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Method for Evaluation of the Economic Efficiency of Using Tractors in the Course of Implementation of a New Maintenance Method in Farms of the Omsk Region

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***Abstract*— Solution to the problem of improving the reliability of machine and tractor fleet in the production conditions of agricultural business is an important and urgent task for engineering department of agro-industrial complex. It can be solved by reducing the downtime of machines for maintenance using intensive methods for performing operations during low-stress period of field work, as well as outsourcing part of maintenance operations to specialized maintenance companies. Currently, one machine operator operates several machines and cannot perform maintenance and repair operations on time. Therefore, it is reasonable to outsource a part of complex maintenance and repair work to specialized companies. The article calculates maintenance costs at two levels: farm units of the agro-industrial complex and specialized maintenance enterprises. During forming a maintenance system at farms, dealer system can be implemented only in large ones with high profitability. Based on the studies, a method was developed for defining the economic efficiency of tractor operation in the course of implementation a new form of maintenance in the farms of the Omsk Region. The determination of the reduction of unit costs from the outsourcing of operations for complex technical maintenance during stressful period of field work by the farms of the Omsk Region to specialized enterprises have proved the effectiveness of the new concept of maintenance. Maintenance organization in cooperation with specialized centers will not only reduce the cost of equipment maintenance organization, but also increase the profitability of farm.**

***Keywords*—machine-tractor unit, maintenance, dealer system, failure, profitability, operating time.**

I. Introduction

Participants in the modern system of interaction and maintenance organization in agro-industrial sector are the following: agricultural producers as receivers of machines; performers of maintenance services as work performers during machine use; and manufacturers of machines as sellers of their products. Agricultural producers are the main ones in this scheme, and manufacturers of machines and maintenance performers are here to meet their needs what shows the priority of agricultural work in the system of interaction and maintenance organization [1].

In present-day conditions, it is reasonable to outsource the part of complex maintenance and repair work to dealer enterprises during long low-stress period; it guarantees higher quality of work than performed at a farm. The better the quality of preventive maintenance, the lower the percentage of sudden equipment failures during stressful period of sowing and harvesting [2]. Solution to the problem of machine downtime during failure handling and maintenance can be carried out by reducing the time for maintenance due to its intensification during low-stress period of field work [3].

II. Research Methodology

A. *Objects and methods*

Methods of mathematical modeling and statistical processing of results were used as basic research methods. Method of assessment the economic efficiency of tractor operation during implementing a new form of maintenance in the farms of the Omsk Region was considered. Farms with high revenue in the form of earnings can spend part of it on maintenance provided by dealer enterprises what will result in higher quality and volume of maintenance operations and will directly influence the reliability of equipment.

B. *Research design*

We have developed a method for calculating the share of maintenance that can be outsourced to a specialized maintenance enterprise based on determining the costs of Maintenance-2 and Maintenance -3 performed at farm (M) and at specialized maintenance enterprise (Z).

For this calculation, we need to find the costs of Maintenance-2 and Maintenance-3 performed at farm according to the formula

$$M = \left(\bar{t}_{moj} + \frac{t_{moj} \cdot \bar{t}_{отк}}{t_{удто}\, Н_{отк}} + \frac{t_{moj} \cdot \bar{t}_{p}}{t_{удто}\, Н_{px}} \right) (S_x + C_{zv}) \qquad (1)$$

where $\bar{t}_{moj}$ – duration of maintenance, h;

t_{moj} –complexity of maintenance, man-hours;

$\bar{t}_{отк}$ –duration of failure handling, h;

$\bar{t}_{р}$ – duration of equipment repair, h;

$t_{удто}$ – specific complexity of maintenance, man-hours/h;

$H_{отк}$ – time to failure, h;

$H_{рх}$ – time between repairs, h;

S_x – cost of maintenance, RUR/h;

C_{zv} – cost of downtime per hour, RUR.

