Theoretical substantiation of machine-tractor fleet technical maintenance system on the example of Omsk region agricultural enterprises

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Abstract. Machine and tractor fleet increasing reliability problem solution in the production conditions of agricultural enterprises is an important and urgent task of agro-industrial complex engineering service. It can be solved by the machines downtime reducing for maintenance (maintenance service) with intensive method use of performing operations in the unstrained field work period, as well as maintenance service transfer to specialized technical service enterprises partly. One of the contradictions inherent in the of machine maintenance planned system is work timing coincidence of, that is, the more time, the more maintenance operations must be performed. As a result, during intense field work periods, the machine operator, in order to ensure high operating time, to the prevention detriment is forced to eliminate only failures consequences, which leads to their increase, machines productivity is reduced, and operation costs are increasing. In modern conditions, when the machine operator has more than one machine, he is not physically able to perform maintenance and repair operations on time. Therefore, it is advisable to transfer to specialized enterprises part of the work on complex maintenance and repair. The article proposes and justifies technical service formation structure at agro-industrial complex enterprises.

1. Introduction

Machines productivity increasing in modern conditions with the current tendency to reduce machine operators number is possible at the expense of tractor driver load reducing - the maintenance and repair work due to maintenance specialization and intensification.

The aim of the work is to determine agricultural production mechanization level factors influence on agricultural enterprises profitability on Omsk region example, to specify maintenance work share that the agricultural commodity producer can transfer to technical service specialized enterprises for a certain profitability.

As the main research methods, observation methods were used directly in machine and tractor fleet operating conditions, literature sources data with conditions comparability assessment, and also experiments data carried out at agro-industrial complex enterprises. Mathematical modeling and statistical processing methods of the results were used in experimental data processing.

Agricultural machinery technical service system can only be vital, taking into account the using machines priority for agricultural work. The main feature of agricultural machinery use is agricultural work volumes unevenness of performed in different year periods [1]. Table 1 shows workload distribution per month as annual work percentage in management areas.
Table 1. Work scope for the month, % to the annual

| Period     | Northern Caucasus and Southern Ukraine | Northern Kazakhstan, Siberia, the Urals | The Central Non-Chernozem Zone | North-West |
|------------|----------------------------------------|----------------------------------------|--------------------------------|------------|
| Winter     | 4-5                                    | 2-4                                    | 5-6                            | 6-7        |
| Normal     | 8-10                                   | 6-12                                   | 8-12                           | 8-10       |
| Stressed   | 14-16                                  | 20-26                                  | 12-14                          | 10-12      |

From Table 1, we can conclude that for a stressed period in Siberia, one-fourth of mechanized works annual volume is accounted for. During this period, it is necessary to perform a large amount of field work in a short space of time, the non-productive machines downtime for maintenance, repair and failures consequences elimination, which should be reduced to a minimum, is a deterrent.

In engineering and technical service opinion, machine operator loading by machinery maintenance and repair should not exceed 20 - 25%. If the machine operator performs the maintenance, then he performs only 24% of planned services total number, if the master-installer is connected and he combines locksmith duties in troubleshooting, the scope of work is 43%, with a full specialization of 89%.

Thus, in order to form an effective technical service system in modern conditions, it is necessary to organize a farm repairer service, specializing in servicing modern sophisticated equipment, and also provide a modern repair base. In the conditions of agricultural production at the present time, this becomes practically impossible, as it incurs a huge amount of unproductive expenditure, in addition, even large agricultural enterprises can not afford to maintain a whole staff of repair workers all year round with work seasonality in the conditions of agricultural production. But to organize modern technology maintenance, without existing system changing, is impossible.

In Omsk region agricultural production conditions, the most effective maintenance system is firm service dealer system with network creation of independent dealer services and special enterprises for complex aggregates repair. Technical service dealer system provides for maintenance and repairs by the dealer. The firm and the dealer enter into a dealer agreement. In the Omsk region agricultural machinery producer dealers are: OAO "Semirechye Supply Base"; OOO PSK "Omskdizel"; OOO "Terra", OOO "AvtoSpetsMash"; OOO SeverTransAgro; SCL "Supply base Agromash" ; JSC "Baza Agrocomplect"; OOO "Siberian Base"; FSUE "Omsk Experimental Plant"; IP Shumilov VV, OOO "OmskAgroLizing", LLC "SibzavodAgro" [2].

