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Modelling of investment decisions on technical support of agricultural enterprises

Abstract. *Introduction.* Limited availability of machinery for agricultural enterprises, as well as the high intensity of its use, is accompanied by a decrease in investment activity in the agricultural sector. This necessitates a rational choice of suitable source of investment for technical upgrading and minimising of investment costs of business entities. *The purpose* of the article is modelling of making optimal decisions in the process of investing in technical support of agricultural enterprises under the conditions of their limited access to investment resources. *Results.* The authors of the article have developed a dynamic economic and mathematical model to optimise investments in the renewal of existing facilities at agricultural enterprises. The use of this model will facilitate further rationalisation of economic decision-making on the allocation of investment resources through time.

The study was conducted in respect of investments in the purchase of beet harvesters that would be used in the area of 2,000 hectares. The possibility of buying the Ukrainian machinery as well as the equipment of foreign production was considered. The problem can be solved by means of four optimisation criteria: 1) minimum cost of the investment project on the purchase of equipment; 2) minimum cost of the project including operating costs with the use of equipment; 3) minimum cost of the project in terms of investments which should be taken from external sources when using depreciation deductions for the investment; 4) minimum cost of the project in terms of investments which should be taken from external sources when using depreciation deductions for the investment and taking into account operating costs. According to the criteria of optimisation, the authors have developed the best plans of investment by the years of the investment project. It has been found that, based on the criterion of cost minimisation, buying of different types of machinery made in Ukraine is preferred despite its lower productivity. We determined that the possibility of taking into account operating costs in cash flows does not change the final optimal structure of the planned number of machinery, affecting only the total cost of the investment project - USD 326,400 and USD 620,100. In the first case, the optimal investment plan provides for the purchase of all machinery during the first year of the project; the second case covers a period of four years. The budget of capital investment reduces the implementation of the investment project due to the accumulation of external resources - USD 244,800 and USD 538,500 with or without operating costs, respectively. For these two alternatives, a minimum value of the investment program is also achieved when buying machinery only of the Ukrainian production. Moreover, the need to take borrowed funds occurs only during the first year of the project, in the amount of USD 244,800 in both cases.

Conclusions. This economic and mathematical model allows agricultural enterprises to establish investment volumes needed for the purchase of any particular type of equipment for agricultural production. Choosing the most appropriate source of investment can minimise investment costs and establish a rational investment portfolio under certain requirements and restrictions. This will allow agricultural enterprises to plan investments in the renewal of their facilities with regard to the production by the best option, given the productivity of agricultural machinery and the planned sowing areas.

Keywords: Dynamic Economic and Mathematical Model; Investment; Investment Projects; Technical Support; Agriculture

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Моделювання прийняття інвестиційних рішень щодо технічного забезпечення аграрних підприємств

Анотація. У статті розроблено динамічну економіко-математичну модель оптимізації інвестування технічного забезпечення аграрних підприємств. Визначено отримані альтернативні варіанти реалізації інвестиційного проекту, що оцінюються за чотирма критеріями оптимізації. Застосування запропонованої моделі дає змогу аграрним підприємствам оптимізувати прийняття господарських рішень щодо розподілу в часі інвестицій у придбання будь-якого окремого виду техніки для виробництва сільськогосподарської продукції та обрати найбільш прийнятне джерело інвестування, що, при дотриманні певних вимог і обмежень, дозволяє мінімізувати інвестиційні витрати та сформувати раціональний інвестиційний портфель.

Ключові слова: динамічна економіко-математична модель; інвестування; інвестиційний проект; аграрне виробництво.