Costs of performing complex maintenance by specialized maintenance enterprises are calculated by the formula:

$$Z=\left(\bar{t}_{moj}+\frac{t_{moj}\cdot\bar{t}_{отк}}{t_{удто}\,H_{отк}}+\frac{t_{moj}\cdot\bar{t}_{р}}{t_{удто}H_{рх}}\right)(S_x+C_{zv})+\frac{2R_{xjv}}{v_{mp\,v}}\left(C_{mp}+C_{zv}\right) \quad (2)$$

where R_{xjv} – radius of transportation of equipment for repair and maintenance, km;

V_{mpv} – equipment transportation speed, km/h;

C_{mp} – cost of equipment transportation, RUR;

Share of operations that can be outsourced to a specialized maintenance enterprise will be found by ratio

$$\varphi_{jv}=1-\frac{Z}{M} \quad (3)$$

For an example of calculating unit costs reduction from the outsourcing of complex maintenance during stressful period of agricultural work, three agricultural producers of the Omsk Region were taken; we conventionally named them Farm No.1, Farm No.2 and Farm No.3. The costs of Maintenance-2, Maintenance-3 and failure handling during stressful and low-stress periods of work for the main types of tractors working on these farms were defined; results are shown in Table 1.

TABLE I. CALCULATION OF COSTS FOR COMPLEX TYPES OF MAINTENANCE AND FAILURE HANDLING AA A RESULT OF OUTSOURCING OPERATIONS DURING STRESSFUL AGRICULTURAL PERIOD

Parameter		Farm		
		Farm No.1	**Farm No.2**	**Farm No.3**
Total costs for M-2, M-3 and failure handling during stressful period, RUR	K-744	2782270	391955	3825185
	John Deere-8420	268900	-	-
Total costs for M-3 during the low-stress period, thousand RUR	K-744	156850	41605	156 8450
	John Deere-8420	17450	-	-

Evaluation of unit costs reduction for farms from the outsourcing complex types of maintenance during stressful agricultural period is based on the costs presented in Table 1. Calculation results are shown in Table 2.

TABLE II. CALCULATION OF THE SHARE OF FARM COSTS REDUCTION FROM THE OUTSOURCING COMPLEX TYPES OF MAINTENANCE AND FAILURE HANDLING DURING STRESSFUL AGRICULTURAL PERIOD

Farm	Parameter	
	Cost reduction, RUR	***Cost reduction share***
Farm No.1	2906825	0.121
Farm No.2	350344	0.095
Farm No.3	3668340	0.133

In the course of this research, the features of MTF maintenance organization in farms depending on the following factors were established:

- F – area of arable land, ha;

- K_T – index of farm land ploughness;

$$K_T=\frac{F}{F_1} \quad (4)$$

where F_1– total area of farm land, ha.

- e – density of mechanized work, conventional reference ha / ha of arable land;

$$e=\frac{W_{sum}}{F} \quad (5)$$

where W_{sum} – total operating time of tractors during a year, conventional reference ha;

- ε – machine supply, kW/100 ha of arable land;

$$\varepsilon=\frac{100\sum iN_i}{F} \quad (6)$$

where $\sum_i N_i$ – total capacity of agricultural machines, kW.

- ξ – uneven loading of equipment for the i-th periods of use;

$$\xi=\frac{W_i}{W_{sum}} \quad (7)$$

where W_i – operating time of agricultural machinery for the considered i-th period.

- ρ_i – compactness of land equal to the average radius of the farm, km;

- X_4 – the number of tractor drivers/machine operators per 100 ha of arable land;

- X_5 – skill level of tractor drivers/machine operators.

Studying MTF maintenance organization of farms with dirrefent types of farming with the help of mathematical models, it was found that the considered parameters influence the substantiation of agricultural machinery maintenance types as follows (Table 3).

TABLE III. THE IMPACT OF PARAMETERS ON THE CONDITIONS OF MTF MAINTENANCE ORGANIZATION OF THE FARMS

Parameter strength	F	K_T	e	ε	ξ	ρ_i	X_4	X_5
Πx_i, %	39	5.4	2.7	9.8	7.5	3.2	7.2	25.3

The greatest impact on the efficiency of MTF maintenance organization is provided by: the area of arable land Π_F=39%, skill level of tractor drivers/machine operators Π_{X_5}=25.3%, machine supply Π_ε= 9.8%, uneven loading of equipment Π_ξ=7.5%, and the availability of tractor drivers/machine operators Π_{X_4}=7.2%.

Based on the studies, it was established that MTF maintenance station should be organized in the place with the smallest radius of equipment transportation, and the material and technical base should be located at the enterprises with qualified specialists.

Maintenance of agricultural machinery should be organized out of season using annual maintanance planning. In the routine and preventive system, number maintenance depends on the operating time, not on the time of year and season [4].

Equipment maintenance organization in accordance with annual maintenance plan takes into account the peculiarities of agricultural production and ensures the timeliness and full performing of ongoing maintenance [5].

