during one working day was 5.82 h. When half of this time was allocated to eliminating equipment failures, the total time spent on technical service increased to 7.51 h.

Under these conditions, the number of combine harvesters that could be served by a single mobile workshop was determined using the following equation:

$$m(\Delta t_\delta) = \frac{m(\overline{t}_y + \Delta t_\delta)}{\overline{t}_y} = \frac{8(4,6+2,91)}{4,6} = 13 \text{ units;} \qquad (5)$$

where $m$ is the current number of combine harvesters served by the mobile workshop, and $\Delta t_\delta$ is the reduced idle time, h.

According to the calculation results, a single mobile workshop can provide technical service not only to eight, but also to 13 grain combine harvesters. Under these conditions, the time allocated to failure elimination accounts for 66.1% of the working day, while the workload of the mobile workshop increases to 68%.

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**Table 2. Working Time Distribution of a Mobile Workshop Serving 13 Grain Combine Harvesters**

| Working day activities | Duration, h | Share, % |
|---|---|---|
| Maintenance of the mobile workshop vehicle | 0.22 | 1.9 |
| Failure elimination in combine harvesters | 7.51 | 66.1 |
| Idle time due to the absence of service requests | 2.91 | 25.6 |
| Personal needs | 0.72 | 6.4 |
| **Total** | **11.36** | **100.0** |

As shown in Table 2, increasing the time allocated to technical service reduced the idle time of the mobile workshop from 51.2% to 25.6%. Consequently, the major part of the working day was devoted to technical service operations. This made it possible to utilize the available service resources more efficiently without deploying an additional mobile workshop.

**Conclusion.** The results of the time-study observations and the calculations based on queueing theory showed that the current workload of the mobile workshop serving grain combine harvesters was 42.4%. The findings revealed that the working time of the mobile workshop was not fully utilized under the existing operating conditions, as a considerable portion of the working day was spent idle due to the absence of service requests. The analysis demonstrated that reducing the idle time of the mobile workshop by 50% would increase the number of grain combine harvesters served by a single workshop from 8 to 13. Under these conditions, the workload of the mobile workshop would increase to 68%, while the idle time would decrease to 25.6%. These findings indicate that the application of queueing theory provides an effective basis for determining the service area and workload of mobile workshops, thereby improving the utilization of service resources and enhancing the efficiency of technical service during the grain harvesting season.

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