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Моделирование принятия инвестиционных решений по техническому обеспечению аграрных предприятий

Аннотация. В статье разработана динамическая экономико-математическая модель оптимизации инвестирования технического обеспечения аграрных предприятий. Определены альтернативные варианты реализации инвестиционного проекта, которые оцениваются по четырем критериям оптимизации. Применение предложенной модели позволяет аграрным предприятиям оптимизировать принятие хозяйственных решений по распределению во времени инвестиций в приобретение любого отдельного вида техники для производства сельскохозяйственной продукции, а также выбрать наиболее приемлемый источник инвестирования, что, при соблюдении определенных требований и ограничений, позволяет минимизировать инвестиционные расходы и сформировать рациональный инвестиционный портфель.

Ключевые слова: динамическая экономико-математическая модель; инвестирование; инвестиционный проект; аграрное производство.

1. Introduction

Evolving economic environment which determines the existence of agricultural enterprises and high requirements to their activities demand implementation of investments in the expanded production of agri-food. Introduction of additional fixed assets, capital endowment and the capital raised due to additional investment resources provide productivity growth, production yield and production costs reduction. However, due to the delayed replacement of worn-out production facilities, inability to purchase materials and technical resources in accordance with the regulatory requirements, there has been a violation of the requirements to agricultural equipment and deadlines of certain technological operations. This is especially true of technical means, the supply of which is currently 40-50% at agricultural enterprises, while 85% of them have the expiring depreciation period and need to be renovated [1]. At the same time, the pressure on the equipment and machinery has increased: a normal level of output per one tractor in Ukraine is 90 hectares of arable land, whereas it comprises 28 hectares in the USA and for France this indicator is 14 hectares. The area of grain and leguminous crops, which accounts for the level of output per one harvester, in our country is 390 hectares, whereas in the USA, France and Germany it equals about 55 hectares [2].

The increased use of agricultural machinery is observed against the background of a significant decline in investment activity in the area, which further complicates the situation. Finding solutions to the problem of available investment sources and efficient use of investments is the basis for technological and organisational upgrading of production, innovations and competitiveness of products.

2. Brief Literature Review

The problem outlined in the article is of considerable interest. Methodical and practical recommendations to improve the efficiency of resource use when making investment decisions were developed by foreign scientists, such as I. Lipsits (Lipsits, 1996) [3], G. Birman and S. Shmidt (Birman, Shmidt, 1994) [4], G. Alexander, J. Beily and W. Sharp (Alexander, Beily, Sharp, 1995) [5]. The processes of modelling the best choice of options on investments is considered in the works by P. Masset (Masset, 1971) [6], D. Norkott (Norkott, 1990) [7] and L. Kruschwitz (Kruschwitz, 2012) [8].

The study of the dynamics and current regular patterns of investment in fixed assets of agricultural production is presented in the works by C. O'Toole, C. Newman and Th. Hennessy (O'Toole, Newman, Hennessy, 2011) [9], M. Lefebvre, K. De Cuyper, E. Loix, D. Viaggi and S. Gomez-y-Paloma (Lefebvre, De Cuyper, Loix, Gomez-y-Paloma, 2014) [10], L. Nabieva, L. Davletshina (Nabieva, Davletshina, 2015) [11].

N. Houssou, X. Diao and Sh. Kolavalli focus their attention on the issue of making rational investment decisions in the agricultural sector [12]. The authors give recommendations regarding alternative investment options of the logistical support for agricultural production, including purchase of technical means.

In the works by Peter R. Tozer (Tozer, 2009) [13], the attention is drawn to the fact that, under the conditions of uncertainty, it is insufficient to use standard criteria for evaluating the effectiveness of investments in the acquisition of technical means by agricultural commodity producers in order to make informed decisions. He substantiates the need for new approaches to the evaluation of the efficiency of investment alternatives, such as a real options method.

A significant contribution to the development of the issue of investment support for agricultural enterprises was also made by scientists M. Kodenska, P. Sabluk (Kodenska, Sabluk, 2012) [14], M. Demyanenko, M. Kisil, Yu. Lupenko (Demyanenko, Kisil, Lupenko, 2012) [15], N. Levchenko (Levchenko, 2012) [16] rightly points out that the competitiveness and technical support of the domestic agricultural sector are impossible without enhancing the investment activity.

