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ECONOMIC SECURITY OF THE INDUSTRIAL ENTERPRISE IN THE FRAMEWORKS OF BUSINESS PROCESS REENGINEERING

Purpose. Formation of an economic and mathematical model as an economic platform for the protection of industrial enterprises in order to implement economic security in the frameworks of business process reengineering.

Methodology. The following methods were used in the research process: methods of theoretical generalization and comparison, analysis and synthesis (to determine the meaning of the concept of "economic security of the enterprise"), statistical method (to analyze the initial data), economic and mathematical modeling of the compositional restructuring of an economic unit – an industrial enterprise (to determine conditions under which it is advisable to reengineer the business processes of an economic unit in order to form a platform of economic security).

Findings. The results are determined by the fact that the theoretical provisions of the paper are brought to the level of specific proposals and have a form suitable for use in practical activities. An example of the practical application of the proposed economic and mathematical model is presented as illustrated by Pivdennyi Mining and Processing Plant (MPP) PJSC, where the essence of the given analysis is revealed. The obtained results proved their effectiveness and feasibility of use at the relevant domestic industrial enterprises.

Originality. For the first time, an approach to the development of economic security of the enterprise on the basis of business process reengineering has been proposed. Economic-mathematical modeling has gained further development in determining the conditions for the feasibility of implementing structural transformations of an economic unit to obtain optimal values of indicators that reveal the essence of the economic security of an industrial enterprise.

Practical value. The analysis of modeling results makes it possible to propose the implementation of imperatives – economic security of the enterprise on the basis of the implementation of its restructuring. Application of the proposed model provides a means to ensure rapid adaptability of industrial enterprises to changes, high flexibility and adaptability of all elements of the system, autonomy and economic functioning of enterprises as a whole and their structural subdivisions. The practice of using the developed economic and mathematical model based on reengineering confirmed the obtained theoretical results.

Keywords: *compositional restructuring, industrial enterprise, economic security, economic and mathematical model*

Introduction. The processes of transformation of the domestic industry require an all-around study and analysis of the results of the enterprise's activities in order to ensure the appropriate stability of its own functioning. Industry has been and remains the engine of the domestic economy. Fast-flowing integration processes in the modern operating conditions of industrial enterprises require the formation and effective use of certain competitive advantages, which should contribute to the development of productive forces, scientific and technical progress, etc. The dynamic character of changes in the external environment requires business entities to anticipate and quickly respond to possible threats. The problem of ensuring economic security is aggravated by some inconsistency of theoretical research with the needs of enterprises in the real sector of the economy. Modern economic conditions of the state require the practical foundations of building a system of economic security of the enterprise rather than the formation of conceptual foundations. Ensuring the stable implementation of the main commercial interests, protection from destabilizing internal and external factors keep up to date the problem of economic security of industrial enterprises on the basis of business process reengineering.

Literature review. The analysis of scientific and practical publications makes it possible to generalize the latest approaches to the concepts of the essence and practical content of the economic security of the enterprise. Despite the significant number of scientific developments, the general definition of the economic security of the enterprise remains controversial. The most progressive approach is the development of the concept and strategy of economic security, closely related to the enterprise's mission and set goals, which allows one to largely prevent the emergence of threats. Researchers E. A. Ivchenko and Yu. A. Ivchenko conducted an analysis of

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approaches to understanding the economic security of the enterprise. The essence of micro-level security was revealed. The properties, functions, structure, status, modes of operation of the economic security system of the enterprise are shown [1, 2]. Lubents I. O. carried out an analysis of the definitions of "economic security of the enterprise". The definition of the concept of "economic security of the enterprise" within the framework of the cost approach has been proposed, and the need to understand the "economic security of the enterprise" as a dynamic system has been emphasized. The necessity of the definition of "economic security of the enterprise" from the standpoint of the nature of the enterprise has been proven [3]. The main elements of the system of economic security of joint-stock companies have been studied by researchers Hryniuk O. S., Korchovna [4]. The most meaningful can be considered the research by K. O. Utenkova, who investigated the multi-vector nature of judgments regarding the principles of the economic security system, which are set forth in the scientific works by leading scientists. She singled out forty-three principles of the economic security system, which are scrutinized in certain combinations by various research authors [5]. Some of the theoretical research in the field of economic security is focused on the protection of enterprise resources from already existing threats or on eliminating the consequences of their influence. Thus, Samal S. A. and Samal L. S. studied the evolution of the concepts of "sustainability" and "economic security of the enterprise" and proposed consideration of the concept of "sustainability of the enterprise" under the lens of economic security [6]. Scientists Kalinichenko L. L., Ship K. V. emphasize the need for the enterprise to adapt to changes in external and internal factors that determine possible crisis phenomena and are a guarantee of survival and development of production [7]. On the contrary, Yarov Yu. O. and Artemenko L. P. define economic security as a system of functional components. The main purpose of each functional component of the enterprise's economic security has been studied [8]. Among the scientific papers of a practical focus, it is possible to single out the research by I. V. Kolodiazhna and K. A. Bukrina, who analyzed and proposed the use of the main effective measures in the system of sustainable functioning of the enterprise [9]. V. L. Dykan and I. V. Volovelska proposed a method of express diagnostics of the enterprise economic security system, which, according to the experts, will reveal the "bottlenecks" of the system for taking further measures to eliminate them. We determined the coefficients of private indicators for assessing the enterprise potential and its competitiveness [10]. The research by O. A. Sorokivska is devoted to the assessment of management functions in ensuring the economic security of a small business enterprise [11]. We consider the studies by D. M. Kvaschuk, which are devoted to the analysis of information and analytical provision of economic security of industrial enterprises, to be rather interesting. The author considered the processes of information and analytical provision of economic security. Research was conducted on the formation of a model of information and analytical support for the economic security of industrial enterprises [12]. Foreign scientists also pay attention to the problem of economic security. Publications of scientists [13, 14] correlate economic security with a certain risk. Appropriate management steps in the business environment to reduce risks are suggested. Scientists logically assume the disruptive effect of risks on the economic security of the enterprise. Summarizing the main results of the analysis of scientific research, we can state that there is not currently any unified approach to ensuring the economic security of the enterprise. High moral and physical wear and tear of the main production assets, lack of financial resources, rupture of cooperative ties put most of the enterprises in the real sector of the economy in a difficult financial situation. As a result, there is a problem of forming and implementing economic security systems capable of providing conditions for reducing the level of threats to the activities of enterprises, which becomes one of the most important tasks of science and practice. Therefore, we consider it expedient to propose a new approach and, in general, an innovative trend regarding the practical provision of the economic security of the enterprise is connected with the need to transition to an active strategy of protecting the economic platform of industrial enterprises. As one of the possible ways of implementing such an approach, there is reengineering of economic entities through their division in order to increase profits while maintaining economic efficiency.

