

## **MANAGEMENT OF INTER-FARM USE OF AGRICULTURAL MACHINERY BASED OF THE LOGISTICAL SYSTEM BOA**

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### **Abstract**

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Features of logistical approach to formation of management process system of intereconomic application of machinery in agriculture have been considered in the article. Peculiarities and ways of organizing and completing individual orders from farmers based on the logistical concept “BOA” have been defined. The research has been carried out on the methodological base which had the author’s development. A marginal type of changes in costs on repairs and technical maintenance in a long-term period has been grounded. A formula has been suggested for more precise planning of costs on repairs and technical maintenance in agriculture. A complex methodical approach to organization of inter-farm use of machinery has been developed focusing on stages of implementing the logistical system “BOA”. A logistical model for optimal completion of farmers’ orders has been created, considering volumes of equipment load. The developed approach has been approved while forming the project of intereconomic use of machinery from six small farms. The limitations for economic benefits from the joint machinery exploitation have been set. The optimal fleet of machinery-tractor equipment and schemes of their application in farming enterprises have been formed based on the logistical concept “BOA”.

*Key words:* agricultural equipment; concept “BOA”; economic benefits; inter-farm; logistics

*JEL Classification:* C61, D70, M11, Q12

### **Introduction**

Nowadays small-scale agricultural business occupies a considerable specific gravity in the production of food. A positive feature of such a form of householding is high motivation to productive labor and rational use of land and other means of production.

In this context the research made by K. Lowder et al. (2016) states that in the whole world there are about 570 million farms. Most of them are managed by families and are small in size agricultural grounds. For today small farms (smaller than 2 ha) process about 12%, and family farms – about 75% of all world agricultural grounds. Moreover scientists pay attention to the

fact that throughout the past years in most countries with above average income there has been trend toward certain strengthening of agricultural producers. However in countries with average and low income the average size of farms has partially decreased.

The activity of a small-scale business has been well agreed with the concept of ecological safety and steady development of agrarian areas (Kolodiychuk, 2014; Kharytonov et al., 2015). However, small farming enterprises as independent subjects of production have a set of organizational issues, which are not typical for a large-scale agrarian enterprise. Hence, the formation of their own complex system of machinery on small land areas is often unreasonable and economically unprofitable.

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Therefore small-sized farming enterprises have to use a set of outside mechanical services. With that purpose different forms of specialized intereconomic use of machinery have been created, one of the most widespread of them is joint exploitation of agricultural machinery in the form of mutual help for neighbors, machinery associations, cooperatives and so on. Despite the significant advantages for farmers, such forms of servicing cooperation are quite complex objects of management. Furthermore, within this system there is joint organization of completing orders, which could be different in size and frequently happen at the same time.

Efficient organization of machinery usage in them often requires application of corresponding ways of support planning and implementation of managerial decisions. As one of them, in our opinion, it is worth noting features of the logistical concept "BOA" (German "Belastungsorientierte Auftragsfreigabe"). This system is focused on the optimal number of places for completing orders depending on the load. It is a methodical approach, so called "funnel", outflow of which symbolizes the completion of orders and the content of the funnel – the condition of parameters of completing orders. At that the process of management takes place in such a sequence: I stage – setting the term of completion (time of duration) of the received and processed tasks to implementation and the division of orders into urgent and less urgent; II stage – definition of feasibility of urgent orders (find out the probability of delivering orders to a certain place at a certain time while it is reasonable to implement at different work places); III stage – verification of "real" orders by composition of the cumulated loading and restrictions in the sphere of loading each workplace (possible for implementation orders are transferred to current realization and impossible ones are moved to the next period of planning) (Bechte, 1980; Buzacott et al., 2012; Engelhardt, 2015).