Choosing the best source of investments to achieve the best results in the agricultural production, I. Novak and N. Verniuk (Novak, Verniuk, 2016) [17] suggest using the tools of economic and mathematical modeling. The studies by M. Chumachenko (Chumachenko, 2012) [18] and N. Karachyna (Karachyna, 2013) [19] also emphasise the need to develop economic and mathematical models in order to optimise investing.

Describing the general approach to optimization of investments, the mentioned works have become the basis for new approaches to the problems related to prioritizing of investment support of agricultural production, justification of the need for investment resources for technical and technological renovation of the branch, determining the most efficient ways of using and improving the efficiency of investments.

3. The purpose of the article is modelling optimal decisions in the process of investing in the facilities of agricultural enterprises under the conditions of limited access to investment resources.

4. Results

Extended and intensive agricultural production can be exercised only based on a system update of material and technical support. Among all the factors of intensification of the agricultural production, mechanization of production processes is viewed to be the most significant, which determines the priority of the relevant investments.

According to specialists of the National Scientific Centre «Institute of mechanisation and electrification of agriculture» of the National Academy of Agrarian Sciences of Ukraine (NAAS of Ukraine), the annual demand of money for the minimum scientifically proven renewal of the technical means in accordance with the technological need is UAH 35 billion or USD 1.4 billion (at a rate of UAH 25 to USD 1), including approximately 30 thousand tractors and 7.5 thousand combine harvesters [20]. The real situation is characterised by the negative dynamics of investments in technical upgrading, except 2015 (Table 1).

These processes are accompanied by a high value of disposal ratio of the agricultural equipment (in 2015 it was 111% for tractors and 135% for combine harvesters) [21]. All this has a negative impact on the resource potential of agricultural enterprises. One of the reasons for such a trend is the high level of depreciation of tractors, harvesting machinery and other types of farm machinery. The average indicator of depreciation of agricultural machinery is 70%, including 78% for tractors and 71% for harvesters [22]. In addition, a particularly acute problem for the agricultural enterprises of different sizes and types of ownership is the lack of sufficient investment resources for technological upgrading, combined with inflationary price increases (in 2014, the consumer price index in Ukraine amounted to 124%; in 2015 it was 149%) [23].

The consequence of the situation is a discrepancy of the number of agricultural machinery in Ukraine available for technological needs. According to the calculations [1], the number of tractors is now 45% of the needs of agriculture, combine harvesters - 48%, beet harvesting equipment - 17.6%, while the percentage for other types of equipment is from 35% to 60%. The indicator of the number of tractors and combines per 1,000 hectares of arable lands shows the poor level of provision with the main types of agricultural machinery in Ukraine, if compared to other countries (Figure 1).

The experience of the EU and the United States shows that farmers there are given a significant amount of public resources aimed at logistics. In particular, in 2012, the EU allocated EUR 42 billion for investment in fixed assets of the agricultural sector; in 2014, it was EUR 89.9 billion [25]. Also, maintenance services are commonly provided by technical centres of mechanical engineering firms. In the UK, for example, 70-90% of agricultural producers resort to their help [26]. In France, there exist co-operatives to share machinery. In Germany, machine centres and companies are created for this purpose rejecting the need for a significant amount of investment in the purchase of machinery by individual farms.

Ukrainian agricultural enterprises increase the level of technical support mainly at their own expense. Currently, the lack of sufficient investment resources for purchasing equipment is a particularly acute problem for the agricultural enterprises of different sizes and types of ownership. Therefore, if we consider the domestic machine-building complex, the efforts are aimed at making equipment which is several times cheaper than similar imported goods, however its disadvantage is somewhat lower productivity. Entities are often compelled to invest in the purchase of expensive foreign production equipment, which significantly increases the cost of finished products. Therefore, there is a need for agricultural producers to make managerial decisions on the most rational and economical use when buying equipment under the conditions of limited investment resources.