Unsolved aspects of the problem. Without diminishing the importance of the latest domestic and foreign scientific and applied achievements in solving the problems of ensuring the economic security of enterprises, we should note a certain lack of attention to the issue of the formation of imperatives for ensuring the economic security of enterprises on the basis of reengineering with the use of economic-economic-mathematical modeling.

The purpose of the article. Formation of an economic and mathematical model as an economic platform for the protection of industrial enterprises for the realization of economic security in the frameworks of business process reengineering.

Methods. For modern market relations of Ukraine, one of the most important issues is achieving the maximum profit of the economic entity while preserving their economic stability. The solution to this objective should be considered from the standpoint of the possibility of compositional restructuring of the economic entity. Such restructuring involves the application of the reengineering process for the effective functioning of an industrial enterprise (in the presence of fierce competition), with the aim of ensuring economic security. The application of the economic and mathematical modeling method makes it possible to synthesize models on the basis of a systemic approach, with the help of which it is possible to carry out simulation modeling based on the means of modern computer technology.

When building an economic and mathematical model of the compositional restructuring of the economic entity by dividing them, it is postulated that it is advisable to proceed from a deep economic qualitative-quantitative analysis of the researched processes. Such an analysis allows controlling its adequacy and logical consistency at each stage of model synthesis.

At the first stage of building an economic and mathematical model of the compositional restructuring of the economic entity, it is natural to highlight the value of the basic economic funds (BEF), which, in fact, lay the foundation for the activity of the economic entity. Economic analysis shows that the real value of the basic economic funds is lower and can be approximated by the function [13]

$$S_1 = S \cdot e^{-\alpha \cdot S}, \quad (1)$$

where S is the value of the basic economic funds, conditional units; S_1 – real value of the basic economic funds, conditional *units;* α – a parameter that takes into account the rate of decline in the value of basic economic funds, 1/conditional units.

Fig. 1 presents the functional dependence of the real value of the basic economic funds (S_1) on the value of the basic economic funds (S). The dashed line shows the ideal option, when the entire value of the basic economic funds ($\alpha = 0$) is realized, the solid line corresponds to (1) ($\alpha = 1$).

Analysis of graphs in Fig. 1 shows that at small cost value of the basic economic funds, the actual value of the basic economic funds increases, but lags behind the ideal option in terms of speed. Then the actual value of the basic economic funds reaches its maximum value (at $S = 1/\alpha$) and then begins to decrease.

The real value of the basic economic funds determines the value of normalized current assets (NCA) of the economic entity and can be approximated by the function

$$S_2 = S_1 \cdot (1 - e^{-\beta \cdot S}), \quad (2)$$

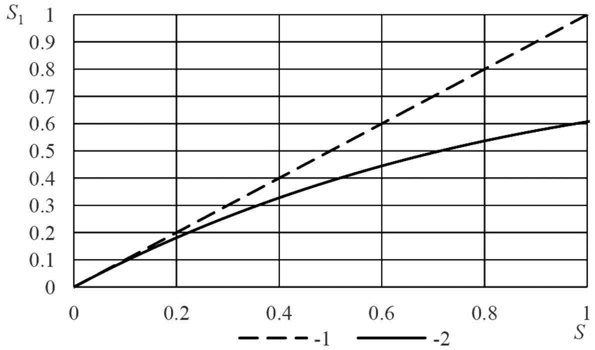

Fig. 1. Dependence of the real value of the basic economic funds on the ideal value of the basic economic funds:
1 – ideal option ($\alpha = 0$); *2 – real option* ($\alpha = 1$)

where S_2 is a value of normalized current assets, conditional units; β is a parameter characterizing the rate of fund return, 1/conditional units.

If the exponent on the right-hand side of formula (2) can be approximated by a linear function, then formula (2) is simplified and becomes

$$S_2 = \beta \cdot S_1 . \tag{3}$$

Fig. 2 shows graphical dependences of the value of normalized current assets on the real value of normalized current assets, calculated according to formulas (2 and 3).

The analysis of the graphs shown in Fig. 2 shows a fairly accurate coincidence of them, which allows us to use the simpler (3).

The income received as a result of the activity of the economic entity is proportional to the value of the normalized current assets, i. e

$$D = q \cdot S_2, \tag{4}$$

where D is an income of the economic entity, *conditional units*; q is a parameter that determines the contribution of the value of the normalized current assets to the income.