The economic relationship between the dealer and the customer is realized through machine cost, spare parts and services. The contract for machine delivery stipulates warranty service terms (from 6 months - a used car, up to 3 years - a new machine), spare parts delivery time and specialists arrival (24 hours, but not more than 72 hours); spare parts delivery (within 10 years after the sale of the machine); tractor operators and machine operators training; documentation presentation [3].

2. Results and Discussion

On one of the dealer centers example you can consider Omsk region corporate service formation main directions. For example, supply base technical center "Siberian" produces not only warranty, but also post-warranty maintenance, as well as current equipment repair. Supply base technical center "Sibirskaya" organized repair engineers mobile teams equipped with mobile maintenance units (MMU). Equipment maintenance is carried out on agricultural producers demand. Depending on application content, the MMU is completed with the necessary equipment and specialists. One of the technical center employees keeps application log for serviced households, the journal indicates: application receipt date, farm name, equipment district and brand and the alleged malfunction. If we consider the polygon for application distribution for Omsk region maintenance services for 2016 (Figure 4.), then we can note a rather large experimental frequency values spread from zero values to 40 applications per season. When determining the number of applications, all requests to the service center were taken into
account, that is, not only the planned maintenance, but also claims for equipment failures among the main customers of the Sibirskaya supply base.

Figure 1. Calls polygon distribution to the service center LLC supply base "Siberian" by Omsk regions for 2016

Analyzing the data presented in Fig. 1, the following conclusions can be drawn: the most demanded service among the districts located closer to Omsk administrative center, for example Omsk District, Okoneshnikovsky District, Moskalensky District, apparently this is due to lower tariffs for servicing for the nearest districts. Also, the maximum applications number can be traced in the areas in which the largest agricultural enterprises are located, for example, in the Kormilovsky district of OOO Kuskom-Agro in the Cherlasky District of SEC Bolshevik, which have high turnover and profitability. Thus, the demand for branded technical service, which is necessary in modern business conditions, can arise only at a certain profitability of the agricultural commodity producer [4, 5].

When forming maintaining a machine and tractor fleet costs mathematical model in a workable state at two levels-the level of a specialized technical service enterprise and an agricultural enterprise, within the permissible values of \( q_{iv} \) - maintenance and repair work fraction that an enterprise can transfer to a specialized enterprise, the following mathematical model:

\[
C_{sjv} = \left(1 - q_{jv}\right)A_{jv} \left[ t_{mj}S_x + t_{mj}C_{zv} + \frac{2R_{xjv}}{v_{mvv}} \left(C_{mp} + C_{zv}\right) + \frac{t_{mj}}{t_{ymen}} \left(t_jS_x + t_jC_{zv}\right) + \frac{t_{mj}}{t_{pm}} \left(t_pS_x + t_pC_{zv}\right) + t_{mj}K_x \right]
\]

where \( S_x \) and \( K_x \) are the prime cost and capital costs for conducting \( j \)-th type of technical service, rub/hour;

\( 2R_{xjv} \) - tractor transport distance to technical service within the farm, km.
Λ_jν - application number arriving for j-th servicing in the ν-th period;
C_{mp} - tractor transportation hour cost, rub;
V_{mv} - speed of tractor transport in the ν-th period, km / h;
C_{νr} - one hour of tractor idle cost in the ν-th period, rub;
\bar{t}_{mj}, \bar{t}_f, \bar{t}_ν - duration of maintenance, failures and repair consequences elimination of the tractor in the farm, hour;
t_{mj} - labor intensity of j-th maintenance, people. hour;
ϕ_{jν} - work scope share for j - the type of MMU allocated to the specialized enterprise;
t_{pm} - the specific complexity of the planned maintenance, which is tractor operation hour;
H_f and H_{νr} - the time between tractor failures and production while servicing it on the farm.

In the cost model (1), \( C_{jν} \), which the economy may incur depending on the profitability, while transferring the work scope share ϕ_{jν} to a specialized enterprise (we denote it by the functional M), and replace the following indices \( R_x, H_{νx}, H_{νc}, S_x, K_x \) and the corresponding values \( R_c, H_{νc}, H_{νs}, S_c, K_{Cc} \) and which are defined as \( \bar{t}_{jc} \), the distance to the specialized enterprise, the operating time for failure and the overhaul time of the tractor if it were serviced by a specialized enterprise, the cost price and costs, and we call this expression the functional \( Z \). Provided that the total costs for maintenance and repairs \( C_{νr} - which may incur the business \( C_{νr} = C_{νr} + C_{νs} \rightarrow Z \rightarrow \min \), tend to a minimum value, we get the expression:

\[
C_{jν} = \Lambda_{jν} \cdot M + \Lambda_{jν} \cdot Z - ϕ_{jν} \cdot \Lambda_{jν} \cdot M
\]

(2)

If the two functionals M and Z are jointly solved, under the condition that M - Z ≥ 0, it is possible to determine the share of the scope of maintenance and repair work (ϕ_{jν}) that the AC enterprise can transfer to the dealer maintenance company.