The strategy and mechanism of implementing logistical concept "BOA" in the system of management at present have been profoundly processed in the environment of manufacturing-supply activity. It especially concerns the sphere of management over stocks in the industry and machine building (Knecht, 1991; Wiendahl, 2003; Lödding, 2016b). But potential features of using aspects of philosophy "Belastungsorientierte Auftragsfreigabe" in the system of management of servicing organizations (where stocks are absent in principle) have been studied much less. On the whole the organization of management based on principles of the logistical concept "BOA" is efficient at carrying out individual orders unlike other logistical systems such as "KANBAN", "Fortschritzzahlen" (FZ), "DRP" and "SCOR". Therefore major possibilities of using the mentioned systems in agribusiness had been studied by us under conditions of serial and mass manufacturing (Velychko, 2015a; Velychko, 2015b; Velychko, 2014b). In previous works the base for widening the

existing knowledge had been formed including their transition to new objects of logistical management in the agricultural servicing cooperation. Thus in many spheres of economy it is reasonable to use logistical concepts focused on coordination of individual orders. This issue starts to be more essential in case of joint usage of machinery-tractor fleet by small land users on the cooperative basis.

The process of rational organization of inter-farm use of machinery in agriculture is an object of attention for many modern researches. Moreover this issue has been considered as essential in works of such scientists as Kenkel (2007), Long (2007), Yang (2009), Li (2009), Colson (2010), Ginder (2010), Başarık (2015), Yildirim (2015), Artz (2016), Hickey (2016), Naeve (2016), Reed (2016) and others.

Logistical approach to modeling in the system of management of agrarian machinery use was studied by Sabir (1990), Folinas (2010), Kheir (2010), Jinfeng (2010), Dongmei (2012), Hameed (2012), Kamboj (2012), Li (2012), Bosona (2013), Maradun (2013), Vasylieva (2013), Hunt (2016), Pawellek (2016) and others.

The logistical concept "BOA" was firstly studied in great detail in the dissertation work by W. Bechte (Bechte, 1980). Later it was further developed in scientific works by many authors and remains vital for the current business environment. At different times this concept was represented by different scientists such as Knecht (1991), Wiendahl (2003), Buzacott (2012), Werner (2013), Wannenwetsch (2014), Engelhardt (2015), Yakut (2015), Lödding (2016a, 2016b) and other scientists.

Artz et al. (2010) pay attention to the fact that for small agrarian enterprises the joint machinery is an efficient alternative in access to modern highly technological operations. And inter-farm machinery use enables farmers to remain competitive under conditions of a higher concentration of agricultural production. At that the rational distribution of the work pressure on machinery can significantly reduce logistical costs.

In other publications G. M. Artz along with L. Naeve (2016) systematized both advantages and disadvantages of inter-farm machinery use in agriculture. Apart from that they point out that the issue of complexity in organizing the mechanism of machinery exchange could be eased with the help of the detailed prospective work planning.

The experience of agriculture in China and Turkey testifies that the most important problem is adaptation of members of intereconomic machinery use for small-scale land tenure. Moreover the prospect innovations in machinery cooperatives were viewed by such scientists as Li et. al. (2009), as well as Başarık and Yildirim (2015) based on the improved internal mechanism of management.

In this context Folinas et. al. (2010) suggested a logistical system of monitoring over implementation of technological op-

erations in agriculture. The developed by Hameed et. al. (2012) objectively-focused model of work imitation of agricultural machinery in the field is of great interest to the machinery management. However the application of this and previous models in case of inter-farm use of machinery requires additional consideration for features of management during cooperation.

Studies by Yakut (2015) are dedicated to possibilities of receiving competitive advantages due to intellectual analysis of data in the sphere of production and logistics. In this context Kheir (2010) in his doctoral dissertation carried out the examination of data on exploitation of agricultural machinery use costs with the equation system developed by American Society of Agricultural and Biological Engineers (ASABE).

At the same time the solution to the system of linear equations has been considered by a German scientist Lödging (2016a) as the important component of implementation of the logistical concept "BOA". However the same author Lödging (2016b) draws attention to the application of this concept mainly in the industrial sphere.

Thus in previous researches the methodological principles of application of different logistical systems and concepts considering national, field and situational factors have been studied. At that in most studies the main attention was focused on logistical modeling of solutions in the system of the material flow, to a smaller extent – in the sphere of serving the business. Besides systems of managing operational processes in agrarian enterprises have been rarely studied in the integration with such means of rationalistic logistics as (BOA, Lean production, FZ), as well as the concept of SCM (SCOR-model). Also insufficient attention has been paid to the development of complex

mechanisms of organizing interaction between members of the agrarian servicing cooperative on the base of modern logistics. Despite numerous scientific developments, the logistical concept "Belastungsorientierte Auftragsfreigabe" still has a set of niches for studying. The latter to a bigger extent, concerns the organization of the system of machinery use in the agrarian sector. Therefore there is a need to study this issue more profoundly with considering the previous results.