Formulas (1, 3 and 4) can be written in the form of ratio ratings

$$\frac{S_1}{S} = e^{-\alpha \cdot S}; \quad \frac{S_2}{S_1} = \beta \cdot S_1^2; \quad \frac{D}{S_2} = q. \tag{5}$$

Then the income of the economic entity, according to (5), is recorded in the form

$$D = \beta \cdot q \cdot S^2 \cdot e^{-2\alpha \cdot S}. \tag{6}$$

Whereas, the profit will be recorded as the difference between the income and the value of the basic economic funds of the economic entity

$$P = D - S,$$

or, taking into account (6),

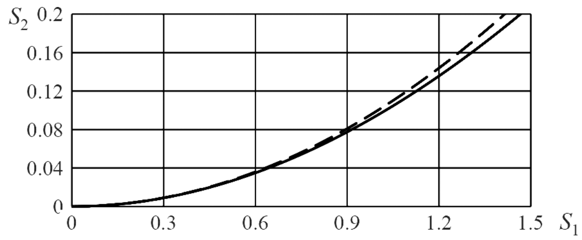

Fig. 2. Dependence of the value of the normalized current assets on the real value of the normalized current assets:
1 – calculation according to (2); *2 – calculation according to formula* (3), ($\beta = 0.1$)

$$P = S \cdot (\beta \cdot q \cdot S \cdot e^{-2\alpha \cdot S} - 1). \tag{7}$$

Economic effectiveness of the economic entity

$$E = \frac{P}{S},$$

or according to (7)

$$E = \beta \cdot q \cdot S \cdot e^{-2\alpha \cdot S} - 1 \tag{8}$$

is natural to be considered as a criterion of economic sustainability of the economic entity.

As a general matter, the objective of optimal management of the economic entity based on the developed economic and mathematical model given by formulas (7 and 8) can be formulated as follows: to ensure the maximum profit of the economic entity with economic efficiency, i. e. economic sustainability, which is not less than the specified value.

Mathematically, such a problem can be written in the following way

$$P(S) \to \max_S; \tag{9}$$

$$E(S) \geq E, \tag{10}$$

where E is a given value of economic efficiency, which ensures the lower limit of economic sustainability of the economic entity, *conditional units*.

However, under the process of setting real objectives, when the maximum profit is achieved, it may turn out that the profit obtained is insufficient. This results in the need to supplement the setting objectives (9, 10) with a condition

$$P(S) \geq \underline{P}, \tag{11}$$

where $\underline{P}$ is a given minimum allowable profit of the economic entity, *conditional units*.

In the expanded form, optimal control objective (9, 10 and 11), according to (7 and 8), will be written in the form

$$\begin{cases} S \cdot (\beta \cdot q \cdot S \cdot e^{-2\alpha \cdot S} - 1) \to \max\limits_S \\ S \cdot (\beta \cdot q \cdot S \cdot e^{-2\alpha \cdot S} - 1) \geq \underline{P} \\ \beta \cdot q \cdot S \cdot e^{-2\alpha \cdot S} - 1 \geq E \end{cases}. \tag{12}$$

To solve the problem (12), it is advisable to switch to dimensionless quantities by introducing the notation

$$\hat{P} = \alpha \cdot P; \quad \hat{S} = \alpha \cdot S; \quad \gamma = \frac{\beta \cdot q}{\alpha}; \quad \hat{P} = \alpha \cdot \underline{P}. \tag{13}$$

Then formulas (6 and 8) will respectively take the following form

$$\hat{P} = \hat{S} \cdot \left(\gamma \cdot \hat{S} \cdot e^{-2\hat{S}} - 1\right); \tag{14}$$

$$E = \gamma \cdot \hat{S} \cdot e^{-2\hat{S}} - 1. \tag{15}$$

It should be emphasized that equalities (14 and 15) can be considered as a parametric representation of the economic and mathematical model of the economic entity, which connects the profit of the economic entity with its economic efficiency, and the value of the basic economic funds acts as a parameter

$$\begin{cases} \hat{P} = \hat{S} \cdot E \\ E = \gamma \cdot \hat{S} \cdot e^{-2\hat{S}} - 1 \end{cases}. \tag{16}$$

Excluding the parameter from the system of equations (16), you can get a clear representation of the dependence of profit on economic efficiency. Indeed, using the first equation from the system of equations (16), we find

$$E = \gamma \cdot \frac{\hat{P}}{E} \cdot e^{-2\frac{\hat{P}}{E}} - 1. \tag{17}$$

The obtained equation (17) is non-linear and does not allow the analytical solution of one variable relative to another. Using the root function, which is part of the Mathcad software package, equation (17) was numerically solved for different values of the parameter γ and the graphs depicted in Fig. 3 were constructed. Analysis of graphs in Fig. 3 shows that one value of economic efficiency corresponds to two values of profit, except for extreme points. The lower value of the profit corresponds to a small value of the profit cost, a large value of the profit cost corresponds to the upper value. Extreme values of profit and economic efficiency can be discovered by finding the extremes of functions (14 and 15).