In order to make an optimal investment decision, a dynamic economic and mathematical model was developed to optimise investments of fixed capital. The use of this model will allow having efficient use of investment resources to renew the technical means for agricultural production with the limited investment support. The problem is solved by methods of linear programming in Microsoft Excel electronic processor under the «Search solutions». In justification, the task was to choose the best project from a given set in terms of the selected goal. Each of them was designed for a specific time period.

In this work, we consider the possibility of buying modern

Tab. 1: Dynamics of purchasing new agricultural machinery (tractors and combine harvesters) by Ukrainian agricultural enterprises

Indicator	2011	2012	2013	2014	2015
Purchased tractors, quantity	2983	3010	2788	1822	2095
Purchased tractors, total cost					
million UAH	1352.4	1471.9	1512.7	1305.5	2627.4
million USD	169.1	184.0	189.1	87.0	109.5
Purchased combine harvesters, quantity	925	621	600	389	521
Purchased combine harvesters, total cost					
million UAH	1288.6	877.6	869.4	749.0	1663.0
million USD	161.1	109.7	108.7	50.0	69.3

Source: [21]

domestic (KC-6Б-10 or PKM-6-07 - names in Ukrainian) and imported from France (M41 MH Matrot) beet combine harvesters. Information concerning cost, productivity, direct operating costs of technical means was included in the matrix obtained on the basis of the studies conducted by scientists at Scientific Research Institute of Productivity of Agroindustrial Complex and Lviv Branch of Leonid Pogorilyy Ukrainian Scientific Research Institute of Forecasting and Testing of Machinery and Technologies for Agricultural Production (L. Pogorilyy UkrNDIPVT) (see Table 2, hereinafter data are in USD, at a rate of UAH 25 / USD 1).

In general, the related problem can be solved by applying several functions, depending on the objectives (see Table 3).

The system of indicators, forming restrictions imposed on possible solutions, includes ten conditions (see Table 4).

In the recording of limitations of economic and mathematical problem, there are the following notations:

The optimal investment plans in the purchase of equipment according to the years of implementation of the investment project were received as a result of solving the economic and mathematical problem. Calculations were made for an area of 2,000 hectares. Comparing results of investment

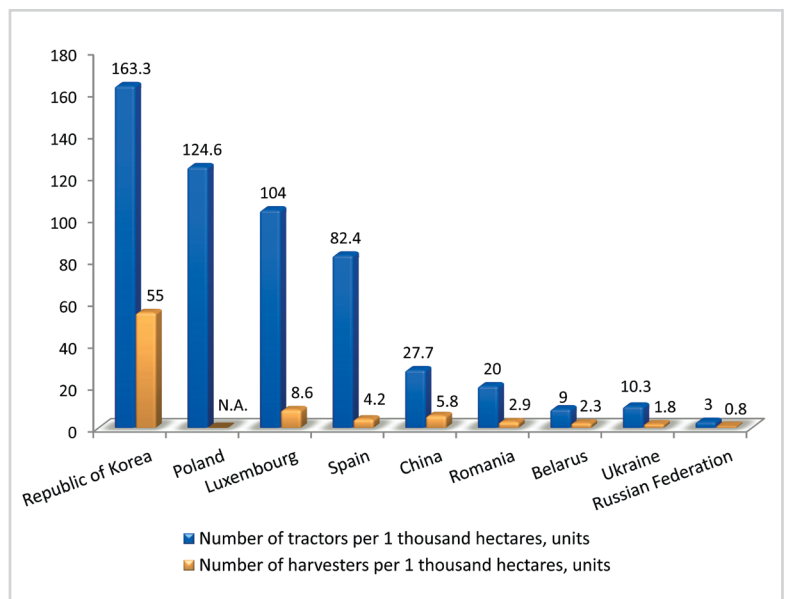


Fig. 1: The level of provision with the main types of agricultural machinery, units per 1,000 hectares of arable lands
Source: Compiled by the authors using [24]

