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ECONOMIC FEASIBILITY OF REEQUIPMENT TERMS BASED ON PROFITABILITY CRITERION

The article deals with improved methodic approach to form initial profitability factor of production while solving the dynamic optimization problem of technological machinery substitution in the technical reequipment process based on the innovations.

Keywords: technologies, equipment, dynamic optimization, innovations, profitability, technical reequipment production.

Problem statement in general. One of the most urgent problems in modern economic development in Ukraine is necessity of production efficient technological reequipment in each industrial brunch. The problem is paid special attention owing to the development of cooperation between our state and European Union. It creates both economic opportunities and new challenges in the sphere of native products competitiveness growth, renovation of the main funds and technologies based on innovations. One of the effective mechanisms to ground technical reequipment of production, to substitute exhausted equipment is method of the dynamic optimization, which requires methodic approach improvement to form initial data, particularly profit size, calculated a priori, for the whole period of production system work.

Analysis of the recent research and publications. The conducted analysis of research and publications concerning stated problem confirms its urgency [1-10]. In the scientific work Kremer N.Sh. observes criteria of optimality and algorithm to solve reequipment task [1]. In his book Fedoseev V.V. determines possible strategies of the optimization [2] by Bellman's principle. The work of authors edited by Kuznetsov A.V. shows methods to form optimization models [3] with distinguishing of productive functions. The books of Troyanovsky V.M. [4] and Khazanova L.E. [5] demonstrate several approaches to form initial data in tasks of dynamic optimization, which require the further methodic improvement.

Goncharov V.V. [7] and Samochkin V.V. [8] in their research suggest methods of the industrial enterprises flexible technical and technological development using effective organizational and economic approaches, but the questions to formalize initial data in mathematic modeling tasks are shown very limited.

Kaplan's R.S. [9] and Markides's C. [10] works observe innovative approaches to organize system managerial processes within corporations. At the same time problems to renovate technical-technological production base grounded on profitability have to find efficient decision, particularly through dynamic optimization of reequipment terms.

Unsettled questions, which are part of the general problem. The monograph [6] on production technical reequipment innovative problems suggests methodic approach to solve the mentioned problem, but it requires to simplify for practical use conditions in real production terms.

The object of the article is to improve methodic to determine a priori initial data in order to solve optimization task concerning exhausted equipment substitution in the process of production technical reequipment.

Main material. Let's observe the suggested methodic approach to determine profit sum $P_i(t)$ within production value, made in *i*-year on equipment, the age of which for beginning of *i*-year is *t*-years. Index $P_i(t)$ is one of the main initial parameters, necessary to solve mentioned optimization task, considering time factors (economic after-action).

It's well-known, that production value, produced for *i*-year on the equipment *t*-years old, is:

$$V_i(t) = Q_i(t) \cdot S_i(t), \tag{1}$$

where $Q_i(t)$ – amount of production, produced in the *i*-year on the *t*-years old equipment; $S_i(t)$ – price of the production item, produced in *i*-year on the *t*-years old equipment.

Simultaneously, rentability $R_i(t)$ of the products, produced in the i-year on the equipment *t*-years old is determined by ratio:

$$R_{i(t)} = \frac{P_i(t)}{V_i(t)}. \tag{2}$$

Taking into account the above mentioned we can present $P_i(t)$ in such form:

$$P_i(t) = R_i(t) \cdot V_i(t). \tag{3}$$

Let introduce the presumption that annual amount of the produced goods $Q_i(t)$ is planned on the level of possible productivity $G_i(t)$ equipment which is *t*-years old, that annually decrease as a result of physical ageing, even considering planning and preventive, current and capital repairs, i.e. there is identity:

$$Q_i(t) = G_i(t). \tag{4}$$

Formula (3) to calculate profit sum $P_i(t)$ in the *i*-year can be given in the following way, considering (1-4):

$$P_i(t) = R_i(t) \cdot G_i(t) \cdot S_i(t). \tag{5}$$

Analyzing the formula (5), we can mention that indexes *R, G, S* are functions which are *t*-years old of technological equipment, i.e. they can be changed in the time space. Thus one needs to define character of these functional dependencies, that will allow to calculate profit amount $P_i(t)$.

