https://doi.org/10.33271/nvngu/2024-6/169

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ASSESSMENT OF THE ECONOMIC SECURITY OF AN INDUSTRIAL ENTERPRISE IN THE PARADIGM OF THE SYSTEMIC AND SYNERGETIC APPROACH

Purpose. Evaluation of the synthesis of levels of economic security of an industrial enterprise in order to prevent possible threats.

Methodology. The research uses the methodological principles of the system-synergistic approach, while the enterprise itself is considered as a system object which is under the influence of internal and external disturbances. Statistical methods of analysis of emission values of certain indicators that characterize the functioning of an industrial enterprise are used. The possibility of applying a statistical approach based on the theory of emissions is substantiated.

Findings. Problematic issues of ensuring the adoption of the level of economic security at industrial enterprises are researched and analyzed. As a tool for analyzing the situations that have developed at enterprises, the possibility of using a statistical approach based on the theory of emissions is substantiated. The synthesis of levels of economic security is proposed to be determined on the basis of a system-synergistic approach.

Originality. The issue of defining economic security, as information about the emissions of a certain economic indicator presented as a random time process, has gained further development. Determining the probability of the ordinates of the process exceeding a given level is envisaged, and finding the probabilistic characteristics of the time of the ordinates of a random process remains above this level.

Practical value. The analysis of the results regarding the determination of the levels of economic security was studied at the enterprises of PIVDGZK JSC. The values of the following economic indicators were analyzed: net income from product sales; cost of goods sold; pre-tax profit. The results of the calculations showed that the largest average number of emissions both for one month and for a given time interval is attributable to the cost price. That is, the average duration of the emission and the average area of the emission, which is limited by a function above a given level, refers to such economic indicator as profit before taxation. Such indicators have a negative impact on the economic security of the enterprise.The conducted analysis provides grounds for the relevant services to implement management actions to prevent possible threats to the economic security of the enterprise.

Keywords: *economic security, random process, indicator, statistical approach*

Introduction. Effective development of the economy of Ukraine in modern conditions is possible only on the basis of the wide use of scientific and technical achievements and the formation of a powerful domestic intellectual potential. The current state of the national economy in general and its real sector indicate a decline in production. Enterprises of the real sector of the economy function in an external competitive environment. The interaction of the external and internal environments of the enterprise form the basis for a systematic study of the processes of assessing their economic security. From the side of the external environment, there can be both threats and opportunities with regard to the impact on enterprises. Ukraine's integration into the world economic system, globalization processes significantly affected the functioning of enterprises in general and, accordingly, their economic security separately. Naturally, the economic security of the enterprise depends on a significant number of factors that are quite difficult, in general, to take into account. This is primarily due to the fact that the enterprise is a complex system object, which is characterized by stochastic behavior. This feature of the enterprise is due not so much to the presence of some sources of random obstacles for the enterprise, but to the complexity of the enterprise itself, as a system object, and the inevitable significant number of various secondary (from the point of view of economic security) processes associated with this. Therefore, the behavior of the system object – the enterprise is most often "unexpected", and this surprise is more convenient to consider as a random factor. Any enterprise contains a large number of such "surprises", which is evidence of its complexity. There is a tendency to call accidental what is secondary and insignificant for the realization of the economic security of the enterprise. This approach is well developed in statistical decision-making theory. To apply this statistical approach, it is suggested to consider a separate economic indicator for the enterprise, represented by a random time process. Thus, the actual problem of assessing the economic security of enterprises is considered in a new aspect, namely, from the standpoint of statistical assessment of the quality of the enterprise's functioning during a given period of time. For this purpose, relevant time series characterizing the production are analyzed by studying their emissions that disrupt the functioning of the production. Such emissions can lead to a violation of the economic security of the enterprise. Such emissions can lead to a violation of the economic security of the enterprise. A conclusion is made about the possibility of assessing the economic security of the enterprise by studying the values of emission indicators.

Literature review. Research and analysis of problems related to the economic security of the enterprise is represented by a significant number of works in the scientific field. Thus, the authors Zaichenko K.S. and Dima N.I. considered the meaning and role of economic security. The concept of economic security is structured and, in the opinion of scientists, the negative impact of these structural units is highlighted [1]. The work by the authors Sytnyk H.V., Blakyt H.V., Gulyae-