Figure 1 shows a graph of the dependence of revenue share that can be used to pay for equipment maintenance when it is outsourced to specialized enterprises on farm area.

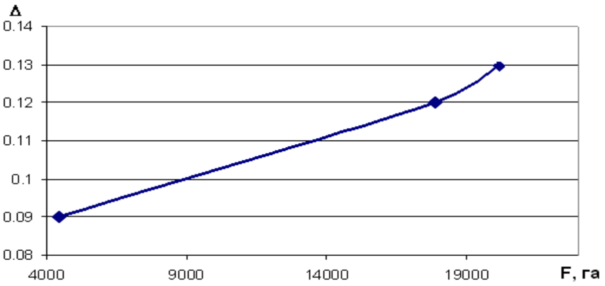

Fig. 1. Dependence of revenue share on farm area

The analysis reveals that the larger the farm and the greater its profitability, the larger share can be used for outsourcing maintenance to specialized enterprises.

The calculation of maintenance share was carried out on the basis of Maintenance-2 parameters for Kirovets and John Deere-8420 tractors in the conditions of farms and specialized enterprises (SE) (Table 4).

TABLE IV. DATA FOR MAINTENANCE-2

Parameter	Kirovets		John Deere-8420	
	SE	***Farm***	***SE***	***Farm***
$\bar{t}_{moj}$ – duration of maintenance, h	4.1	6.5	4.6	10.5
S_x – cost of maintenance, RUR/h	555	480	595	495
C_{zv} – cost of downtime per hour, RUR	2110	2110	2110	2110
R_{xjv} – radius of equipment transportation for repair and maintenance, km	135	0	135	0
V_{mpv} – equipment transportation speed, km/h	60	0	60	0
C_{mp} – equipment transportation cost, RUR	1010	0	1010	0
t_{moj} – complexity of maintenance, man-hours	9,7	11,7	4,2	5,4
$t_{y\partial mo}$ – specific complexity of maintenance, man-h/h	0.15	0.09	0.147	0.13
H_{OTK} – time to failure, h	210	160	490	325
$\bar{t}_{om\kappa}$ – duration of failure handling, h	6.95	29	6.98	33
H_{Px} – time between repairs, h	3510	2510	4580	3020
$\bar{t}_p$ – duration of equipment repair, h	45	165	40	200

In accordance with the method, the costs for Maintenance-2 of Kirovets and John Deere-8420 tractors were found for SE (Z) and the farm (M) (Table 5).

TABLE V. COST OF MAINTENANCE-2

Parameter	Kirovets		John Deere-8420	
	SE (Z)	***Farm (M)***	***SE (Z)***	***Farm (M)***
Costs, RUR	32397,4	110072,8	27335,7	45642,1
Share φ	0,715		0,401	

The calculation for Kirovets and John Deere-8420 tractors showed that the share of Maintenance-2 operations that can be outsourced to a specialized enterprise was 0.715 and 0.401.

Figure 2 shows the dependence of the share of Maintenance-2 operations that can be outsourced to a specialized enterprise, from the radius from the farm to SE.

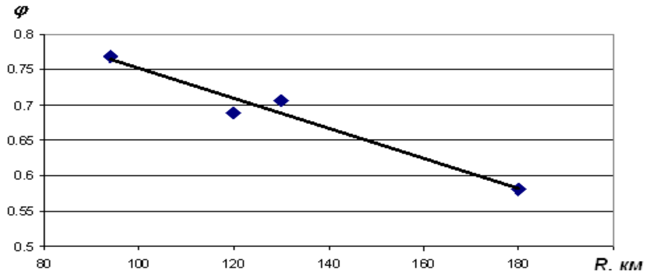

Fig. 2. Graph of the share of Maintenance-2 operations outsourced to SE as a function of radius

Based on the data obtained for four farms, the pattern of change, $\varphi = f(R)$ (Figure 3) was established in the form of the formula

$$\varphi = -0.0021 \cdot R + 0.9628 \quad (8)$$

where R is the distance between SE and farm.