The purpose of the research was to develop the author's model for planning decisions in the system of management of inter-farm machinery use based on the logistical system "BOA", as well as its approval in practice.

## Materials and Methods

The scientific-research work was carried out on the methodological base developed by the author. Hence the previous definition of the praxeological approach as the basis for logistical knowledge was used in the development of the methodology of the present work. The research has been systematically built on the previously developed author's interpretation of a term and a complex of means of rational logistics (Velychko, 2014a). Consequently the complex methodological approach to the application of the logistical concept "Belastungsorientierte Auftragsfreigabe" in the system of management over inter-farm machinery use between farmers was formed.

With the purpose to illustrate its mechanism, six farming enterprises have been selected from the Dnipropetrovsk region (Ukraine). The total area of arable land of independent farming enterprises was 246 ha, and the territory for land use of each of them is located nearby or within 5 km (Table 1).

**Table 1**  
**Area of arable land and availability of agricultural machinery in farming enterprises**

Farming enterprise	Area of arable land, ha	Agricultural equipment	
		Tractors, Combines	Agricultural machines
Nyva	37.5	KhTZ-181; IuMZ-8070	PON-3.35; PNV-5-35; KPH-4; KPE-3.8; BZLS-1.0; AHD-2.1
Zoria	34.5	Feng-Shou FS-240	PLN-3-30; AHD-1.3; MK-1.8
Demetra	52.5	MTZ-82.1	PON-3.35; KPE-3.8; OHN-816; KPS-4; BZTS-1,0
Svitanok	52.5	YuMZ-8040.2; Nyva-Efekt	KPS-4; BZLS-1.0; PPK-4; SZ-3.6A «Astra»; PLN-3-35; PLN-4-35; PSP-8
Kolos	36.0	KhTZ-181; KZS-11 «Dnipro-350»	PLN-3-35; PLN-4-35; KRN-4.2; KPE-3.8; ROU-5; KPS-4; SZM «Nika-4»; VEHA-8; ZhZB-4.2; MVD-900
Zlahoda	33.0	YuMZ-6AKM.40.2	KPS-4; KRN-4.2; PON-3.35; UPS-8; BZSS-1.0; AHD-2.5; SZ-5.4 «Astra»

In the process of carrying out plan estimations for 2017-2018 marketing year, agricultural crops and their areas of arable land in farming enterprises were defined.

Based on the logistical concept "BOA" the algorithm of drawing a plan for joint use of machinery-tractor fleet for six agricultural enterprises on their conditionally total area of arable land 246 ha was developed and tested. The developed methodological approach at the same time provides mandatory application of operations within necessary agritechnical terms and around all types of agricultural works, as well as promotes minimization of farmers' expenses. The implementation of this project included several consequent stages.

In such a way, to provide optimization for joint machinery use for agricultural exploitation of farming enterprises, the following output information was formed: 1) volumes of machinery works for separate technological operations; 2) agri-technical terms for carrying out machinery works; 3) current price value of agricultural machinery; 4) norms of production on the machinery work; 5) planned exploitation costs by types of works. A set of machinery works and their volumes and agritechnical terms of carrying out were set based on the technological maps of growing agricultural crops. The planned parameters of productivity of machinery-tractor equipment as well as the expected consumption of petrol per unit of work were defined based on norms of production and petrol costs for specific agricultural machinery works.

Based on the terms and length of performing the works, the schedule of carrying out operations was drawn, which corresponds to the I stage of implementing the logistical system "BOA". Agritechnical terms of carrying out works are indicated horizontally, their numbers – vertically. According to II stage of the concept "BOA" estimation periods were detected by dividing the agricultural year into separate parts. Some of such periods were united into one estimation period. However, if at least one work appeared which could not be combined with all the other works in this period, a new estimation period was set. The latter corresponds to the principles of implementation of the III stage of the logistical concept "BOA". After that, based on a number of work days of operations, the production of equipment on technological operations was calculated for different periods with variability factor 1.0 and 1.5.