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va N. M. and others is distinguished by a meaningful scientific work. Scientists systematically researched and analyzed the main problems of ensuring the economic security of national entrepreneurship. According to the level of economic systems, the authors investigated the mechanisms of ensuring economic security [2]. Kolodyazhna I. V. and Bukrina K. A. focus attention on the criteria for the formation of economic security. The authors suggest that the state of economic security of the enterprise should be determined on the basis of relevant criteria [3]. Scientists Karachina N. P., Semtsov V. M., Myronchuk V. M., and Balzan M. V. propose to consider the essence of economic security from the standpoint of the relationship between the concepts of "development – economic security – sustainability – efficiency". It should be noted that the definition of such a chain should provide for the unification of indicators that formulate each component [4]. Authors Karachina N. P., Semtsov V. M., Mironchuk V. M. proposed the author's method for assessing the economic security of the enterprise. The author's methodology takes into account the life cycle of the development of a modern domestic enterprise [5]. The systematic nature of economic security research is the basis of E. Danilov's scientific work. The author formulated "... axiomatic provisions that defined the concept of the approach to the functional description of the economic security system...". The conceptual approach to assessing the economic security of the enterprise is meaningfully defined. The author suggests forming a concept based on the following components, namely: economic security of potential use; identification of assessment objects; selection of an approach to assessment [6]. A generalized approach to the essence of ensuring economic security of the enterprise, principles, functions, methods and means of this process is given in [7]. Based on the analysis of analytical information about enterprises of the real sector of the economy, the authors. Ogrenych Yu and Dibrova V. focus attention on possible directions for improving the state of economic security. However, it should be noted here that the given analytical information about one enterprise cannot be taken as generalized [8]. Authors Kovalska L., Golii O., Golii V. propose to consider economic security through the prism of sustainability of economic development [9]. This approach involves the use of all available company resources, which is difficult to implement in practice. Scientists Sadovyak M.S, Begeilo N.V., Fenyk V. O., Prystupa A. A., Matvievskyi N. A., Zapisotskyi I. V. and Ilchyshyn M. Z. emphasize the analysis of the influence of the external environment in formation of the system of economic security of the enterprise in modern conditions. The authors comprehensively investigate the problem and link economic security with national security [10]. An attempt to systematize definitions regarding the essence of the concept of "economic security" is reflected in [11]. The development of information technologies, of course, had a corresponding influence on the formation of the essence of the concept of "economic security of the enterprise". The authors Zhadko K. S., Samoilenko D. M. have developed appropriate approaches in the context of digital technologies [12]. Some authors link, not without reason, the financial and economic security of the enterprise with the efficiency of management [13]. An attempt to form a model for determining a complex indicator of financial and economic security based on financial statements is presented in [14]. The authors Tovpyk D. V., Demyanchuk O. I. propose to highlight financial security as part of the economic security of the enterprise and offer their author's vision [15]. Scientists tried to present a new vision of the essence of the concept of "economic security" through economic activity at the enterprise. Havlovska N., Matyukh S. and Lyubokhinets L. proposed a methodology for assessing the state of economic security of the enterprise. The methodology is based on the formation of indicators according to the functional components defined by the authors [16]. The scientific publication by Kopteva H. M. attracts special attention. The author analyzes in detail modern approaches to the assessment of the economic security of the enterprise, their content, advantages and limitations. It is noted that the lack of a single approach to determining the classification features of approaches to assessing the level of economic security of an enterprise makes it difficult to justify the choice of approach. The author proposed the improvement of classification approaches to the assessment of economic security of the enterprise and methodical support taking into account the peculiarities of its business processes [17]. The appropriate evaluation methods were proposed by scientists Shilo Zh., Piletska S. T., Korytko T. Yu., Tkachenko E. V. [18, 19]. The authors propose to assess the level of economic security based on the formation of integral indicators, which, according to the authors, make it possible not only to determine "...the state of the research object, but also the direction of its development...". Without underestimating the importance and depth of numerous scientific and practical studies in the area of assessing the levels of economic security of enterprises in the real sector of the national economy, the relevance of the topic attracts the attention of scientists.

Unsolved aspects of the problem. The scientific developments presented in the field of economic security level assessment are mainly focused on the application of integral indicators. Instead, scientists ignore the possibility of applying the methodology to the statistical approach based on the theory of emissions. It is proposed to conduct an analysis of time series characterizing indicators of a certain production of the enterprise by studying the values of their emissions. Determination and analysis of the values of emission indicators form the basis for assessing the economic security of the enterprise.

Purpose of the article is to study the emission values of certain indicators that characterize the functioning of an industrial enterprise in order to assess its economic security in the paradigm of a system-synergistic approach.

Results. It is offered to apply a statistical approach based on the theory of emissions as a tool for analyzing the situations that have developed at enterprises. To assess the level of economic security, it is advisable to determine the probability of exceeding the ordinates of the process of a given level and find the probability characteristics of the time when the ordinates of the random process remain above this level.

To apply such a statistical approach, consider a certain economic component of the enterprise, which is represented by a random time process. Let us consider the determination of the emission probability for a given value of the ordinate of a random process and the determination of the average time the random process stays above a given level.