By equating the derivative of function (14) to zero, we obtain an equation that determines the cost value of the basic economic funds, which corresponds to the maximum amount of profit.

$$\frac{d\hat{P}}{d\hat{S}} = 2\cdot\gamma\cdot\hat{S}\cdot e^{-2\cdot\hat{S}}\cdot(1-\hat{S})-1=0. \quad (18)$$

Equation (18) is transcendental and can be solved only by the numerical method. Using the root function, which is included in the Mathcad program complex, depending on the parameter, the roots of equation (18) and, according to (14), the largest amount of profit were found. The results of the calculations were approximated by polynomials using the method of least squares. Thus, the formula for calculating the optimal amount of the basic economic funds was applied by a second order polynomial

$$\hat{S}_{opt}(\gamma) = -0.006\cdot\gamma^2 + 0.137\cdot\gamma - 0.063, \quad (5.5 \le \gamma \le 10). \quad (19)$$

In its turn, the formula for calculating the maximum profit margin takes the form

$$\hat{P}_{\max}(\gamma) = 0.1124\gamma - 0.618, \quad (5.5 \le \gamma \le 10). \quad (20)$$

The dependence of the maximum profit margin on the optimal cost value of the basic economic funds was approximated by a second-order polynomial

$$\hat{P}_{\max}(\hat{S}_{opt}) = 8.931\hat{S}_{opt}^2 - 8.436\hat{S}_{opt} + 1.993. \quad (21)$$

In this case, determination coefficients in formulas (19, 21 and 22) were greater than 0.998, which, according to the Cheddock scale, determines a very high level of the constraint force between variables [15, 16].

By equating the derivative from function (15) to zero, we obtain an equation that determines cost value of the basic economic funds, which corresponds to the maximum value of economic efficiency

$$\frac{dE}{d\hat{S}} = \gamma\cdot e^{-2\hat{S}}\cdot(1-2\cdot\hat{S}) = 0. \quad (22)$$

Having solved the equation (22), we find the cost value of the basic economic funds, which corresponds to the largest value of economic efficiency

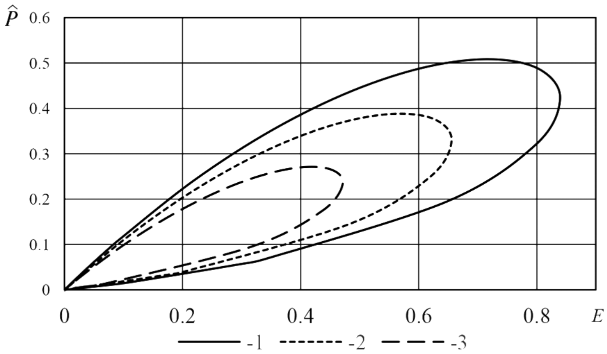

Fig. 3. Graphic representation of the dependence of profit on economic efficiency:
1 – γ = 10; 2 – γ = 9; 3 – γ = 8

$$\hat{S}_E = \frac{1}{2}. \quad (23)$$

Substituting (23) into formula (15), we find the greatest value of economic efficiency

$$\hat{E}\frac{\gamma}{2e_{\max}}. \quad (24)$$

In dimensionless form, the optimal control problem (12) can be written as follows

$$\begin{cases} \hat{S}\cdot(\gamma\cdot\hat{S}\cdot e^{-2\hat{S}}-1) \to \max\limits_{\hat{S}} \\ \hat{S}\cdot\left(\gamma\cdot\hat{S}\cdot e^{-2\cdot\hat{S}}-1\right) \ge \underline{\hat{P}} \\ \gamma\cdot\hat{S}\cdot e^{-2\cdot\hat{S}}-1 \ge E \end{cases}. \quad (25)$$

When solving problem (25), one may encounter the fact that the constraints in it are not implemented. In this case, as far as mathematics is concerned, the formulation of the problem is incorrect. However, involving considerations related to the economy, it is possible to generalize the formulation of this problem. In particular, it can be assumed that structural changes of the considered economic entity are possible. Under such structural changes, it is natural to consider the division of economic entity in order to solve the problem (25).

Statement of basic materials. Let us consider the case of dividing the economic entity into several partial economic entities (PEE) in order to solve problem (25). Considering economic entity and partial economic entities as some aggregates and using the appropriate symbolism adopted in set theory [17], it is possible to write

$$EO = \bigcup_{k=}^{N} PEO_k, \quad PEE \cap PEE_j = \varnothing, \quad (i \ne j), \quad (26)$$

where *PEE* is the k^{th} partial economic entity into which the economic entity is divided; *N* is the total number of *PEEs*; ⋃, ⋂ are union and intersection symbols, respectively; ∅ is the designation of the empty set.

The second condition in (26) indicates that *PEEs* are not related to each other.

Assuming that during the initial distribution of economic entity, all partial economic entities are equal, it is natural to divide the initial cost of basic economic funds in equal parts, i. e.

$$\hat{S}_k = \frac{\hat{S}_0}{N}; \quad (k = 1, 2, \ldots, N), \quad (27)$$

where $\hat{S}_0$ is the initial value of the basic economic funds of the economic entity.

This will allow you to write down the function that determines the profit of *PEEk*

$$(\gamma\cdot\hat{S}_k\cdot e^{-2\cdot\hat{S}_k}-1), \quad (28)$$

and, accordingly, economic efficiency

$$\hat{E}_k = \gamma\cdot\hat{S}_k\cdot e^{-2\cdot\hat{S}_k}-1. \quad (29)$$

The total amount of profit is found taking into account (27) as the sum of the profit margin (28), i.e

$$\hat{P}_0 = \sum_{k=1}^{N}\hat{P}_k = \sum_{k=1}^{N}\hat{S}_k\cdot(\gamma\cdot\hat{S}_k\cdot e^{-2\cdot\hat{S}_k}-1);$$

$$\hat{P}_0 = \sum_{k=1}^{N}\frac{\hat{S}_0}{N}\cdot\left(\gamma\cdot\frac{\hat{S}_0}{N}\cdot e^{-2\cdot\frac{\hat{S}_0}{N}}-1\right) = N\cdot\frac{\hat{S}_0}{N}\cdot\left(\gamma\cdot\frac{\hat{S}_0}{N}\cdot e^{-2\cdot\frac{\hat{S}_0}{N}}-1\right);$$

$$\hat{P}_0 = \hat{S}_0\cdot\left(\gamma\cdot\frac{\hat{S}_0}{N}\cdot e^{-2\cdot\frac{\hat{S}_0}{N}}-1\right). \quad (30)$$