The productivity of machinery-tractor equipment during the estimated period on technological operations was defined as multiplication of daily productivity by a number of work days in the estimated period of the machinery use. Then the calculation of exploitation costs of machinery-tractor equipment was made by technological operations in periods. These costs can be united into several articles: cost of petrol;

expenses on repairing and technical service; permanent costs (costs of rent, depreciation and so on).

Costs on salary for mechanics were not considered since during the work of the machinery-tractor equipment on the outside they were included into the added value for the service.

The calculation of the planned costs on fuel by technological operations was made by the following formula:

$$g = n \times s \times p, \quad (1)$$

where  $g$  – planned fuel costs, currency units;  $n$  – norm on fuel cost per 1 ha of processing, kg;  $s$  – area of processing in the period, ha;  $p$  – price per 1 kg of fuel, currency units.

At planning costs on repairing and technical maintenance the approach, developed by the author, has been used. The outcoming provisions of this method are that efficiency of functioning of the plan-preventive system of technical servicing machinery-tractor fleet in agribusiness to a bigger extent depends on precision of planning costs for repairs and technical maintenance. In the long-term period they can be variable. The analysis of practical application of regulatory planning of such costs in contemporary conditions makes possible to consider that it has a certain number of disadvantages.

Hence since the 1950s in many countries normative plan costs for repairing and technical maintenance of agricultural machinery depending on the initial (balance) price of the machinery have been used. For example, for crop gathering combines at terms of exploitation 2 000 hours, normative costs for repairing and maintenance are 1.7% per every 100 moto-hours of work (Sabir et al., 1990; Hunt and Wilson, 2016). At that the Soviet scientific Institute of Agriculture Electrification developed and recommended the implementation of normative costs for repairing and technical maintenance of agricultural machinery per one unit of the carried out work (Miller, 1970). Beside the Institute of Agrarian Economy of Ukraine recommends plan costs for repairs, maintenance and storage in the amount of 7.9% of initial price of a combine (Ivan and Usenko, 2014; Shvedyk, 2016).

Such approaches to plan costs have one common disadvantage – they do not consider the marginal type of changes in costs on repair and technical servicing (gradual additional growth), which is caused by amounts of production or exploitation terms of agricultural machinery. It enabled the author to propose the theory that with the increase in lifetime of agricultural machinery, the costs for repairing and technical maintenance per 1 ha of the cultivated area increase. So in the 1980s there were researches on defining lifetime of agricultural machinery, which at that moment pointed out to the existence of the marginal type of changes in costs for re-

pairing and technical maintenance (Kenkel and Long, 2007; Kheir, 2010; Pawellek, 2016). At the same time, the essence of this problem was not defined.

Some authors offered the model of unit costs by years of exploitation of complex machinery according to which there are three periods of machinery work. First – early period, in which costs increased almost by a straight line, second – when they are stabilized, third – when costs rise again, and the daily production of machines decreases (Sabir et al., 1990).

It is worth noting the method of planning the costs for repairs per unit of consumed fuel. In this methodology differentiation of such costs as dependence on exploitation term and depreciation terms of the agricultural machinery is carried out. The calculation and correction of costs are carried out individually for each machine (Jinfeng, 2010; Kheir, 2010). Hence, in this planning methodology the marginal type of changes in costs for repairing agricultural machinery, caused by amounts of production or exploitation lifetime is considered. However, there is also one remarkable drawback – specific standards of money spending for repairing periodically become out of date. The development of new norms is not prospective since costs norms will always depend on the influence of inflation processes.

Therefore nowadays it is reasonable to unite several separate elements from the considered methods of plan costs for repairing and technical maintenance. We imply the use of norms of annual costs for repairing and technical maintenance defined in percentage from initial (balance) or current market price of the machinery considering certain fluctuation coefficients. Planning of such expenses is recommended to be made per unit of the consumed fuel according to the author's formula:

$$r = t \times b \times q \times k, \quad (2)$$

where  $r$  – planned annual costs on repairing and technical maintenance of agricultural machinery, currency units;  $t$  – annual planned costs on fuel consumption by agricultural machinery, tons;  $b$  – initial (balance) or current market price of the agricultural machinery, currency units;  $q$  – norm percentage of average costs on repairing and technical maintenance from initial (balance) or current market price of the agricultural machinery, %;  $k$  – coefficient of correction for costs on repairing and maintenance depending on the period of exploitation and depreciation of the unit of agricultural machinery.