Tab. 2: Technical and economic indicators of agricultural machines

Indicator	The name of the combine harvester		
Brand name of the combine harvester	PKM-6-07	KC-6Б-10	M41 MH Matrot
Productivity of the combine harvester, ha/h	1.17	1.14	1.46
Cost of the combine harvester, thousand UAH (thousand USD)	680 (27.2)	680 (27.2)	1718 (68.7)
Direct operating costs, UAH (USD) / ha	679.7 (27.2)	666.9 (26.7)	1174.1 (47.0)
including depreciation payments, UAH (USD)/ ha	290.6 (11.6)	298.3 (11.9)	588.4 (23.5)

Source: Made by the authors based on [27; 28]

Tab. 3: Alternative types of the objective function of the optimisation model of investing fixed capital for the agricultural enterprise

No.	The criterion of optimization	The objective function
1	The minimum cost of the investment project on buying equipment	$W = \sum_{t=1}^M y_t \rightarrow \min$
2	Minimum project cost, including operating costs when using equipment	$F = \sum_{t=1}^M y_t + \sum_{t=1}^M \bar{e}_t \rightarrow \min$
3	Minimum cost of the project in terms of investments that should be involved from external sources (e.g., loans) when using depreciation payments for investments for buying equipment	$U = y_1 + \sum_{t=2}^M Z_t \rightarrow \min$
4	Minimum cost of the project in terms of investments that should be involved from external sources, taking into account operating costs, provided that the depreciation payments in the application of technical means are aimed at investment purposes	$\varphi = y_1 + \sum_{t=2}^M Z_t + \sum_{t=1}^M \bar{e}_t \rightarrow \min$

Source: Compiled by the authors

Tab. 4: The system of restrictions of the optimisation model of investing fixed capital for the agricultural enterprise

No.	Condition	Restrictions
1	Condition for determining the cost of purchased equipment	$\sum_{j=1}^N c_j x_{ij} = y_t ; (t \in M)$
2	Condition for determining the area of yield gathered by each combine harvester during the t period	$b_j x_{ij} = s_{ij} ; (t=1) \quad s_{t-1,j} + b_j x_{ij} = s_{ij} ; (t=2,3,\dots, M)$
3	Condition for determining the amount of work (area) performed by combine harvesters during the t period	$\sum_{j=1}^N s_{ij} = \bar{s}_t ; (t \in M)$
4	Condition for the implementation of plans on the planted area of sugar beets	$\bar{s}_t \geq P_t ; (t \in M)$
5	Condition for the implementation of operating costs during the t period	$\sum_{j=1}^N e_j s_{ij} = \bar{e}_t ; (t \in M)$
6	Condition for determining depreciation payments during the t period, thousand UAH	$\sum_{j=1}^N a_j s_{ij} = \bar{a}_t ; (t \in M)$
7	Condition for distribution of depreciation payments during the t period	$\bar{a}_t = r_t + v_t ; (t \in M)$
8	Condition for the formation of sources of financing investments in the purchase of equipment during the t period	$y_t = z_t + r_{t-1} ; (t \in M)$
9	Condition for determining total operating costs during the whole period of the project	$\sum_{t=1}^M \bar{e}_t = E ; (t \in M)$
10	Condition for determining the total cost for equipment purchasing	$\sum_{t=1}^M y_t = Y ; (t \in M)$

Notes:

M - the quantity of periods in which there is investment for purchasing equipment;
 N - the quantity of types of technical means that are purchased due to investing;
 x_{ij} - the estimated amount of purchased combine harvesters of the j kind during the t period;
 s_{ij} - the area of yield gathered by the combine harvester of the j type purchased during the t period;
 P_t - the planned minimum area of crops during the t period;
 b_j - the planned output of the combine harvester of the j type during the whole period of harvesting is calculated using the formula: $b_j = h_j kd$, where h_j - the temporary standard of output of the combine harvester of the j type; k - the workday length; d - the number of working days during the harvesting period;
 c_j - the price of the combine harvester of the j type;
 e_j - regulatory operating costs for the combine harvester of the j type per 1 ha;
 \bar{e}_t - operating costs during the t period;
 a_j - depreciation payments using the combine harvester of the j type per 1 ha of crops;
 r_t - depreciation payments during the t period which can be aimed at the reinvestment (the purchase of new equipment);
 v_t - depreciation balances during the t period;
 Z_t - the amount of investments from external sources required for the purchase of a new equipment in the t period;
 W - the total cost for the purchase of equipment for m years;
 Y - the total cost for the purchase of equipment during the whole period of the project;
 E - total operating costs during the whole period of the project.

Source: Compiled by the authors

programs that differ in their optimality criterion, it is advisable to prefer domestically manufactured beet harvesters to all imported types (see Table 5).

The new equipment manufactured in Ukraine should help reduce production costs and, consequently, increase profitability. Hence, when planning expenditures for investment purposes, the enterprise should also focus on the possibility of reducing production costs by decreasing operating costs while using the equipment. The minimum of such costs is achieved when choosing an investment program by the second embodiment of the objective function (the lowest cost of the project taking into account operating costs). However, in this case the ratio of sources of investment maintenance of technical renewal is not taken into account. The results of the optimisation show that the borrowed funds are involved only in the first year of the project by the criterion of minimising the cost of the project in terms of investment which should be involved from external sources. Thus, the rest of costs for purchasing equipment (10 combine harvesters PKM-6-07 and 2 KC-6Б-10 for the whole period) will be covered by depreciation payments.

5. Conclusions
 As a result of the modelling, variants of the implementation of the investment project are developed to purchase the relevant equipment by agricultural enterprises. These variants are evaluated based on different criteria of the optimisation.

The study was conducted in respect of investments in the purchase of beet harvesters that would be used in the area of 2,000 ha. Moreover, the possibility of buying the Ukrainian machinery, as well as the equipment of foreign production, has also been considered. It has been found that, based on the criterion of minimising the cost of the investment project, purchasing of the Ukrainian machinery is preferred despite its lower productivity.

It has been determined that in case of investment financing exclusively from own sources, minimisation of costs for the project is provided due to purchasing 12 harvesters of the domestic production. Thus, the possibility of taking into account operating costs in cash flows does not change the final optimal structure of the planned number of machinery, affecting only the total cost of the investment project - UAH 8,160 thousand (USD 326.4 thousand) and UAH 15,503.3 thousand (USD 620.1 thousand). In the first case, the optimal investment plan provides for the purchase of all machinery during the first year of the project; the second case will cover a period of four years. The budget of capital investment reduces the implementation of the investment project due to the accumulation of resources from external sources - UAH 6,120 and UAH 13,463.5 thousand (USD 244.8 and USD 538.5 thousand) with or without operating costs, respectively. For these two alternatives, a minimum value of the investment program is also achieved when buying machinery only of the Ukrainian production. Moreover, the need to take borrowed funds occurs only during the first year of the project, in the amount of UAH 6,120 thousand (USD 244.8 thousand) in both cases. The remaining expenditures are planned to provide through the investment objectives of the depreciation charge of the cost of the harvesters.

