Application of service technical clusters for agro-industrial complex of the Novosibirsk region

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Abstract. A decrease in the technical potential of the agro-industrial complex of the regions and Russia due to a decrease in the availability of equipment and significant aging is shown, which imposes special requirements for ensuring its performance due to a well-organized technical service. It is possible to maintain high availability of machinery through the regional system for ensuring the operability of agricultural machinery. The aim of the study is to develop a method for ensuring the operability and availability of equipment for its effective use based on the use of service technical clusters. The system for ensuring the operability of agricultural machinery provides various options for servicing consumers from the following levels: economy, district and region. A normative and calculation method is proposed for determining the parameters of the regional system for ensuring the operability of agricultural machinery in order to reduce labor intensity, according to which its parameters are calculated for model technical service clusters: economy and district. The obtained parameters for model levels of the economy and the district are adjusted taking into account the main actual indicators for the zone served by this level of the system. The proposed regulatory calculation method for determining the parameters of the system for ensuring the operability of agricultural machinery was implemented for the Novosibirsk region. Based on a certain laboriousness of the equipment being serviced, a regional model service cluster and a model service cluster of a farm (a farm with average indicators for the region) are substantiated. The conversion factors from model service clusters to actual enterprises at the district and farm levels are given.

1. Introduction

The subprogram “Technical and technological modernization, innovative development” of the State program for the development of agriculture and regulation of agricultural products, raw materials and food markets for 2013-2020 [1] provides for the innovative development of agriculture, which largely depends on the reliability of the equipment used. Implementation of innovative projects in agriculture without equipment is problematic, however, the decrease in its technical potential, which began with the beginning of the reforms, has not yet been suspended, as evidenced by the data given in table 1 [2].

Table 1. Existence of the equipment in agro-industrial complex of Russia, thousand pieces.

| Type of machines       | 1990   | 2013  | 2014  | 2015  | 2016  |
|------------------------|--------|-------|-------|-------|-------|
| Tractors               | 1365.6 | 475.6 | 466.5 | 458.6 | 454.9 |
| Combine harvesters     | 407.8  | 126.3 | 126.2 | 125.6 | 125.2 |
The availability of tractors and harvesting machines is only 45-60% of the need. With the required energy supply of 300-350 horsepower (hp) per 100 ha of sown area in agriculture, there are only 167.01 liters. pp., and this trend persists for the future [3]. In the Novosibirsk region, energy supply is even less and amounts to 132.2 liters. from. per 100 hectares of arable land [4].

The machine and tractor fleet in the agricultural sector of the Russian economy is currently extremely worn out. The share of the main types of agricultural machinery with an average life of more than 10 years is 62% for tractors, 49% for combine harvesters, and 45% for forage harvesters [3].

Analysis of the state of the machine and tractor fleet showed that in the agro-industrial complex of the Novosibirsk Region, the average age of the equipment, despite the technical re-equipment carried out since 2007, exceeds almost all standard brands of its standard service life (table 2) [5].

### Table 2. Average age of the equipment in agro-industrial complex of the Novosibirsk region.

| Type of machines      | Middle age, years (for January 1st) | The equipment is more senior than 10 years, % (for January 1st) |
|-----------------------|------------------------------------|---------------------------------------------------------------|
|                       | 2012  | 2018  | 2012  | 2018  |
| Tractors              | 19.0  | 13.2  | 92.4  | 78.5  |
| Combine harvesters    | 15.0  | 11.8  | 75.7  | 67.1  |
| Forage harvesters     | 13.8  | 9.1   | 62.4  | 41.6  |

There was a need for modernization and improvement of the repair and maintenance base in Russia as a whole and, in particular, for the regional system for organizing the operability of equipment in crop production for the conditions of Western Siberia, as the equipment wears out and requires maintenance and repair. It is necessary to timely and efficiently ensure the operability of agricultural machinery, which reduces its downtime due to wear and aging in order to carry out technological processes in agrotechnical terms. The provision of facilities for the Novosibirsk Region with facilities for the repair and maintenance base is shown in Table 3.