Services consumer in agricultural machinery technical service sphere can be formed with a certain profitability of the agricultural enterprise. To determine how much the profitability is affected by tractor age, personnel supply with machine operators and power-to-weight ratio, we will study it on a multifactor correlation model of the type [6]:

\[
y = b_0 + b_1 x_1 + b_2 x_2 + ... + b_n x_n
\]

(3)

where y is the dependent variable;
b0 - free term, taking into account unaccounted factors;
x1, x2, x3 - the corresponding factors characterizing personnel supply, tractor age, and power-to-weight ratio.

In this case, the dependent variable y and all factors entering the equation must obey the normal law [7]:

\[
f(x) = \frac{1}{\sigma \sqrt{2\pi}} \exp \left(-\frac{(x_0-x)^2}{2\sigma^2}\right)
\]

(4)

Tractor age can characterize their aging, which affects the reliability. During the conducted researches it is established that tractor aging can be estimated by the aging factor, but this factor effect on the profitability of the enterprise is still unknown. In order to exclude arable land area influence on the yield, we introduce the specific indicator D (RUR / 100ha).

For the study, there were selected 20 farms in the Omsk region with different arable land area, this significantly exceeds the number of observations \((n + 1)\), where n is the number of unknowns.

As a result of the processing of experimental studies, a multifactorial linear model was obtained:
\[ y = 331.874 + 1771.333x_1 - 14.61x_2 + 3.196x_3 \] (5)

Obtained model reliability was evaluated using the Fisher criterion, the obtained data are reliable. Parameters weighting investigating \( P_{x_i} = P_{x1} \) received the following values:

\[ P_{x1} = 29.3\%, \quad P_{x2} = 14.59\%, \quad P_{x3} = 56.11\% \]

Thus, the most significant impact on agricultural enterprise profitability is provided by the power-to-weight ratio (56.11%), then the personnel supply factor (29.3%) goes on, tractor age (14.59%) also influences. During the research it has been established that tractor age varies in a small range, since practically most of the tractors in the Omsk Region are obsolete, the renewal is very slow, at 3-4% per year, and after twelve years of using the technology, the coefficient of technical use practically does not change [8, 9].

Figure 2 shows farm’s revenues distribution, depending on the tractor average age and machine operator number per 100 hectares.

Figure 2. Farm revenue distribution, depending on tractor age and machine operator number

Figure 3 shows farm revenue distribution, depending on the average age of the tractors and the power output of kW / ha.
Figure 3. Farm revenue distribution, depending on tractor age and power-to-weight ratio.

Figure 4 shows the distribution of the farm's revenues, depending on the average machine operator number per 100 hectares and power-to-weight kW/ha.

Figure 4. Farm revenue distribution, depending on the number of machine operators and power-to-weight ratio.
Data dependencies analysis shows that the revenue, and therefore the profitability of the enterprise directly depends on the considered indicators. Thus, the higher farm power density and machine operator number, the greater part of the revenue can be invested in contracts with dealers and specialized maintenance centers.

Maintenance completeness and quality, as well as machines productivity, primarily depends on tractor driver maintenance work loading, as well as the concentration and specialization of the technical service operations performed [10]. We believe that agricultural machinery technical service dealer system formation is possible from the moment of its sale under warranty service, in addition to servicing second-hand equipment, the farm can conclude contracts for after-sales service for complex maintenance and repair in the work proportion volume that can be added at a certain profitability value. For carrying out not labor-intensive technical services, machine operators and the master-adjusters involved in a work stressed period can be involved.

3. Conclusion

Based on studies results, the following conclusions can be drawn:
- in maintenance service formation, machine operator number significant influence and tractor age should be taken into account;
- agricultural enterprise profitability depends most on farm energy-saving capacity (56.11%), and the profitability is affected by machine operator staff provision (29.3%) and machine and tractor fleet age (14.59%);
- agricultural enterprise profitability is one of the main factors that determines concluding technical service contract possibility between the agricultural producer and the dealer and service maintenance enterprises.

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