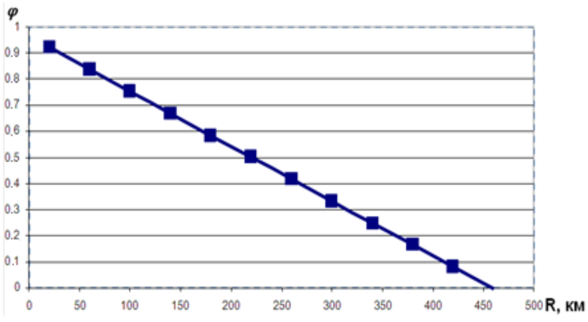

Fig. 3. Forecasting of the share of Maintenance-2 operations outsourced to SE as a function of radius

The critical value of radius for the outsourcing Maintenance-2 operations to SE was defined when the costs of farm tend to the costs of SE; it amounted to (≈ 200–230 km). When the radius increases above 450 kilometers, the costs of farm and SE become equal and the outsourcing of Maintenance-2 operations to SE makes no sense.

In the course of this research, the cost of performing Maintenance-3 in a farm was calculated (Table 6).

TABLE VI. DATA FOR MAINTENANCE-3

Parameter	Kirovets		John Deere-8420	
	SE	***Farm***	***SE***	***Farm***
$\bar{t}_{moj}$ – duration of maintenance, h	8.3	16.55	9.12	17.45
S_x – cost of maintenance, rubles / h	1120	1000	1950	995
C_{zv} – cost of downtime per hour, rubles.	2100	2100	2100	2100
R_{xjv} – radius of equipment transportation for repair and maintenance, km	135	0	135	0
V_{mpv} – equipment transportation speed, km/h	60	0	60	0
C_{mp} –equipment transportation cost, RUR	1010	0	1010	0
t_{moj} – complexity of maintenance, man-hours	26.5	28.5	20.3	23.5
$t_{y\partial mo}$ – specific complexity of maintenance, man-h / h	0.15	0.09	0.145	0.13
H_{OTK} – time to failure, h	210	160	490	325
$\bar{t}_{om\kappa}$ – duration of failure handling, h	6.95	29	6.98	33
H_{Px} – time between repairs, h	3510	2510	4580	3020
$\bar{t}_p$ – duration of equipment repair, h	45	165	40	200

Results based on the calculation are shown in Table 7.

TABLE VII. RESULTS OF COST CALCULATION FOR MAINTENANCE-3

Parameter	Kirovets Maintenance-3		John Deere-8420 Maintenance-3	
	SE (Z)	***Farm (M)***	***SE (Z)***	***Farm (M)***
Costs, RUR	67187,46	32263,3	54075,91	150189,8
Share φ	0,79		0,64	

The calculation for Kirovets and John Deere-8420 tractors showed that the share of Maintenance-3 operations that can be outsourced to a specialized enterprise was 0.79 and 0.64.

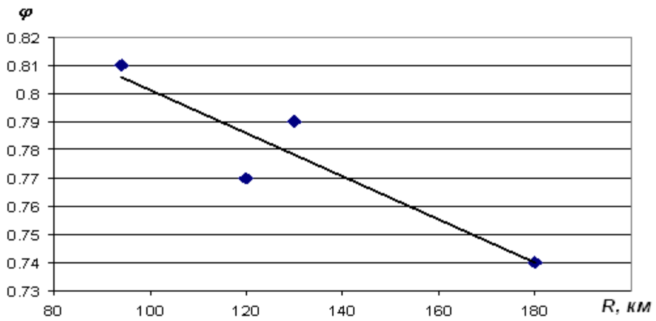

Fig. 4. Graph of the share of Maintenance-3 operations outsourced to SE as a function of radius

Based on the data obtained for four farms, the pattern of change, $\varphi = f(R)$ (Figure 5) was established in the form of the formula

$$\varphi = -0.0008 \cdot R + 0.8775 \quad (9)$$

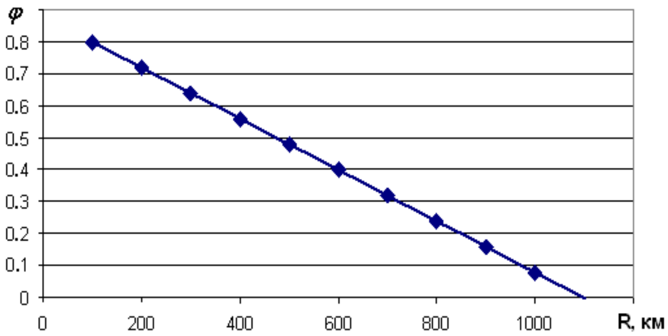

Fig. 5. Forecasting of the share of Maintenance-3 operations outsourced to SE as a function of radius

The critical value of radius for the outsourcing Maintenance-2 operations to SE was defined when the costs of farm tend to the costs of SE; it amounted to (≈ 480–500 km). When the radius increases above 1,100 kilometers, the costs of farm and SE become equal and the outsourcing of Maintenance-3 operations to SE makes no sense.