Therefore planning of costs is carried out based on the plan of repairing and technological maintenance of agricultural machinery for the current year.

Hence, the suggested methodological approach to application of the logistical concept “Belastungsorientierte

Auftragsfreigabe” in the system of inter-farm joint machine use implies the calculation of costs for repairing and technical maintenance considering their marginal type. Empiric studies confirm that such costs in the long-term period are changeable. It made possible to draw the additional conclusion about the fact that, costs for repairing and technical servicing are mainly regressive (changeable in a relatively smaller proportion than amounts of production or exploitation term of agricultural machinery). The importance of relatively precise and grounded planning of costs for repairing and maintenance confirms the fact that in the general structure of costs exploitation of machinery they can be up to 27-39% and they initially depend on the price for agricultural machinery, its production in moto-hours that is the time of exploitation (Hunt and Wilson, 2016).

Standard planning of costs for repairing and technical maintenance of agricultural machinery is a way of effective projection of decision in the management of inter-farm consumption of machinery. It is worth noting that an important component of preparing such decisions made on the basics of the logistical concept “BOA” could be a way of economical-mathematical modeling (Hameed et al., 2012; Vasylieva, 2015). In particular, the method of linear programming was used for it. Besides in the carried out study, the examined costs for repairing and technical maintenance of tractors and combines were used as output data for building the matrix of tasks for linear programming. Planning of these costs was carried out using formula 2.

So considering the marginal type of costs on repairing and technical maintenance in the objective function in the logistical model of the task made possible to select machinery and equipment those among the same brands that have a lower term of exploitation at the moment. During the calculating the norm percentage from annual costs for repairing and technical maintenance from initial market price for cars were taken as a basis for combines – 1.7% per 100 moto-hours of work. In order to calculate this norm per 1 ton of the consumed fuel for combines 100 moto-hours were recalculated into tons of the consumed fuel according to the formula:

$$h = j \times l \times v \times z / 1000, \quad (3)$$

where  $h$  – amount of fuel, tons;  $j$  – number of moto-hours;  $l$  – coefficient of calculating moto-hours into physical hectares;  $v$  – average consumption of fuel, liters/ha;  $z$  – coefficient of turning liters into kg for diesel fuel; 1000 – recalculation of kg into tons.

$$h = 100 \times 1.7 \times 8.8 \times 0.825 / 1000 = 1.234 \text{ tons.}$$

From here the normative percentage of costs from current market price for machinery per 1 ton of fuel:

$$q = 1.7/h, \tag{4}$$

where 1.7 – percent of costs on repairing and technical maintenance per 100 moto-hours of work.

$$q = 1.7/1.234 = 1.38\%$$

The calculated normative percent was used for planned calculations of the stated costs for tractors and combines.

The example of calculating costs on repairing and technical maintenance of the tractor “KhTZ-181” on harrowing in the first calculation period is provided below:

$$r = 0.1806 \times 0.0138 \times 568\,250 \times 1.15 = 1628.67 \text{ UAH}$$

Definition of such planned costs by agricultural machines is carried out with calculating 0.01% from current market price for the machinery per 1 hectare of the processed area. The example of planned costs per agricultural machinery  $r_1$  is provided below:

$$r_1 = b \times 0.0001 \times s_1, \tag{5}$$

where  $r_1$  – area of processing in the year of calculation.

Two periods of planting with the sowing machine “SZ-5.4 “Astra” in another calculating period of costs on repairing and technical maintenance were:

$$r_1 = 138\,560 \times 0.0001 \times 133.5 = 1849.78 \text{ UAH}$$

The calculation of the planned depreciation costs by tractors, combines and agricultural machines was carried out on the basis of the planned amount of annual production of tractors and combines (under the condition that the separate unit will perform the whole amount of possible technological operations). Moreover, the planned amounts of the annual shared machinery production by all possible operations were: KhTZ-181 (1) and KhTZ-181 (2) – 1495.5 ha; MTZ-82.1 – 1975.5 ha; IuMZ-8070, YuMZ-8040.2 and YuMZ-6AKM.40.2 – 1900.5 ha; Feng-Shou FS-240 – 60 ha; Nyva-Efekt and KZS-11 “Dnipro-350” – 168 ha.