### Table 3. Provision of facilities in the Novosibirsk Region with facilities for the repair and maintenance base.

| Area         | Number of farms | Provision of repair and maintenance facilities, % |
|--------------|-----------------|---------------------------------------------------|
|              | Technical repair workshops | Points of technical maintenance | Garages for tractors | Garages | Oil depots |
| Krasnozyorsky | 26               | 88.5                                             | 23.1                    | 100     | 88.5     | 84.6   |
| Karasuksky    | 19               | 84.2                                             | 47.4                    | 100     | 94.7     | 94.7   |
| Bagansky      | 12               | 100                                              | 41.7                    | 100     | 100      | 100    |
| Kupinsky      | 24               | 91.7                                             | 29.2                    | 100     | 100      | 100    |
| Chistoozyorny | 21               | 85.7                                             | 23.8                    | 100     | 95.2     | 90.5   |
| Kochkovsky    | 10               | 100                                              | 50.0                    | 100     | 100      | 100    |
| Dovolensky    | 13               | 92.3                                             | 61.5                    | 100     | 100      | 100    |
| Tatar         | 22               | 100                                              | 68.2                    | 100     | 100      | 100    |
| Ust-Tarksky   | 14               | 92.8                                             | 28.6                    | 100     | 100      | 92.8   |
| Chanovskoy    | 17               | 94.1                                             | 100                     | 100     | 100      | 88.2   |
| Vengerovskoy  | 22               | 95.5                                             | 100                     | 100     | 100      | 100    |
| Kyshtovsky    | 19               | 100                                              | 36.8                    | 100     | 100      | 100    |
| Northern      | 11               | 100                                              | 45.5                    | 100     | 100      | 100    |
| Kuibyshev     | 24               | 91.7                                             | 8.3                     | 100     | 100      | 100    |
| Barabinsk     | 17               | 94.1                                             | 100                     | 100     | 100      | 100    |
| Zdvinsky      | 15               | 86.7                                             | 20.0                    | 100     | 100      | 100    |
The size of the repair and maintenance base is influenced by many factors, and first of all, the number of equipment it serves.

Similar research results were obtained in other regions of the Russian Federation: the aging trend of the machine and tractor fleet continues. Due to the insufficient supply of equipment to rural producers, due to a decrease in the number of machine and tractor fleets and its significant deterioration and increased load, the problem of ensuring its performance is particularly acute. Under these conditions, in accordance with the concept developed by the Ministry of Agriculture of the Russian Federation [6], the creation of a well-organized technical service was and remains a prerequisite for the efficient use of technology.

The purpose of the study is to develop a method for ensuring the operability and high availability of agricultural machinery for its effective use based on the use of service technical clusters in the regional system for ensuring the operability of agricultural machinery.

Research objectives:
- substantiate the parameters of the technical service model cluster at the district and farm levels;
- determine the coefficients of transition from model clusters to actual levels at the district and farm levels.

2. Materials and methods

To service both old and newly acquired machines, a system is being developed to ensure the operability of equipment in relation to the conditions of the Novosibirsk region. At present, open joint-stock company Agrosnabtehservice and dozens of large and small firms and dealers, whose actions are not coordinated, are servicing rural producers in the region. The agrotechnical service system of the region includes 8 technical centers (including the head office), 15 repair and technical enterprises, 21 enterprises at the district level of agro-technical supply, trade and exhibition sites, storehouses and repair and maintenance facilities for farms.

The basis of the developed regional system for ensuring the operability of agricultural machinery is the current system of the open joint-stock company Agrosnabtehservice. Research on the development of a regional system for ensuring the operability of equipment in the agro-industrial complex for the conditions of the Novosibirsk region has been carried out since 2010 using the methodology [7] in accordance with reasonable main directions [8]. In this case, specific features of the region are taken into account, and both the technical component of the system under consideration and the organizational ones are adjusted. Moreover, taking into account current trends in the development of agricultural production in Russia, special attention is paid to the information component of the system. The principles of the formation of the system for ensuring the operability of agricultural machinery are given in the sources [9, 10]. The structure of the system for ensuring the operability of agricultural machinery is substantiated, which provides for various options for servicing agricultural machinery from the following levels: agricultural enterprise, district (inter-district), region. For each level, the following key indicators are taken into account:

| Location   | Number | Equipment Utilization | Machine Condition | Tractor Condition | Availability | Efficiency |
|------------|--------|-----------------------|-------------------|-------------------|--------------|------------|
| Ubinsky    | 16     | 87.5                  | 18.8              | 100               | 100          | 93.8       |
| Kargatsky  | 12     | 83.3                  | 16.7              | 100               | 91.7         | 91.7       |
| Chulym     | 14     | 85.7                  | 50.0              | 100               | 100          | 92.2       |
| Kolyvansky | 16     | 91.3                  | 62.5              | 100               | 93.8         | 87.5       |
| Kochenovsky| 24     | 66.7                  | 54.2              | 100               | 100          | 95.8       |
| Novosibirsk| 25    | 88.5                  | 19.2              | 100               | 100          | 96.1       |
| Iskitim    | 26     | 80.8                  | 100               | 92.3              | 100          | 96.2       |
| Horde      | 19     | 94.7                  | 89.5              | 100               | 100          | 94.7       |
| Suzunsky   | 16     | 75.0                  | 100               | 100               | 93.8         | 87.5       |
| Cherepanovsky | 21 | 90.3                  | 80.9              | 80.9              | 100          | 100       |
| Maslyaninsky | 14 | 92.9                  | 50.0              | 100               | 100          | 100       |
| Toguchinsky | 29   | 89.7                  | 19.2              | 100               | 100          | 100       |
| Bolotninskiy | 17 | 88.2                  | 35.3              | 100               | 100          | 100       |
| Moszkowski | 14     | 85.7                  | 21.6              | 100               | 100          | 100       |
| TOTAL      | 560     | 91                    | 54.8              | 100               | 100          | 97.9       |
- the amount of mechanized work performed by this model of machines;
- the intensity of demand for maintenance and repair of parts, components and assemblies of machines of this model;
- classiness and provision of mechanics of the serviced zone with this level of the system for ensuring the operability of agricultural machinery.

Our previous studies have found that when eliminating the consequences of failures of 74.5%, spare parts are required. Therefore, it is necessary for each level to have a reasonable reserve for the exchange fund of spare parts, that is, parts, assemblies and assemblies. At each level, there must be the necessary amount of equipment and devices both in quantity and in nomenclature, as well as the number of mobile technical means for carrying out maintenance and eliminating the consequences of failures. To accommodate the equipment, justified areas and maintenance personnel are needed, that is, personnel: maintenance technicians, diagnosticians, repairmen, drivers and other specialists. The scope of maintenance and repair work at each level of the system for ensuring the operability of agricultural machinery depends on the availability of equipment and its brand composition, on the volume of mechanized work performed, on the age of the equipment used.

To ensure the operability of agricultural machinery, as the main components of the system for ensuring the operability of agricultural machinery we accept service clusters of the agricultural enterprise (economy) and district (inter-district), respectively $i = 1$ and $i = 2$.

For the parameters of each $i$-th level we take:
- $N_y$ – quantity of the carried-out services the $i$-go enterprise of level, (technical maintenances, scheduled repairs, not scheduled repairs, elimination of failure consequences), piece.
- $Y_j$ – the level of a reserve of spare parts $j$-go names, piece.
- $P_j$ - frequency of delivery of spare parts $j$-go names, h.
- $F_i$ –area of the service enterprise, sq.m;
- $N_i$ – the number of mobile tools, equipment for maintenance and repair.

For implementation of the selected options of the organization of technical maintenance and repair it is reasonable to carry out forming of a system of ensuring operability of agricultural machinery in agro-industrial complex of area on the basis of a normative calculation method, i.e. its parameters need to be calculated in relation to model levels of economy and the area which are taken for model service technical clusters. Then the received parameters for model levels of a system of ensuring operability of agricultural machinery are adjusted by coefficients taking into account the key actual indicators on the zone serviced by this level. At the level of areas when ensuring operability of the equipment in agro-industrial complex interdistrict cooperation which is implemented through the technical centers is reasonable. The technical center in the system of ensuring operability of agricultural machinery at the regional level – the main service enterprise – is taken for a model cluster.