Let a be the value of the ordinate of the differentiated random process $X(t)$, the outliers beyond which are investigated. Let us determine the possibility that an emission will occur during the time interval dt following the time t. In order for an emission to occur under the specified conditions, two conditions must be met:

- at the moment of time t the condition is fulfilled

$$X(t) < a, \tag{1}$$

and at the moment of time $t + dt$

$$X(t + dt) > a. \tag{2}$$

Therefore, the probability of an emission in the time interval dt is written in the form

$$P[X(t)\langle a; X(t + dt)\rangle a]. \tag{3}$$

Taking into account the smallness of the time interval dt with an accuracy of the infinitesimal of the second order, it is possible to write

$$X(t + dt) = X(t) + V(t)dt. \tag{4}$$

Hence, inequality

$$X(t + dt) > a,$$

is equivalent to inequality

$$X(t) + V(t)dt > a,$$

or

$$a - V(t)dt < X(t). \tag{5}$$

Instead of two inequalities determining the presence of an emission in the time interval (3), one can write one double inequality

$$a - V(t)dt < X(t) < a, \ (V(t) > 0). \tag{6}$$

To calculate the probability of realization of inequality (6), it is necessary to consider the two-dimensional distribution law of the ordinate of the random function $X(t)$ and its derivative $V(t)$ at time t

$$f(x, v|t). \tag{7}$$

Then for the sought probability of emission we get

$$P\left[a - V(t)dt < X(t) < a\right] = \int_{0}^{\infty} \int_{a-v\cdot dt}^{a} f(x,v|t)dxdv. \tag{8}$$

Taking into account the fact that

$$\int_{a-v\cdot dt}^{a} f(x,v\,|\,t)dx = v\cdot dt\cdot f(a,v\,|\,t),$$

formula (8) takes the form

$$P\left[a - V(t)dt < X(t) < a\right] = dt\cdot\int_{0}^{\infty} f(a,v\,|\,t)vdv. \tag{9}$$

Formula (9) shows that the probability of emission during the interval dt is proportional to the length of this interval. Therefore, it is expedient to introduce the concept of time density for the probability of release, denoting $p(a\,|\,t)$ the probability of release for level a at the moment of time calculated per unit of time, i. e. putting.

$$P\left[a - V(t)dt < X(t) < a\right] = p(a|t)dt, \tag{10}$$

where

$$p(a\,|\,t) = \int_{0}^{\infty} f(a,v\,|\,t)vdv. \tag{11}$$

Similarly, the time density of the probability of crossing a random function $X(t)$ of level a is calculated from top to bottom according to the formula.

$$\hat{p}(a\,|\,t) = -\int_{-\infty}^{0} f(a,v\,|\,t)vdv, \tag{12}$$

of the random function $X(t)$ above the level a for the time interval will be the value

$$\bar{t}(a) = \int_{0}^{T}\int_{a}^{\infty} f(x\,|\,t)dxdt. \tag{13}$$

In turn, the average amount of emissions over time will be the value

$$\bar{n}(a) = \int_{0}^{T}\int_{0}^{\infty} vf(a,v\,|\,t)dvdt. \tag{14}$$

Then, by dividing (13) by (14), the average emission duration is found

$$\bar{\tau}(a) = \frac{\bar{t}(a)}{\bar{n}(a)},$$

or

$$\bar{\tau}(a) = \frac{\int_{0}^{T}\int_{a}^{\infty} f(x\,|\,t)dxdt}{\int_{0}^{T}\int_{0}^{\infty} vf(a,v\,|\,t)dvdt}. \tag{15}$$

The derived formulas are especially important for steady-state processes, because for processes that have settled over time, the average duration of the emission has obvious significance. For stationary processes, these formulas are simplified, since the density of the distribution of ordinates of a random function, and the density of the distribution of ordinates and velocities does not depend on time. Denoting these distribution values by $f(x)$ and $f(x, v)$, it can be seen that the time integration in formulas (13, 14 and 15) is reduced to multiplication by the time interval T.

$$\bar{t}(a) = T\int_{a}^{\infty} f(x)dx; \tag{16}$$

$$\bar{n}(a) = T\int_{0}^{\infty} vf(a,v)dv; \tag{17}$$

$$\bar{\tau}(a) = \frac{\int_{a}^{\infty} f(x)dx}{\int_{0}^{\infty} vf(a,v)dv}. \tag{18}$$

For stationary processes, the concept of the average amount of emissions per unit of time can be introduced

$$\bar{\nu}(a) = \frac{\bar{n}(a)}{T}. \tag{19}$$

Considering (17), we have

$$\bar{\nu}(a) = \int_{0}^{\infty} vf(a,v)dv, \tag{20}$$

i. e. it is equal to the probability of emission per unit of time (11).