The calculation of planned costs on depreciation of tractors and combines was carried out according to the formula:

$$d = b10\% (12\%) / w \times s_1, \tag{6}$$

where  $d$  – depreciation costs, currency units;  $w$  – planned amount of annual production by machines, ha; 10% (12%) – percent of deduction for depreciation of tractors and combines.

For example for the tractor “KhTZ-181” harrowing in the first calculation period the costs on depreciation were:

$$d_1 = (568\,250 \times 0.1/1495.5) \times 193.5 = 7352.48 \text{ UAH.}$$

The calculation of planned costs on depreciation by agricultural machines ( $d_2$ ) was made according to the similar formula. But there the percentage of depreciation was 5.

For example for machines “MVD-900” in the second calculating period the costs on depreciation were:

$$d_2 = (112\,458 \times 0.05 / 246) \times 60 = 1371.44 \text{ UAH.}$$

Altogether it made possible to calculate the for the objective function of the logistical model task the total amount of costs on shared inter-farmer exploitation of machinery-tractor fleet by technological operations according to calculated periods.

The calculated output data were used for building the matrix of the logistical task model. When the matrix of the model was drawn 20 groups of variables were considered. The first group of variables ( $x_1 - x_8$ ) meant the needed number of machines of the certain type, which were used for the work in the first period; ( $x_9 - x_{27}$ ) – in the second; ( $x_{28} - x_{34}$ ) – in the third; ( $x_{35} - x_{44}$ ) – in the fourth; ( $x_{45} - x_{68}$ ) – in the fifth; ( $x_{69} - x_{74}$ ) – in the sixth; ( $x_{75} - x_{83}$ ) – in the seventh; ( $x_{84} - x_{87}$ ) – in the eighth; ( $x_{88} - x_{91}$ ) – in the ninth; ( $x_{92} - x_{95}$ ) – in the tenth; ( $x_{96} - x_{101}$ ) – in the eleventh; ( $x_{102} - x_{127}$ ) – in the twelfth; ( $x_{108} - x_{127}$ ) – in the thirteenth; ( $x_{128} - x_{144}$ ) – in the fourteenth; ( $x_{145} - x_{161}$ ) – in the fifteenth; ( $x_{162} - x_{165}$ ) – in the sixteenth; ( $x_{166} - x_{167}$ ) – in the seventeenth; ( $x_{166} - x_{167}$ ) – in the eighteenth; ( $x_{170} - x_{176}$ ) – in the nineteenth; ( $x_{176} - x_{196}$ ) – in the twentieth.

The first group of limitations (1-34) provides the performance of volumes of works in all periods. The other group of limitations (35-169) implied the minimal number of tractors, combines and agricultural machines of different brands, which are necessary to carry out the works by corresponding equipment by periods. The third group of limitations (170-196) identified the number of tractors, combines and other agricultural equipment which is in possession of six farming enterprises.

Criteria for optimal solution to the logistical task are minimal costs on exploitation of machinery-tractor fleet of six farming enterprises.  $c_i$  stands for costs on performing by the searched for machinery-tractor equipment  $i$ -crop technological operations in each period ( $i = \overline{1, M}$ ). Objective function had the following view:

$$\sum_{i=1}^M c_i x_i \rightarrow \min \tag{7}$$

The formed matrix of the logistical model of a task was solved with the help of the method of linear programming within environment Microsoft Excel.

## Results and Discussions

As a result of solving the task of finding the optimal variant for a plan of joint inter-farmer machinery use of six enterprises, the following units were included: tractor “MTZ-

82.1” (farming enterprise “Demetra”); tractor “KhTZ-181” (farming enterprise “Kolos”); combine “Nyva-Efekt” (farming enterprise “Svitanok”). The optimal variant also included all agricultural machines except for MK-1.8 and AHD-1.3 (farming enterprise “Zoria”).

In the conclusion there was comparative contrast of effective data in case of intra-farm and inter-farm exploitation of machinery (Table 2).

Also there was calculation of costs of farming enterprises for mechanization in proportion per 1 ha of arable land (Table 3).