Let's introduce one more presumption: the rentability value for the calculated period ($i = \overline{1,N}$ years) of the production system work is fixed:

$$R_i(t) = R = const. \tag{6}$$

For production item price index $S_i(t)$ it is reasonably to consider its dependence on the level of expected annual inflation. For this purpose we will introduce the prognosticated inflation coefficient K_{in}, which may be defined by the data of official sources from economic information or by the expert prognosticated estimations method.

For the beginning of the production system first working year ($i=1$) the production item

value $S_1(t)$ is calculated due to the price setting methodic at the concrete enterprise.

For the selected year (i) of the productive system work the production item value $S_i(t)$ considering prognosticated inflation coefficient can be calculated by formula:

$$S_i(t) = S_1(t) \cdot (1 + i \cdot K_{in}). \quad (7)$$

To determine productivity dynamics $G_i(t)$ of equipment we suggest on the basis of amortizing approach, which reflects the process concerning value and productive features decrease of the technological equipment in time space in relation to their initial (nominal) meanings, by the following algorithm.

According to the Statement (Standard) in business account S(S)BA-7 "Main means" one uses the following methods for amortization of the main funds: straightline, decrease of the remaining value, fast decrease of the remaining vale, cumulative, productive, tax. The observed further methodic approach may be used concerning any standard amortization method.

For each mentioned method annual norm of amortization A_p is calculated, that is index to decrease main funds object value and its technical-technological features decrease (including – productivity).

For the straightline method, which is distinguished by simple calculations of amortization and possibility its steady distribution in reported periods, annual amortization norm A_p is:

$$A_p = \frac{C_A}{N} = \frac{C_b - C_L}{N}, \quad (8)$$

where C_A – equipment value, that is amortized; N – term of the equipment use, years; C_b – balanced (initial) value of the main funds; C_L – liquidation value of the main funds.

To define productivity dynamics $G_i(t)$ of equipment we will use ageing coefficient $K_{(AG)i}(t)$, calculated on the base of A_p annual amortization norm:

$$K_{(AG)i}(t) = i \cdot \frac{A_p}{C_A}, \quad (9)$$

and coefficient of equipment workability $K_{(WA)i}(t)$, which is connected with ageing coefficient $K_{(AG)i}(t)$ with ration:

$$K_{(WA)i}(t) = 1 - K_{(AG)i}(t). \quad (10)$$

The workability coefficient determines ability of the equipment to conduct their productive functions on the level which correspond possibilities of its initial value undepreciated part. But one can define organization and technical factors which influence the increase or decrease of workability coefficient. These are particularly factors such as all repair and preventative works quality, level of the workers' qualification, who exploit machines, mechanisms, available conditions of the equipment productive exploitation.

To show the mentioned factors work let's introduce modification coefficient W, which may change (increase or decrease) calculated ageing and workability coefficients due to the standard methods, i.e. modify (correct) their values according to the act of real (negative or positive) equipment exploitation conditions.

According to the mentioned methodic approach we will suggest to use modified workability factors $K^{м}_{(WA)i}(t)$ and ageing factors $K^{м}_{(AG)i}(t)$ in the following form:

$$K^{м}_{(WA)i}(t)= 1 – K^{м}_{(AG)i}(t); \quad K^{м}_{(AG)i}(t)= W \cdot K_{(AG)i}(t). \tag{11}$$

Analytical sense to use modified ageing and workability factors is to determine real, considering some impact factors, dynamics of the gradual equipment productivity decrease $G_i(t)$ from its maximum value $G_1(t)$ (that is maximum value of the workability coefficient in the first exploitation year), to the productivity value, that corresponds minimum value of the workability coefficient in the last equipment exploitation year.

For any year (i) of the productive equipment work its productivity $G_i(t)$ can be calculated by formula:

$$G_i(t) = G_1(t)\cdot[K^{м}_{(WA)i}]. \tag{12}$$

The received equipment productivity factors due to the suggested method give opportunity to calculate a priori the profit value $Pi(t)$ in each year of the mentioned equipment exploitation. It is the main starting factor to solve tasks to substitute exhausted main funds by dynamic programming method.