At the same time, the value of the economic efficiency of each PEE_k, according to (27 and 29), will be determined by formula

$$\widehat{E}_k=\gamma\cdot\frac{\widehat{S}_0}{N}\cdot e^{-2\cdot\frac{\widehat{S}_0}{N}}-1;\quad (k=1,2,\ldots,N),\tag{31}$$

i. e. will be constant.

Then, problem (25) for the case of division *PEE* by *N* can be written in the form

$$\begin{cases}\widehat{S}_0\cdot\left(\gamma\cdot\frac{\widehat{S}_0}{N}\cdot e^{-2\cdot\frac{\widehat{S}_0}{N}}-1\right)\rightarrow\max\limits_{\widehat{S}_0}\\ \widehat{S}_0\cdot\left(\gamma\cdot\frac{\widehat{S}_0}{N}\cdot e^{-2\cdot\frac{\widehat{S}_0}{N}}-1\right)\geq\underline{\widehat{P}}\\ \gamma\cdot\frac{\widehat{S}_0}{N}\cdot e^{-2\cdot\frac{\widehat{S}_0}{N}}-1\geq\underline{\widehat{E}}\end{cases}.\tag{32}$$

When dividing economic entity into *N PEE*, a natural issue arises at what initial cost of basic economic funds it is economically beneficial to carry out such a division. To do this, it is necessary to compare the profit of economic entity with that which will be obtained after the division of economic entity into *PEE*, that is, to solve the inequation

$$N\cdot\widehat{P}\left(\frac{\widehat{S}_0}{N}\right)>\widehat{P}(\widehat{S}_0).\tag{33}$$

According to (14 and 30), inequation (33) takes the form

$$\widehat{S}_0\left(\gamma\frac{\widehat{S}_0}{N}e^{-2\cdot\frac{\widehat{S}_0}{N}}-1\right)>\widehat{S}_0(\gamma\widehat{S}_0e^{-2\cdot\widehat{S}_0}-1).\tag{34}$$

Carrying out the transformation of inequation (34), we consistently obtain

$$\begin{gathered}\frac{1}{N}e^{-2\cdot\frac{\widehat{S}_0}{N}}>e^{-2\cdot\widehat{S}_0};\quad\frac{1}{N}>e^{-2\cdot\widehat{S}_0+2\cdot\frac{\widehat{S}_0}{N}};\\ \ln N\left\langle 2\cdot\widehat{S}_0\left(1-\frac{1}{N}\right);\quad\widehat{S}_0\right\rangle\frac{N\cdot\ln N}{2\cdot(N-1)}.\end{gathered}\tag{35}$$

Inequation (35) indicates the condition imposed on the value of the initial cost of the basic economic funds for the economically beneficial division of the economic entity into the partial economic entities. Thus, the inequation (35) determines the smallest value of the initial cost of the basic economic funds, under which there is an effect of the division of the economic entity into partial economic entities, depending on their *N* number

$$\widehat{S}_0=\frac{N\cdot\ln N}{2\cdot(N-1)}.\tag{36}$$

Fig. 4 shows the function graph (36).

At the same time, there is a matter of the maximum profit margin that can be obtained after the division of the economic entity into partial economic entities. For this purpose, it is necessary to investigate function (30) to the maximum. To do this, we equate the derivative of this function to zero

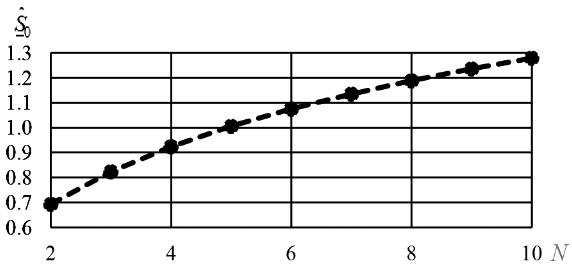

Fig. 4. The graph of the dependence of the smallest initial cost of the basic economic funds on the number of partial economic entities, in which there is an effect of the division of the economic entity into partial economic entities

$$\frac{d\widehat{P}_0}{d\widehat{S}_0}=2\gamma\cdot\frac{\widehat{S}_0}{N}\cdot e^{-2\cdot\frac{\widehat{S}_0}{N}}\left(1-\frac{\widehat{S}_0}{N}\right)-1=0.\tag{37}$$

Equation (37) is transcendental and admits only a numerical solution. If you enter a designation

$$\widehat{S}=\frac{\widehat{S}_0}{N},\tag{38}$$

then the solution of (37) will be presented in the form

$$\gamma=\frac{e^{2\cdot\hat{s}}}{2\cdot\hat{s}\cdot(1-\hat{s})}.\tag{39}$$

Solving equation (39) relative to (38), we find the value of the initial cost of the basic economic funds under which the maximum profit is achieved

$$\hat{s}_{opt}=0.0441\cdot\gamma+0.2832,\quad(5.6\leq\gamma\leq 10).\tag{40}$$

At the same time, the determination coefficient is equal to

$$R^2=0.9719,$$

which, according to the Chaddock scale, determines a very constraint force between the variables.