Hence for all six farming enterprise, inter-farm use of machinery can has economic benefits over intra-farm. The most evident those advantages are for farming enterprises “Svita-

nok”, “Nyva” and “Kolos”. For them at any of the mentioned added values inter-farm exploitation of machinery is more efficient. For framing enterprises “Zoria”, “Demetra” and “Zlahoda” such organization of machinery use ceases being profitable if the added value to the machinery services from machinery of other farmers exceeds 30%.

Hence the application of machinery at the inter-farm basis for the present six farming enterprises can be economically beneficial for both sides only under the conditions if the added value for the outside machinery services of enterprises will not exceed 30% of self-cost.

Besides some farming enterprises receive additional income from providing machinery services to their neighbors (Table 4).

**Table 2**

**General costs of farming enterprises on mechanization with different forms of organization and use of machinery, UAH**

Farming enterprise	Usage of machinery			
	Intra-farm (by self-cost)	Inter-farm (with the added value to the self-cost)		
		10	30	50
Nyva	206064	117000	138150	159075
Zoria	143892	109440	129483	149409
Demetra	181278	156420	178065	199485
Svitanok	338067	156600	178470	200115
Kolos	281421	106614	115884	125154
Zlahoda	150867	119160	143712	162648

**Table 3**

**Costs of farming enterprises for mechanization per 1 ha of arable land with different forms of organizational use of the machinery, UAH**

Farming enterprise	Usage of machinery			
	Intra-farm (by self-cost)	Inter-farm (with the added value to the self-cost)		
		10	30	50
Nyva	5495	3120	3684	4242
Zoria	4171	3172	3753	4331
Demetra	3453	2979	3392	3800
Svitanok	6439	2983	3399	3812
Kolos	7817	2962	3219	3477
Zlahoda	4572	3611	4355	4929

**Table 4**

**Additional income of farmers from providing machinery services with the added value 10 %, UAH**

Type of the machinery (farm-owner)	Total	including the income from the work in farming enterprises					
		Nyva	Zoria	Demetra	Svitanok	Kolos	Zlahoda
Tractor «MTZ-82.1» («Demetra»)	18171	2025	4428	–	3672	4320	3726
Tractor «KhTZ-181» («Koloss»)	21061	5400	2714	4928	3213	–	4806
Combine «Nyva-Efekt» («Svitanok»)	43389	8775	7398	11610	–	7749	7857

Thus for farming enterprises correspondingly it will be: “Nyva” – 89064 UAH (savings on costs); “Zoria” – 34452 UAH (savings on costs); “Demetra” – 43029 UAH (savings on costs – 24858 UAH and additional income from providing machinery services – 18171 UAH); “Svitanok” – 224856 UAH (savings on costs – 181467 UAH and additional income from providing machinery services – 43389 UAH); “Kolos” – 195868 UAH (savings on costs – 174807 UAH and additional income from providing machinery services – 21061 UAH); “Zlahoda” – 31707 UAH (savings on costs) – Table 2 and 4.

The prices go down most significantly for those enterprises where provision with machinery is extremely high. At the increase in amounts of production of such machinery due to processing areas of other households, the costs per unit of the performed work decreases. This situation is typical for two enterprises – “Svitanok” and “Kolos”.

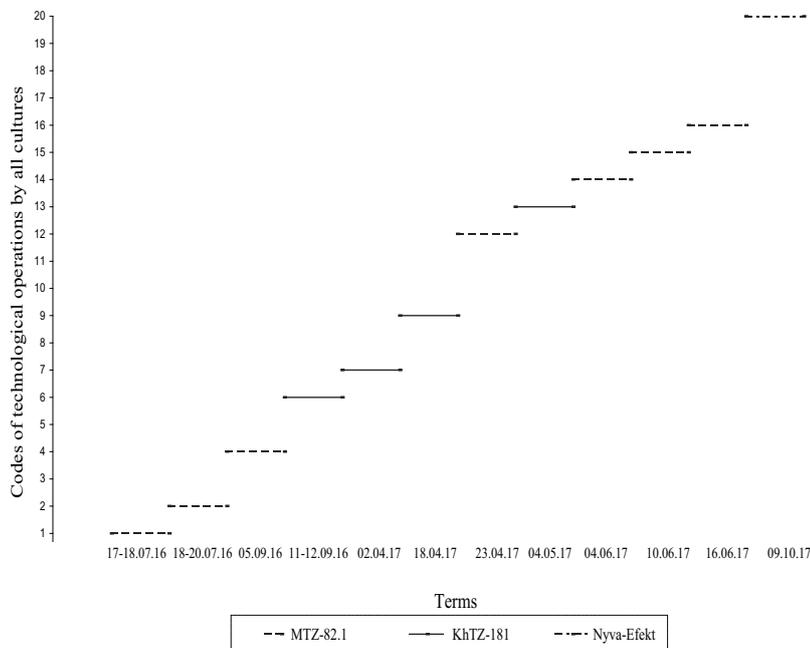
For the farming enterprise “Nyva” the decrease in costs takes place due to release from work of two powerful tractors “KhTZ-181” and “YuMZ-8070”. Under the condition that the tractor “KhTZ-181” as such which had worked its depreciation term and will be written off, the tractor “YuMZ-8070” will be rented out, perform the work on the outside or the farmer will sell it to another person, the significant effect will be provided.