To calculate modification coefficient W is suggested by expert estimations method, which are given by the involved experts (without limitation of their number), well-experienced in peculiarities and conditions of the concrete technological equipment exploitation.

The objects of the expert evaluation are the following n group of the equipment exploitation factors (n = 1...6):

– quality of the equipment plan and advanced repairs (n = 1);
– quality of the equipment current repairs (n = 2);
– quality of the equipment capital repairs (n = 3);
– quality of the workers' qualification, engaged in the equipment exploitation (n = 4);
– quality of the passport (standard) equipment exploitation conditions (n = 5);
– quality of the equipment exploitation specific conditions (n = 6).

The aim of the expert evaluation is to determine expert estimations concerning degree to keep nominal (project) equipment exploitation regimes.

Expert evaluation is carried out with the help of experts groups in number j persons (in the next example j = 1…5), who give their estimations (b_{jn}) by 10-point scale (b_{jn} = 1…10) for each (n) evaluating object. Bigger evaluation value corresponds to bigger level of the equipment exploitation quality. We suggest different and simplified approach relatively the item stated in the work [6]. At the same time 10-point scale is more substantial than 4-point scale, used in the mentioned above research.

After determination of the evaluations by experts (b_{jn}) for each expert evaluation object the average expert evaluation is calculated ($\bar{b}_n$):

$$\bar{b}_n = \sum b_{jn} : j\,. \tag{13}$$

Average expert evaluations for each object are used to calculate average expert evaluation ($\bar{b}_w$) in the whole evaluating objects group (n):

$$\bar{b}_w = \sum \bar{b}_n : n. \quad (14)$$

The next step is to define modification coefficient W by the following creative formula, proposed by us to use in calculations, considering approaches mentioned in the work [6, p. 141]:

$$W = 1 - k \cdot (b_0 - \bar{b}_w), \quad (15)$$

where $b_0 = 5,5$ – average value of the possible expert evaluations by the mentioned above scale; $k = (0,05\text{-}0,07) - W$ critical delimitation coefficient, that defines possible diapason of modification coefficient values from W_{min} to W_{max}.

For the selected diapason of expert evaluations $b_{jn} = 1...10$ the calculated modification coefficient values will be located within:

under k = 0,05
$$\begin{cases} W_{max} = [1\text{-}0,05(5,5\text{-}10)] = 1,225; & (16) \\ W_{min} = [1\text{-}0,05(5,5\text{-}1)] = 0,775; & (17) \end{cases}$$

under k = 0,07
$$\begin{cases} W_{max} = [1\text{-}0,07(5,5\text{-}10)] = 1,315; & (18) \\ W_{min} = [1\text{-}0,07(5,5\text{-}1)] = 0,685. & (19) \end{cases}$$

The choice of critical delimitation coefficient (k) is agreed by the expert group together with technical specialists from enterprise (workshop, productive department) before expert evaluation considering technological processes peculiarities in some production types, existing experience of exploitation and equipment workability renewal.

Then possible diapason of modified workability coefficient values $K^{м}_{(WA)i}(t)$ is determined depending on the critical delimitations coefficient:

under k = 0,05:

$$max\{K^{м}_{(WA)i}(t)\} = W_{max} \cdot K_{(WA)i}(t) = 1,225 \cdot K_{(WA)i}(t); \quad (20)$$
$$min\{K^{м}_{(WA)i}(t)\} = W_{min} \cdot K_{(WA)i}(t) = 0,775 \cdot K_{(WA)i}(t); \quad (21)$$

under k = 0,07:

$$max\{K^{м}_{(WA)i}(t)\} = W_{max} \cdot K_{(WA)i}(t) = 1,315 \cdot K_{(WA)i}(t); \quad (22)$$
$$min\{K^{м}_{(WA)i}(t)\} = W_{min} \cdot K_{(WA)i}(t) = 0,685 \cdot K_{(WA)i}(t). \quad (23)$$

To represent the suggested methodic approach the Table 1 gives expert evaluations (b_{jn}) to calculate modification coefficient W (based on the control example).