Considering (38), formula (39) takes the form

$$\widehat{S}_{0opt}=N(0.0441\cdot\gamma+0.2832),\quad(5.6\leq\gamma\leq 10).\tag{41}$$

Then, according to (28 and 40), the maximum profit margin is equal to

$$\begin{gathered}\widehat{P}_{k\max}=\hat{s}_{opt}(\gamma\hat{s}_{opt}e^{-2\hat{s}_{opt}}-1),\quad\left(k=1,2,\ldots,n\right),\\ (5.6\leq\gamma\leq 10).\end{gathered}\tag{42}$$

Approximation of formula (42) by parameter γ resulted in the following formula

$$\widehat{P}_{k\max}=0.1121\gamma-0.6196,\quad(5.6\leq\gamma\leq 10).\tag{43}$$

At the same time, the determination coefficient is equal to

$$R^2=0.999.$$

Taking into account (30), the maximum cost of the aggregate profit will be as follows

$$\widehat{P}_{0\max}=N(0.1121\gamma-0.6196),\quad(5.6\leq\gamma\leq 10).\tag{44}$$

In its turn, according to (41 and 44), the dependence of the maximum aggregate profit margin on the optimal value of the initial cost of the basic economic funds is approximated by formula

$$\widehat{P}_{0\max}=9.0203\widehat{S}^2_{0opt}-8.5475\hat{s}_{0opt}+2.0289.\tag{45}$$

At the same time, the determination coefficient is equal to

$$R^2=0.9993.$$

The maximum economic effectiveness is found by finding the maximum of function (31). For that to happen, we equate the derivative of this function to zero

$$\frac{dE}{d\widehat{S}_0}=\frac{\gamma}{N}e^{-2\cdot\frac{\widehat{S}_0}{N}}\left(1-\widehat{S}_0\frac{2}{N}\right)=0.\tag{46}$$

Having solved equation (46), we find

$$\widehat{S}_{0opt}=\frac{N}{2}.\tag{47}$$

At the same time, the maximum value of economic effectiveness is equal to

$$E\frac{\gamma}{2\cdot e_{\max}},\tag{48}$$

which coincides with (24).

Thus, within the framework of the built economic and mathematical model, the maximum cost of economic effectiveness remains constant during the division of the economic entity. The last circumstance makes it possible to determine the setting imposed on the number of partial economic entities, under which (32) will be fulfilled and the maximum economic effectiveness will occur. For that to happen, it is necessary to substitute (48) into formula (25), which will give the profit margin

$$\widehat{P}_0\left(\frac{N}{2}\right)=\frac{N}{2}\cdot\left(\frac{\gamma}{2\cdot e}-1\right). \quad (49)$$

According to setting (32), we get

$$\frac{N}{2}\cdot\left(\frac{\gamma}{2\cdot e}-1\right)\geq\underline{\widehat{P}}. \quad (50)$$

Solving inequation (50) with respect to the number of PEEs, we find

$$N\geq\frac{4\cdot e\cdot\underline{\widehat{P}}}{\gamma-2\cdot e}. \quad (51)$$

Thus, according to setting (51), when dividing economic entity into N partial economic entities, the simultaneous fulfillment of two setting is realized – the limitation on profit margin is fulfilled and the maximum economic efficiency is achieved (44). At the same time, the maximum economic efficiency, according to (48), must satisfy setting

$$\frac{\gamma}{2\cdot e}-1\geq E. \quad (52)$$

If it is necessary to achieve the maximum profit according to (32), then the economic effectiveness in this case will be equal to

$$E(\widehat{S}_{0opt})=\gamma\cdot\frac{\widehat{S}_{0opt}}{N}\cdot e^{-2\cdot\frac{\widehat{S}_{0opt}}{N}}-1. \quad (53)$$

Taking into account (41), formula (53) will be written in the form

$$E(\widehat{S}_{0opt})=\gamma\cdot(0.0441\cdot\gamma+0.2832)\times \times Ee^{-2\cdot(0.0441\cdot\gamma+0.2832)}-1. \quad (54)$$

As an illustration of the practical application of the proposed methodology, a step-by-step solution for Pivdennyi Mining and Processing Plant (MPP) PJSC is given. Thuswise, first of all, it is necessary to build an economic and mathematical model of the activity of Pivdennyi Mining and Processing Plant (MPP) PJSC. The construction of such a model consists of selecting its structure and finding the parameters included in this structure. According to the general approach described above, the structure of the economic and mathematical model is set by formula (6)

$$D=\delta\cdot S^2\cdot e^{-2\alpha\cdot S}, \quad (55)$$

where $\delta=\beta\cdot q$.

Let us include α, δ as unknown parameters. Statistical data in the amount of 50 were selected to find the parameters [18].

Data can be represented as pairs of input and output variables

$$S_i,\ D_i;\quad (i=1,2,\ldots,50). \quad (56)$$

To simplify the finding of the parameters included in formula (54), let us convert formula (55) taking logarithms up to the form

$$y=a+b\cdot S, \quad (57)$$

where $y=\ln\left(\frac{D}{S^2}\right);\ a=\ln\delta;\ b=-2\alpha.$

Finding the values of the parameters included in formula (57) is carried out using the method of least squares, which is realized by minimizing the functional using statistical data (56)

$$F(a,b)=\sum_{i=1}^{50}(y_i-a-b\cdot S_i)^2\rightarrow\min_{a,b}. \quad (58)$$

The studies given in [18], as well as relevant statistical information [19, 20] were used for the calculations.