According to the standard concept, the cluster is any object group which is subjectively perceived as belonging to one class, making homogeneous group. In our case, it the enterprises which are carrying out technical service for rural producers. Let's give a concept of model levels (clusters) on the example of economy. Model economy is such economy which in relation to this model of machines has average for farms of area the volume of the mechanized works $\bar{W}$, average for farms of area intensity of demand $\bar{\lambda}$, on technical maintenance and repair and average for farms of area classiness and security with machine operators $\bar{K}$, determined respectively by formulas:

$$\bar{W}_x = \frac{W_x}{n_x},$$  \hspace{1cm} (1)

$$\bar{\lambda}_x = \frac{\lambda_x}{n_x},$$  \hspace{1cm} (2)

$$\bar{K}_x = \frac{n_1+2n_2+3n_3}{n_0},$$  \hspace{1cm} (3)
where $W_o$ – the volume of the mechanized works which is carried out by this model of machines in the area at. aa. hectare;

$\lambda_o$ – intensity of demand for technical maintenance and repair of this brand of machines in the area, 1/h;

$n_x$ – the number of farms in the area, piece;

$n_1, n_2, n_3$ – number of machine operators in the field of respectively 1, 2 and 3 classes;

$K_{01}, K_{02}, K_{03}$ – respectively, coefficients of security with machine operators of the 1st, 2nd and 3rd classes by this brand of machines in the area;

$n_o$ – total number of machine operators in the area, the people;

$K_{0x}$ – average coefficient of security with machine operators in model economy.

Between coefficients on services of technical service such interrelation is traced: the sum of coefficients on tractors and on combine harvesters for farms is respectively equal to coefficients of demand for services of areas in which there are these farms. On tractors it is 1.368, and on combine harvesters – 1.561 (see Table 4 and 5).

Accounting of coefficients of demand for services of technical service by consumers will help to create with higher quality technical services of the service enterprises, to improve supply with spare parts and in general to increase efficiency of links of a system of ensuring operability of agricultural machinery.

The model area is defined to similarly model economy, but the number of the technical centers to areas and data on a zone which it services (volume of the performed works and the number of the serviced equipment of this model) are considered.

The indicators characterizing model service clusters of the Novosibirsk region which are given in [10] are determined by formulas 1-3 and formed a basis for their choice. Calculations are carried out in the Excel program of the Windows system. When calculating intensity of demand for technical maintenance and repair the labor input of their carrying out was considered.

3. Results and discussion

It is known that readiness of machines is expressed through coefficient of technical readiness:

$$K_a = \frac{T_f}{T_f + T_r},$$

where $K_a$ – availability quotient of the equipment; $T_f$ – an average time between failures, h; $T_r$ – mean time to repair of operability of machines, h.

The recovery time of operability of machines can be written in a look:

$$T_r = T_r' + T_{dec}$$

where $T_r'$ – minimum possible recovery time of operability of the machine, h; $T_{dec}$ – time for troubleshooting, decision-making, depending on information support of specialists, search and delivery of necessary spare parts, h.

Researches are directed to reduction of recovery time of operability of machines which depends on efficiency of a system of ensuring operability of agricultural machinery. In turn, the efficiency of a system of ensuring operability of agricultural machinery in many respects depends on as far as parameters of different levels of a system, in our case it is levels economy-area-area, will be interconnected among themselves that continuous execution of technological processes in agrotechnical terms was provided. Average values of model service technical clusters for the Novosibirsk region at the level of the area and economy which make according to 54,000 hectares and 3,800 hectares of an arable land are defined. Coefficients of demand for services of technical service or coefficients of transition are received from model service technical clusters to actual which consider specific of areas. According to areas, they are given in Table 4.
Table 4. Values of coefficients of demand for services of technical service for areas of the Novosibirsk region.