As a result (Table 1) of the conducted expert evaluation concerning production equipment exploitation conditions quality, there was determined impact diapason of the modification coefficient W on the workability coefficient value $K_{(WA)i}(t)$ calculated by standard *S(S)BA*-7 "Main means", upwards with $W < 1$ or downwards (with $W > 1$) within $\pm$ 22,5% (choosing critical delimitation coefficient k = 0,05) and within $\pm$ 31,5% (with k = 0,07).

Table 1 – **Expert evaluations (b_{jn}=1…10) to define ageing modified coefficients $K^{M}_{(AG)i}(t)$ and workability $K^{M}_{(W)i}(t)$ of the technological equipment**

Expert evaluation objects (n = 1…6)	Expert evaluations (b_{jn}), j = 1…5 – number of experts, n – number of expert evaluation objects					Average expert evaluation for separate objects $\bar{b}_n = \sum b_{jn}:j$
	Expert j =1	Expert j = 2	Expert j = 3	Expert j = 4	Expert j = 5	
Quality of the equipment plan and advanced repair (n = 1)	b_{11} = 7	b_{21} = 6	b_{31} = 5	b_{41} = 4	b_{51} = 5	$\bar{b}_1$ = 5,4
Quality of the equipment current repairs (n = 2)	b_{12} = 6	b_{22} = 6	b_{32} = 6	b_{42} = 4	b_{52} = 4	$\bar{b}_2$ = 5,2
Quality of the equipment capital repairs (n = 3)	b_{13} = 4	b_{23} = 4	b_{33} = 5	b_{43} = 4	b_{53} = 5	$\bar{b}_3$ = 4,4
Quality of the workers' qualification, (n = 4)	b_{14} = 6	b_{24} = 8	b_{34} = 9	b_{44} = 9	b_{54} = 7	$\bar{b}_4$ = 7,8
Quality of the passport (standard) equipment exploitation conditions (n = 5)	b_{15} = 6	b_{25} = 5	b_{35} = 4	b_{45} = 4	b_{55} = 4	$\bar{b}_5$ = 4,6
Quality of the equipment exploitation specific conditions: vibration level, irradiating, dusting etc (n = 6)	b_{16} = 8	b_{26} = 7	b_{36} = 9	b_{46} = 8	b_{56} = 6	$\bar{b}_6$ = 7,6
Average expert evaluation on the group of objects: $\bar{b}_w = \sum \bar{b}_n : n$						$\bar{b}_w$ = 35,0:6 = 5,83
Modification coefficient: $W = 1 - k(b_0 - \bar{b}_w)$, where b_0 = 5,5 – average value of the possible expert evaluations; $k - W$ critical delimitations coefficient						W=1 – 0,05·(5,5 – 5,83) = = 0,9835
Workability modified coefficient: $K^{M}_{(WA)i}(t) = 1 - K^{M}_{(AG)i}(t)$						
Ageing modified coefficient: $K^{M}_{(AG)i}(t) = W \cdot K_{(AG)i}(t)$						

Graphic representation of the modification coefficient W on the workability coefficient $K_{(WA)i}(t)$ dynamics is shown in Figure 1.