As a result of the calculations, the following parameter values were obtained

$$a^*=-1.18323;\quad b^*=-0.08384. \quad (59)$$

According to the designation in formula (56), we find the values of the parameters in formula (55)

$$\delta^*=0.306289;\quad \alpha^*=0.041919. \quad (60)$$

Taking (59) into account, formula (54) will take the form

$$D=0.306289\cdot S^2\cdot e^{-0.08384\cdot S}. \quad (61)$$

Fig. 5 shows graphs of the amounts of income provided in Fig. 5 and calculated by formula (60) depending on expenses.

The analysis of the graphs shows their good coincidence, which is confirmed by a rather large value of the determination index on the Chaddock scale, which is equal to

$$R^2=0.966. \quad (62)$$

According to (12), with due regard to (60), the mathematical formulation of the optimal control objective will take the form

$$\begin{cases} S\cdot(0.306289\cdot S\cdot e^{-0.08384\cdot S}-1)\rightarrow\max\limits_{S} \\ S\cdot(0.306289\cdot S\cdot e^{-0.08384\cdot S}-1)\geq\underline{P} \\ 0.306289\cdot S\cdot e^{-0.08384\cdot S}-1\geq E \end{cases}. \quad (63)$$

Taking into consideration the fact that, according to (13),

$$\gamma=\frac{\delta}{\alpha}=\frac{0.306289}{0.041919}=7.307, \quad (64)$$

in a dimensionless form, the mathematical setting of the optimal control objective with due regard to (25) will take the form

$$\begin{cases} \widehat{S}\cdot(7.307\cdot\widehat{S}\cdot e^{-2\widehat{S}}-1)\rightarrow\max\limits_{\widehat{S}} \\ \widehat{S}\cdot(7.307\cdot\widehat{S}\cdot e^{-2\cdot\widehat{S}}-1)\geq\underline{\widehat{P}} \\ 7.307\cdot\widehat{S}\cdot e^{-2\cdot\widehat{S}}-1\geq \end{cases}. \quad (65)$$

Let it be set

$$\underline{P}=4.5;\quad E=0.3. \quad (66)$$

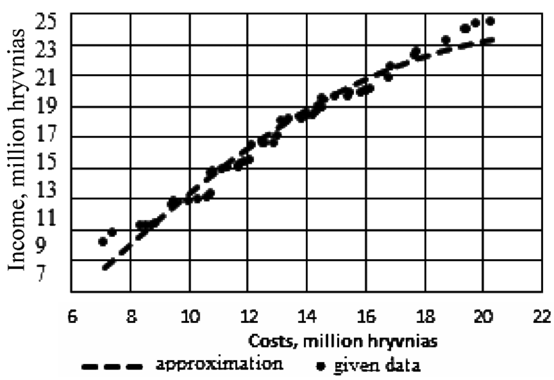

Fig. 5. Graphs of income statistical indicators and income calculated by formula (60), *depending on expenses*

Then, taking into account that, according to (13),

$$\widehat{\underline{P}} = \alpha \cdot \underline{P} = 0.041919 \cdot 4.5 = 0.1886,$$

problem (65) will be written as follows

$$\begin{cases} \widehat{S} \cdot (7.307 \cdot \widehat{S} \cdot e^{-2\widehat{S}} - 1) \to \max\limits_{\widehat{S}} \\ \widehat{S} \cdot (7.307 \cdot \widehat{S} \cdot e^{-2 \cdot \widehat{S}} - 1) \geq 0.1886. \\ 7.307 \cdot \widehat{S} \cdot e^{-2 \cdot \widehat{S}} - 1 \geq 0.3 \end{cases} \tag{67}$$

Considering (19, 20 and 64), we find

$$\widehat{S}_{opt}(7.307) = 0.618; \tag{68}$$

$$P_{\max}(7.307) = 0.203; \tag{69}$$

$$E = 7.307 \cdot \widehat{S}_{opt} \cdot e^{-2 \cdot \widehat{S}_{opt}} - 1 = 0.312. \tag{70}$$

Thus, in respect that the constraints in (67), according to (69 and 70), are fulfilled, we conclude that the problem is solved. In real values, according to (13), we have

$$S_{opt} = \frac{\widehat{S}_{opt}(7.307)}{\alpha} = \frac{0.618}{0.041919} = 14.742; \tag{71}$$

$$P \frac{\widehat{P}_{\max}}{\alpha \dfrac{0.203}{0.041919}_{\max}} \quad . \tag{72}$$

Let us consider the second case when

$$\underline{P} = 6; \quad E = 0.3.$$

In this case we have

$$\widehat{\underline{P}} = \alpha \cdot \underline{P} = 0.041919 \cdot 6 = 0.2515. \tag{73}$$

Thus, problem (65) will be written in the form

$$\begin{cases} \widehat{S} \cdot (7.307 \cdot \widehat{S} \cdot e^{-2\widehat{S}} - 1) \to \max\limits_{\widehat{S}} \\ \widehat{S} \cdot (7.307 \cdot \widehat{S} \cdot e^{-2 \cdot \widehat{S}} - 1) \geq 0.2515. \\ 7.307 \cdot \widehat{S} \cdot e^{-2 \cdot \widehat{S}} - 1 \geq 0.3 \end{cases} \tag{74}$$

According to the problem solved above, the condition on the limitation of the profit margin is not fulfilled, since, taking into account (69 and 74), we have

$$0.0203 < 0.2515. \tag{75}$$

Therefore, the matter of the need to divide economic entity in a certain number of partial economic entities arises. Using inequality (51 and 52), we find

$$N \geq 1.462; \tag{76}$$

$$E_{\max} = \frac{\gamma}{2e} - 1 = 0.344. \tag{77}$$

Taking into consideration (76), we conclude that economic entity should be divided into at least two partial economic entities, i. e

$$N = 2. \tag{78}$$

Then, according to (41) and (44), we have

$$\widehat{S}_{0opt} = 2 \cdot (0.0441 \cdot 7.307 + 0.2832) = 1.211; \tag{79}$$

$$\widehat{P}_{0\max} = 2(0.1121 \cdot 7.307 - 0.6196) = 0.399. \tag{80}$$

Taking into account (77 and 80), we see that the constraints of problem (74) are fulfilled. Thus, formulas (77—80) determine the solution to problem (74).