Based on the analyzed data for specialized enterprises in the Omsk Region, it was found that the specialists travel using mobile technical maintenance units to conduct Maintenance-2 of machines at the distance of up to 250 km, and for Maintenance-3 – up to 500 km; this fact is confirmed by the calculations [6]. The farther the farm is from SE, the more expensive is maintenance, while service receiver and SE are in unequal partnerships, since the service receiver compensates for the cost increase [7].

The share of outsourced operations φ for complex types of maintenance to a specialized enterprise is determined from the savings resulting from outsourcing operations during stressful period.

$$\varphi = 1 - \frac{Z}{\sum Э} \quad (10)$$

where

$\sum Э$ – total savings of farm from outsourcing Maintenance-2 and Maintenance-3 operations during stressful period;

Z – costs for Maintenance-2 and Maintenance-3 performed at SE.

Figure 6 shows the dependence of φ on the savings obtained during outsourcing of complex types of maintenance.

High cost savings during maintenance of equipment will allow farms to outsource the complex types of maintenance to specialized enterprises [8, 9].

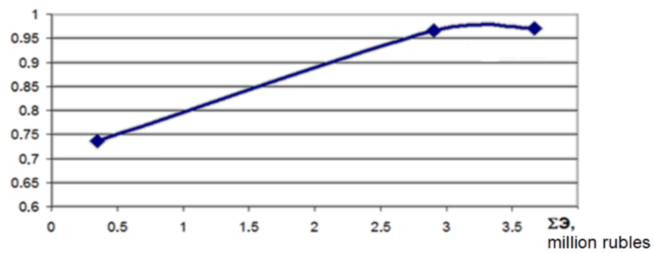

Fig. 6. Dependence of the share of maintenance outsourced to SE on cost savings

III. Suggestions and Results

Based on the calculations performed, the following recommendations can be made: for $\varphi \geq 0,5$ all operations on complex types of maintenance should be outsourced to a specialized enterprise; that will increase the reliability and efficiency of using tractors.

Support service of equipment at specialized enterprises increases its reliability and reduces the number of failures, while time between repairs increases by 40% (Figure 8), and the time to failure – by 30% (Figure 8) [10,11].

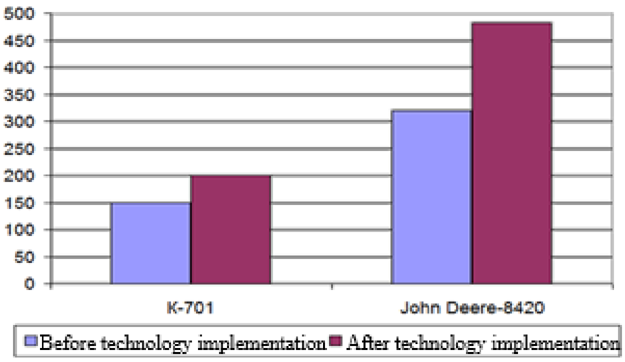

Fig. 7. H_{OTK} – time to failure, h

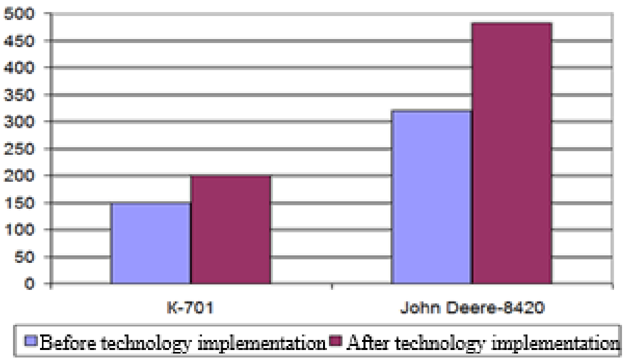

Fig. 8. H_{Px} – time between repairs, h

IV. Conclusions

According to the research results, the following conclusions were made:

1. The following factors influence the efficiency of maintenance organization: the area of arable land Π_F=39.1%, skill level of tractor drivers/machine operators Π_{X_5}=25.2%, machine supply Π_{ε} = 9.7%, availability of tractor drivers/machine operators Π_{X_4}=7.3%, and irregular loading of MTF Π_{ξ}=7.6%.