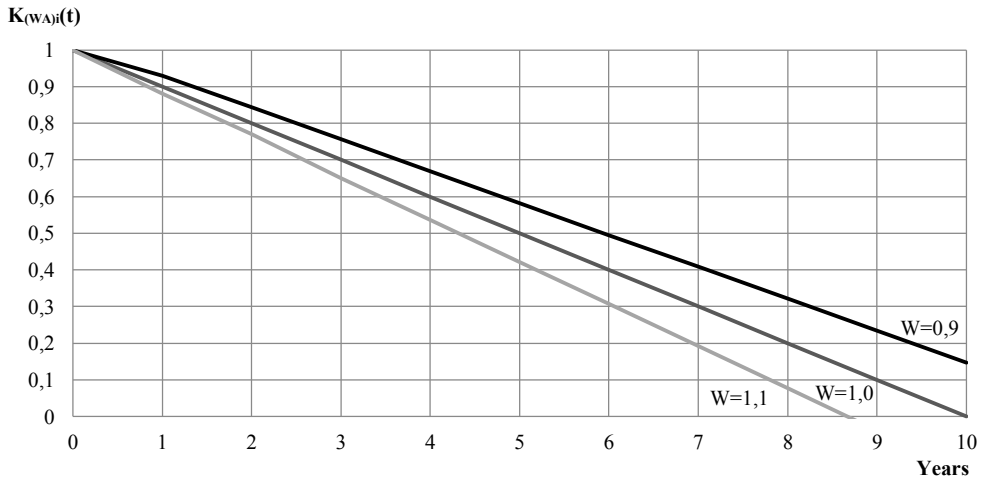

Figure 1 – **Equipment workability coefficient dynamics $K_{(WA)i}(t)$ (control example) depending on modification coefficient impact W**

With $W < 1$equipment workability is increased to conduct its productive functions and its useful exploitation term is prolonged. Vice versa with $W > 11$ equipment workability is decreased to conduct its productive functions and its useful exploitation term is shortened. Based on the conducted transformations (6-23) formula (5) of the profit value $P_i(t)$ as part of the production cost, produced in each i-year on the equipment which is t years old may be given in the following form:

$$P_i(t) = R \cdot G_1(t) \cdot [K^{M}_{(WA)i}(t)] \cdot S_1(t) \cdot (1 + i \cdot K_{IH}). \quad (24)$$

To conduct calculations in reequipment process optimization task one can suppose that formula (24) about profit value is self-sufficient. But it is reasonably to propose improved approach for profit calculation and use, based on factor of $P_i(t)$ possible economic after-action.

The after-action factor is supposed assumptions of possibility to separate profit part, received in any production system working year, with purpose of its further deposit use, i.e. investment to the depositary banking account to get additional (depositary) profit. Such approach to use profit can form additional source of finances, oriented to the technical reequipment and to organization of innovative products output.

Let's introduce coefficients to carry out necessary calculations:

1) $\beta_{(CUR)i} = \overline{0,1}$ – profit current use $P_i(t)$, received in i-year, that defines its part which is directed to the enterprise current needs;

2) $\beta_{(DEP)i} = \overline{0,1}$ – profit depositary use $P_i(t)$, received in i-year, that defines its part which is directed to get additional depositary profit.

The condition to apply mentioned coefficients is:

$$\beta_{(CUR)i} + \beta_{(DEP)i} = 1. \quad (25)$$

Considering given presumptions profit value $P_i(t)$ may be given in the next way:

$$P_i(t) = P_{(CUR)i}(t) + P_{(DEP)i}(t), \quad (26)$$

where $P_{(CUR)i}(t)$ – part of the profit value $P_i(t)$, established for current use at the enterprise and $P_{(DEP)i}(t)$ – part of the profit $P_i(t)$, established to invest on the depositary banking account in the period from i-year to N-year of the dynamic optimization process, i.e. for term $(N - i)$-years.

$$P_{(CUR)i}(t) = \beta_{(CUR)i} \cdot P_i(t); \quad (27)$$

$$P_{(DEP)i}(t) = \beta_{(DEP)i} \cdot P_i(t). \quad (28)$$

Thus, the final formula to get profit $P_i(t)$ from product output on the equipment which is years old, considering economic after-action factor (capitalization of profit) is given in the following way:

$$P_i(t) = P_{(CUR)i}(t) + P_{(DEP)i}(t) \cdot [1 + d]^{N-i}, \quad (29)$$

where *(N – i)* – period of the profit part depositary saving; *d* – prognosticated value of the annual banking depositary rate.

The proposed methodic approach and imputed analytical – computation algorithm gives opportunity to determine profit value a priori $P_i(t)$ for any *i*-year of the technological equipment work for substitution terms further optimization using standard dynamic programming methods [1-5].