In the farming enterprise “Zoria” a high level of constant

losses has been formed due to the fact that tractor “Feng-Shou FS-240” performs a short list of technological operations. At carrying out such operations by the machinery of other farmers, depreciation threats and, consequently the self-price of 1 ha will be smaller due to the increase in the field of machinery use.

In the farming enterprises “Demetra” and “Zlahoda” in case of inter-farm machinery use the costs for modernization are reduced not so significantly as in other enterprises. It testifies to the fact that in them the load of their own machinery is better compared to other enterprises. But the tractor “YuMZ-6AKM.40.2”, which belongs to the farming enterprise “Zlahoda”, has already exhausted its depreciation period and hence, in prospect should be written off the balance. Apart from that the farming enterprise “Demetra” can obtain additional income from providing machinery services to other five farming enterprises with the tractor “MTZ-82.1” (Table 4). Hence, in the prospect, economic benefits from intereconomic use of machinery for those enterprises are quite evident.

In the future for the complete machinery fleet in case of intereconomic machinery use except for tractors, which were included in the optimal variant, it is worth having one more tractor – “YuMZ-6AKM.40.2”. In prospect any other machinery of farming enterprises can be: written off the balance due to the expiry date; sold to another person; used for providing commercial services outside; rented out.



**Fig. 1. Graph of implementing individual orders of the farming enterprise “Demetra” in 2017-2018 in case of inter-farm machinery use (growth of sunflower)**

In the context of completing individual orders, based on the logistical concept “BOA” graphs of inter-farm machinery use for the operating year were drawn. They were developed as a result of the optimal plan of joint exploitation of machinery-tractor fleet, which was achieved due to the solution of the logistical model of the task. An example of this graph for the farming enterprise “Demetra” is provided in the Figure 1.

The machinery association could be the most efficient form of incorporation, within which it is reasonable to carry out intereconomic machinery use of six farming enterprises.

## Conclusions

The logistical approach to management of the operational systems makes possible to significantly increase the level of their reliability, thrift and efficacy. By its type the inter-farm machinery use is a business process, which is focused on organization of completing individual orders on technological operations. The logistical concept “BOA” is one of the approaches which makes possible to provide the effective management over such a process in the context of its features. At that the organization of implementing the logistical system “BOA” requires the formation of the complex methodological approach.

**Theoretical value** The developed methodology of organization of inter-farm machinery use considers: requirements of the stages of the logistical system “BOA” and the sequence of their implementations; the marginal type of costs for repairing and technical maintenance; planning of implementation of orders regarding the volumes of load on agricultural machinery; flexibility in price formation toward side technological services depending on the level of constant losses; limits of economic benefits from the joint machinery usage.

**Practical value** The suggested mechanism makes possible to carry out technological operations in the needed agrotechnical terms during all periods of agricultural works, as well as it helps to minimize farmers’ costs for technical maintenance of production in case of joint exploitation of machinery. On its basis complex optimal graphs of machinery use in farming enterprises can be created. The logistical model also makes possible to form the rational machinery-tractor fleet for joint farmers’ use.

Further scientific research in the system of management over inter-farm machinery use it is worth considering the researches of the possibilities of the logistical system “Lean production”.

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