| Area             | Values of coefficients of demand on services of technical service |   |
|------------------|---------------------------------------------------------------|---|
|                  | tractors | harvesting combines |   |
| Bagansky         | 0.783    | 1.444               |   |
| Barabinsk        | 0.407    | 0.608               |   |
| Bolotinskoy      | 0.313    | 0.456               |   |
| Vengerovsky      | 1.004    | 1.280               |   |
| Dovolenky        | 1.440    | 1.865               |   |
| Zdvinsky         | 0.812    | 0.561               |   |
| Iskitim          | 1.506    | 1.170               |   |
| Karasuksky       | 1.020    | 1.590               |   |
| Kargatsky        | 0.314    | 0.725               |   |
| Kolyvansky       | 0.635    | 0.719               |   |
| Kochenyovsky     | 1.368    | 1.561               |   |
| Kochkovsky       | 1.274    | 1.666               |   |
| Krasnozyorysk    | 3.617    | 1.245               |   |
| Kuibyshev        | 1.089    | 1.181               |   |
| Kupinsky         | 1.760    | 2.664               |   |
| Kyshtovsky       | 0.092    | 0.526               |   |
| Maslyaninsky     | 0.301    | 0.509               |   |
| Moszkowski       | 0.195    | 0.333               |   |
| Novosibirsk      | 1.190    | 1.432               |   |
| Horde            | 2.436    | 1.924               |   |
| Northern         | 0.042    | 0.251               |   |
| Suzunsky         | 1.217    | 1.052               |   |
| Tatar            | 1.123    | 0.865               |   |
| Toguchinsky      | 2.341    | 1.508               |   |
| Ubinsky          | 0.452    | 0.608               |   |
| Ust-Tarksky      | 0.533    | 0.427               |   |
| Chanovsky        | 0.276    | 0.270               |   |
| Cherepanovsky    | 1.044    | 0.941               |   |
| Chistoozyorny    | 0.893    | 0.286               |   |
| Chulym           | 0.523    | 0.339               |   |
| Total            | 30       | 30                  |   |

Data in Table 4 are obtained on districts of the area (all them 30) taking into account their specifics: the volume of the performed works, existence of the equipment by brands and its age, classiness and security with machine operators and other factors. Similar to the area transition coefficients from a model service technical cluster of economy of area to the actual farms on the example of Kochenyovsky district (Table 5) are defined. The following relationship can be traced between the coefficients for technical services: the sum of coefficients on tractors and on combine harvesters for farms is respectively equal to coefficients of demand for services of areas in which there are these farms. On tractors, it is 1.368, and on combine harvesters – 1.561 (see Table 4 and 5).

Table 5. Values of coefficients of demand for services of technical service for farms of Kochenyovsky district of the Novosibirsk region.

| Name producer | Area arable lands, hectare | Values of coefficients of demand on services of technical service |   |
|---------------|-----------------------------|---------------------------------------------------------------|---|
| Closed Joint-Stock Company Krasnaya Slavyanka | 6456 | 1.372 | 1.575 |
Accounting of coefficients of demand for services of technical service by consumers will help to create with higher quality technical services of the service enterprises, to improve supply with spare parts and in general to increase efficiency of links of a system of ensuring operability of agricultural machinery.

The basic general provisions on development of a regional system of ensuring operability of agricultural machinery in agro-industrial complex of the Novosibirsk region using model service technical clusters are reported and got approval on section of mechanization, power and transport of Scientific and technical council of the Ministry of Agriculture of the Novosibirsk region.

4. Conclusion
- The method of ensuring operability of agricultural machinery is developed for a regional (regional) system with use of model service technical clusters of areas and farms.
- The developed method allows consumers to define demand for services of technical service differentially: taking into account existence of the equipment by brands and its age, volume of the performed works, classiness and security with machine operators and other factors influencing it.
- Model service technical clusters for service of consumers at the regional level and level of economy for the Novosibirsk region with arable land according to 54,000 hectares and 3,800 hectares are defined.
- Transition coefficients from model levels to actual, characterizing demand for services of technical service are proved. For areas of the Novosibirsk region, they are in an interval 0.042 … 3.617 for Northern and Krasnozyorsky districts for tractors and 0.251 … 2.664 for Northern and Kupinsky districts for combine harvesters, respectively.
- Using the example of farms of Kochenevsky district, the demand coefficients for technical services were determined, which range from 0.171 to 3.347 for tractors and from 0.256 to 3.881 for combine harvesters. The relationship between the demand coefficients for the technical services of farms and the area in which they are located is revealed. The sum of the demand coefficients for farm services is equal to the coefficient of this area defined for districts of the area.

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