To illustrate the suggested methodic approach the Table 2 presents calculating factors of technological equipment exploitation – test bench КС – М to to check electrical commutative bundles, produced by enterprise LLC SPE "Electric equipment ОК" (Kharkiv) for motor-and-tractor branch needs.

Table 2 – **Factors of the technological equipment exploitation considering modification coefficient *W* impact**

Factor of the equipment exploitation	Numeral values of equipment exploitation factors during i = 1…6 years					
	i = 1	i = 2	i = 3	i = 4	i = 5	i = 6
1.Ageing coefficient due to S(S)BA-7	0,0	0,2	0,4	0,6	0,8	1,0
2.Workability coefficient due to S(S)BA-7	1,0	0,8	0,6	0,4	0,2	0,0
3.Modified ageing coefficient	0,0	0,1967	0,3934	0,5901	0,7868	0,9835
4.Modified workability coefficient	1,0	0,8033	0,6066	0,4099	0,2132	0,0165
5.Profit from equipment use (th. UAN) considering modification coefficient	94,08	83,67	69,30	50,96	28,65	2,38

Technical and economic factors of the equipment: equipment initial productivity $G_1 = 600$ wares per year; price per product unit in the first production year $S_1 = 0,7$ thousand UAH; prognosticated annual inflation coefficient $K_{IN} = 0,12$ (12%); plan rentability $R = 0,2$ (20%); plan term of the equipment use 6 years; cost of the equipment that is amortized $C_A = 240,0$ thousand UAH; annual norm of amortization $A_a = 40$ thousand UAH.

The modification coefficient $W = 0,9835$, defined by the expert data (Table 1) is used for calculations, results of which are shown in the Table 2. As coefficient $W < 1$, it influences decrease of the ageing coefficient and, properly, increases equipment workability annual coefficient due to the calculations according to S(S)BA-7. The row 5 (Table 2) presents annual profit value obtained from equipment exploitation, which can be used as initial data to calculate a priori terms of the main funds substitution by the dynamic optimization method.

In the given example we take a priori presumption, that annual profit sums are fully used for enterprise current needs, including for its technical reequipment, without distinguishing of some profit part for depositary use. The coefficient of the current profit use due to the formula (25) is: $\beta_{(CUR)} = 1$.

Conclusions and areas for further studies. After conducted studies author investigates improved methodic to form profit size $P_i(t)$ from equipment work during *N* years, as a priori – calculated value, to use dynamic programming method in tasks for production technical reequipment feasibility.

It is also suggested to differentiate calculated profit size $P_i(t)$ per each year of the

production system work, for separate constituents with possibility to use both for current needs for technical reequipment and for profit part capitalization, particularly through depositary banking multiplication.

Scientific novelty consists in investigation of the improved approach to form initial data to solve optimization task of equipment substitution during technical reequipment. It has either theoretical and methodological meaning, or practical orientation in terms of real production systems, provides much confidence and quality to make managerial decisions.

As perspective for further studies one can propose methodic improvement of the a priori total costs determination for equipment exploitation and repair, as one of the significant starting factors in the dynamic programming task in the production technical reequipment process. It will provide more rational usage of resources to renovate production base at the enterprise.

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Економічне обґрунтування термінів заміни устаткування на засадах критерію прибутковості

У статті запропоновано удосконалений методичний підхід до формування вихідного показника прибутковості виробництва при вирішенні динамічної оптимізаційної задачі заміни технологічного устаткування в процесі технічного переоснащення підприємства на основі інновацій.

Ключові слова: технології, устаткування, динамічна оптимізація, інновації, прибутковість, технічне переоснащення виробництва.

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Экономическое обоснование сроков замены оборудования на основе критерия прибыльности

В статье предложен усовершенствованный методический подход к формированию исходного показателя прибыльности производства при решении динамической оптимизационной задачи заменены технологического оборудования в процессе технического переоснащения предприятия на основе инноваций.

Ключевые слова: технологии, оборудование, динамическая оптимизация, инновации, прибыльность, техническое переоснащение производства.

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