In real values, according to (13), we have

$$S_{0opt} = \frac{1.211}{0.041919} = 28.889;$$

$$P_{0\max} = \frac{0.399}{0.041919}.$$

It is clear that the solution to problem (65) does not exist.

Conclusion. The recovery of the domestic economy from the crisis, increasing its potential and increasing the efficiency of production is impossible without significant prerequisites for the formation of a platform for the economic security of enterprises, later economic entities (EE), based on reengineering processes. This will make it possible to implement, on an innovative basis, the development of investments in technical rearmament and reconstruction. Ukrainian companies already have some experience in this direction. However, in most cases, an administrative and situational model of support for outdated economic entites is used, rather than their modernization development based on modern digital technologies.

Theoretical and economic analysis of models of application of innovation and investment processes of economic entities for the practical provision of economic security shows that, in general, it is possible to use foreign experience. However, in modern domestic conditions, there is a need to create an optimized model of application of reengineering business processes of a national model, which would work effectively on its own intellectual, resource and material and technical basis. The practical use of such models creates a basis for ensuring the economic security of the enterprise, as it contains the relevant main system indicators.

Against the background of the unstable economy of Ukraine and a rather acute shortage of free financial funds that can be directed to real investment, correct reasoning and decision-making are of critical importance. This is the most responsible and difficult stage in the process of managing economic security. It is almost impossible to correct or at least compensate for errors in this area. Therefore, the protection of the enterprise from external and internal threats depends on how objectively and comprehensively such justification is carried out. The imperfection of assessing the effectiveness of the use of funds for technical rearmament in the conditions of the modern economy at the level of an economic entity determined the need to review not only scientific concepts, methodological and practical recommendations for the implementation of economic security management of economic entity, but as well require the development and implementation of new, more effective and adequate approaches to modern economic realities. One of these offers the provision of economic security of an industrial enterprise in the frameworks of business process reengineering.

The current state of Ukraine's economy requires substantial modernization of economic facilities in order to ensure the ability to resist external and internal threats. Modern domestic economic realities raise one of the most important issues of ensuring the economic security of an industrial enterprise. One of the possible ways to solve this issue is the formation of imperatives to ensure the economic security of industrial enterprises based on reengineering with the use of economic and mathematical modeling. The application of the economic and mathematical modeling method made it possible to find out under what conditions it is expedient to carry out structural transformations of an economic unit in order to ensure the appropriate indicators regarding the safe economic platform of an industrial enterprise. A particular case of the use of economic and mathematical modeling of the restructuring process of an industrial enterprise in order to obtain optimal values of indicators that reveal the essence of the economic security of an industrial enterprise is given. The developed model will ensure rapid adaptability of enterprises to changes, high flexibility and adaptability of all system elements, autonomy and economy of functioning of enterprises as a whole and their structural divisions. The practice of applying the developed economic and mathematical model confirmed the obtained theoretical findings.

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Економічна безпека промислового підприємства в парадигмі реінжинірингу бізнес-процесів

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Мета. Формування економіко-математичної моделі як економічної платформи захисту промислових підприємств задля реалізації економічної безпеки в парадигмі реінжинірингу бізнес-процесів.

Методика. У процесі дослідження використані методи: теоретичного узагальнення й порівняння, аналізу та синтезу (для визначення змісту поняття «економічна безпека підприємства»); статистичний (для аналізу вихідних даних); економіко-математичне моделювання структурної перебудови економічної одиниці – промислового підприємства (для визначення умов, за яких доцільно проводити реінжиніринг бізнес-процесів економічної одиниці задля формування платформи економічної безпеки).

Результати. Результати визначаються тим, що теоретичні положення роботи доведені до рівня конкретних пропозицій і мають форму, придатну для використання у практичній діяльності. Наведено приклад практичного застосування запропонованої економіко-математичної моделі на прикладі підприємства ПАТ «Південний ГЗК», де розкрита сутність наведеного аналізу. Отримані результати довели їх дієвість і доцільність використання на відповідних вітчизняних промислових підприємствах.

Наукова новизна. Уперше запропоновано підхід до розбудови економічної безпеки підприємства на засадах реінжинірингу бізнес-процесів. Набуло подальшого розвитку економіко-математичне моделювання щодо визначення умов доцільності впровадження структурних перетворень економічної одиниці для отримання оптимальних значень показників, що розкривають сутність економічної безпеки промислового підприємства.

Практична значимість. Аналіз результатів моделювання дає можливість запропонувати впровадження імперативів економічної безпеки підприємства на основі впровадження його реструктуризації. Застосування запропонованої моделі дозволяє забезпечити швидку пристосовуваність промислового підприємства до змін, високу гнучкість і адаптивність усіх елементів системи, автономність і економічність функціонування підприємств у цілому та їх структурних підрозділів. Практика використання розробленої економіко-математичної моделі на основі реінжинірингу підтвердила здобуті теоретичні результати.

Ключові слова: *структурна перебудова, промислове підприємство, економічна безпека, економіко-математична модель*

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