Tab. 5: Optimal investment plans for the renewal of beet harvesters

Year of the project implementation	Indicators	The criterion of optimisation			
		Minimum cost of the investment project on the purchase of equipment		Minimum cost of the investment project on the purchase of equipment	
		without taking into account operating costs using equipment	without taking into account operating costs using equipment	without taking into account operating costs using equipment	without taking into account operating costs using equipment
1	Purchasing of PKM-6-07, unit of equipment	12	9	1	7
	Purchasing of KC-6Б-10, unit of equipment	0	0	8	2
	Purchasing of M41 MH Matrot, unit of equipment	0	0	0	0
	The cost of the project, thousand UAH (thousand USD)	8160.0 (326.4)	6120.0 (244.8)	6120.0 (244.8)	6120.0 (244.8)
	Operating costs, thousand UAH (thousand USD)	2098.1 (83.9)	1573.6 (62.9)	1573.8 (62.9)	1573.6 (62.9)
	Investments from other sources, thousand UAH (thousand USD)	-	-	6120.0 (244.8)	6120.0 (244.8)
2	Purchasing of PKM-6-07, unit of equipment	0	1	0	1
	Purchasing of KC-6Б-10, unit of equipment	0	0	1	0
	Purchasing of M41 MH Matrot, unit of equipment	0	0	0	0
	The cost of the project, thousand UAH (thousand USD)	0	680.0 (27.2)	680.0 (27.2)	680.0 (27.2)
	Operating costs, thousand UAH (thousand USD)	2098.1 (83.9)	1748.4 (69.9)	1748.7 (69.9)	1748.5 (69.9)
	Investments through depreciation payments, thousand UAH (thousand USD)	-	-	680.0 (27.2)	680.0 (27.2)
3	Purchasing of PKM-6-07, unit of equipment	0	1	0	1
	Purchasing of KC-6Б-10, unit of equipment	0	0	1	0
	Purchasing of M41 MH Matrot, unit of equipment	0	0	0	0
	The cost of the project, thousand UAH (thousand USD)	0	680.0 (27.2)	680.0 (27.2)	680.0 (27.2)
	Operating costs, thousand UAH (thousand USD)	2098.1 (83.9)	1923.2 (76.9)	1923.5 (76.9)	1923.3 (76.9)
	Investments through depreciation payments, thousand UAH (thousand USD)	-	-	680.0 (27.2)	680.0 (27.2)
4	Purchasing of PKM-6-07, unit of equipment	0	1	0	1
	Purchasing of KC-6Б-10, unit of equipment	0	0	1	0
	Purchasing of M41 MH Matrot, unit of equipment	0	0	0	0
	The cost of the project, thousand UAH (thousand USD)	0	680.0 (27.2)	680.0 (27.2)	680.0 (27.2)
	Investments through depreciation payments, thousand UAH (thousand USD)	-	-	680.0 (27.2)	680.0 (27.2)
	Investments from other sources, thousand UAH (thousand USD)	-	-	0	0
Number of purchased combine harvesters during the period of the project implementation					
PKM-6-07, unit of equipment		12	12	1	10
KC-6Б-10, unit of equipment		0	0	11	2
M41 MH Matrot, unit of equipment		0	0	0	0
Operating costs during the period of the project implementation, thousand UAH (thousand USD)		8392.3 (335.7)	7343.3 (293.7)	7344.4 (293.8)	7343.5 (293.7)
The total project cost during the period of the project implementation, thousand UAH (thousand USD)		8160.0 (326.4)	8160.0 (326.4)	8160.0 (326.4)	8160.0 (326.4)
The value of the objective function, thousand UAH (thousand USD)		8160.0 (326.4)	15503.3 (620.1)	6120.0 (244.8)	13463.5 (538.5)

Source: Calculated by the authors

In this research, the above economic and mathematical model allows individual agricultural enterprises to establish investment volumes needed for the purchase of any particular type of equipment for the agricultural production. The choice of the most appropriate source of investment minimises investment costs and establishes a rational investment portfolio under certain conditions and limitations. This will allow agricultural

enterprises to plan investments in the renewal of their facilities with regard to the production by the best option, given the productivity of agricultural machinery and the planned sowing areas. Further studies may be aimed at developing a range of tools to identify and optimise risks that accompany the practical implementation of investment projects under the conditions of instability and uncertainty.

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