3. The calculation of cost savings from outsourcing operations on complex types of maintenance during stressful period and the share of maintenance for outsourcing to a specialized maintenance enterprise of the Omsk Region has proved the effectiveness of this method of maintenance. Maintenance organization in cooperation with specialized centers will not only reduce the cost of equipment maintenance organization, but also increase the profitability of farm.

4. The calculation of the share of operations that can be outsourced to specialized enterprises showed the following: when performing Maintenance-2 for Kirovets and John Deere-8420 tractors, the share will be 71.5% and 40.1%, respectively; when performing Maintenance-3, the share will be 79 and 64%, respectively.

5. Equations were obtained that make it possible to forecast the dependence of the share of operations on complex types of maintenance that can be outsourced to a specialized enterprise on the radius.

6. Outsourcing the share of operations on Maintenance-2 and Maintenance-3 to a specialized enterprise at $\varphi \geq 0.5$ will increase the reliability and efficiency of using tractors, reduce the number of sudden failures, while the time between repairs increases by 40%, and time to failure – by 30%.

References

[1] A. I. Anosova and M. K. Buraev, “Improvement of technical service machines in agriculture based on the evaluation and analysis the technological level repair facilities,” Dostizheniya nauki i tekhniki APK (Achievements of Science and Technology in AIC), No. 10, pp. 65-68, 2014. (in russ.)

[2] A. V. Kuchumov and A. V. Belokopytov, “Technical and Technological Supply of Agricultural Producers under Conditions of Transition to Innovative Economy,” Dostizheniya nauki i tekhniki APK (Achievements of Science and Technology in AIC), Vol. 31, No. 12, pp. 78 – 81, 2017. (in russ.)

[3] O. V. Myalo, V. V. Myalo, S. P. Prokopov, A. P. Solomkin, and A. S. Soynov, “Theoretical substantiation of machine-tractor fleet technical maintenance system on the example of Omsk region agricultural enterprises,” Journal of Physics: Conference Series, Vol. 1059, 2018. https://doi.org/10.1088/1742-6596/1059/1/012005

[4] G.V. Redreev, “Ensuring Machine and Tractor Aggregates Operability,” IOP Conference Series: Materials Science and Engineering, Vol. 142, No. 1, 2016. https://doi.org/10.1088/1757-899X/142/1/012085

[5] V. I. Chernoivanov, Maintenance and repair of machinery in agriculture. Moscow-Chelyabinsk: State R&D Institute of Technology, Chelyabinsk State Agricultural Engineering University, 2003. (in russ.)

[6] G. V. Redreev, O. V. Myalo, S. P. Prokopov, A. P. Solomkin, and G. A. Okunev, “Machine-Tractor Aggregates Operation Assurance by Mobile Maintenance Teams,” IOP Conf. Series: Materials Science and Engineering, Vol. 221, 2017. https://doi.org/10.1088/1757-899X/221/1/012016

[7] N. I. Selivanov, V. V. Matyushev, N. I. Chepelev, and I. A. Vasiliev, “Formation of a Fleet of Farm Tractors in Krasnoyarsk Krai,” Dostizheniya nauki i tekhniki APK (Achievements of Science and Technology in AIC), Vol. 31, No. 9, pp. 72 – 75, 2017. (in russ.)

[8] N. M. Ivanov, A. E. Nemtsev, and V. V. Korotkikh, “Technology of Agro-Industrial Complex - Qualitative Service,” Dostizheniya nauki i tekhniki APK (Achievements of Science and Technology in AIC),. Vol. 30, No. 4, pp. 81 – 82, 2016. (in russ.)

[9] L. A. Babchenko, Development of technical maintenance for agricultural machinery: Doctor of Science Dissertation (Technical Sciences). Almaty, 2010.

[10] S. D. Shepelev, V. D. Shepelev, Z. V. Almetova, N. P. Shepeleva, and M. V.Cheskidov, “Modeling the Technological Process for Harvesting of Agricultural Produce,” IOP Conference Series: Earth and Environmental Science, Vol. 115, 2018. https://doi.org/10.1088/1755-1315/115/1/012053

[11] N. I. Tchernyshev, O. E. Sysoev , D. B. Solovev, E. P. Kiselyov, “Basic robotecnical platform for implementation of accurate farming technologies,” Bulletin of Electrical Engineering and Informatics, Vol. 7, No. 4, 2018.