It can be shown that the average area bounded by the realization of a stationary random function $X(t)$ above a given level a during emission is given by the formula

$$\bar{s}(a) = \frac{1}{\bar{\nu}(a)}\int_{a}^{\infty} xf(x)dx - a\cdot\bar{\tau}(a). \tag{21}$$

To obtain final numerical results, it is necessary to have the densities of the distributions under consideration.

For a normal process, the most important from the point of view of applications, simple calculation formulas can be obtained. For a normal stationary process, the distribution law of the ordinates of the random function $X(t)$ is expressed by the formula

$$f(x) = \frac{1}{\sigma_x\sqrt{2\pi}}e^{-\frac{(x-\bar{x})^2}{2\sigma_x^2}}, \tag{22}$$

where x – is the mathematical expectation of the ordinate of the random function $X(t)$; σ_x is the standard deviation of the ordinate of the random function $X(t)$.

Given that the rate of change in the ordinate of the random function $V(t)$ and the ordinate of the random function $X(t)$ are independent quantities, their two-dimensional density of the probability distribution decomposes into the product of the normal densities of the distribution for each of the coefficients, i. e.

$$f(x,v) = \frac{1}{\sigma_x\sqrt{2\pi}}e^{-\frac{(x-\bar{x})^2}{2\sigma_x^2}}\cdot\frac{1}{\sigma_v\sqrt{2\pi}}e^{-\frac{v^2}{2\sigma_v^2}}, \tag{23}$$

where σ_v is the standard deviation of the rate of change in the ordinate of the random function $V(t)$.

The mathematical expectation of the rate of change in the ordinate of a random function is zero due to the stationarity of the random process.

Substituting formula (23) into formula (21) gives for the average number of emissions per unit of time, or, which is the same for the time density

$$\overline{\nu}(a)=p(a)=\int_0^{\infty} v\frac{1}{\sigma_x\sqrt{2\pi}}e^{-\frac{(x-\overline{x})^2}{2\sigma_x^2}}\cdot\frac{1}{\sigma_v\sqrt{2\pi}}e^{-\frac{v^2}{2\sigma_v^2}}dv;$$

$$\overline{\nu}(a)=p(a)=\frac{1}{\sigma_x\sqrt{2\pi}}e^{-\frac{(x-\overline{x})^2}{2\sigma_x^2}}\int_0^{\infty} v\cdot\frac{1}{\sigma_v\sqrt{2\pi}}e^{-\frac{v^2}{2\sigma_v^2}}dv. \qquad (24)$$

We calculate the integral separately by replacing the variable. Finally, we find

$$\overline{\nu}(a)=p(a)=\frac{1}{\sigma_x\sqrt{2\pi}}e^{-\frac{(a-\overline{x})^2}{2\sigma_x^2}}\cdot\frac{\sigma_v}{\sqrt{2\pi}};$$

$$\overline{\nu}(a)=p(a)=\frac{\sigma_v}{2\pi\sigma_x}e^{-\frac{(a-\overline{x})^2}{2\sigma_x^2}}. \qquad (25)$$

Similarly, substituting (22 and 25) into (18) gives the formula for calculating the average duration of the emission

$$\overline{\tau}(a)=\frac{\displaystyle\int_a^{\infty}\frac{1}{\sigma_x\sqrt{2\pi}}e^{-\frac{(x-\overline{x})^2}{2\sigma_x^2}}dx}{\displaystyle\frac{\sigma_v}{2\pi\sigma_x}e^{-\frac{(a-\overline{x})^2}{2\sigma_x^2}}};$$

$$\overline{\tau}(a)=\sqrt{2\pi}\frac{1}{\sigma_v}e^{\frac{(a-\overline{x})^2}{2\sigma_x^2}}\int_a^{\infty}e^{-\frac{(x-\overline{x})^2}{2\sigma_x^2}}dx. \qquad (26)$$

We calculate the integral separately by replacing the variable

$$\int_a^{\infty}e^{-\frac{(x-\overline{x})^2}{2\sigma_x^2}}dx=\left|\begin{array}{cc} z=\dfrac{x-\overline{x}}{\sigma_x} & dz=\dfrac{1}{\sigma_x}dx \\ x=a\to z=\dfrac{a-\overline{x}}{\sigma_x} & dx=\sigma_x dz \\ x=\infty\to z=\infty & \end{array}\right|=$$

$$=\sigma_x\int_{\frac{a-\overline{x}}{\sigma_x}}^{\infty}e^{-\frac{z^2}{2}}dz=\sigma_x\left(\int_0^{\infty}e^{-\frac{z^2}{2}}dz-\int_0^{\frac{a-\overline{x}}{\sigma_x}}e^{-\frac{z^2}{2}}dz\right)= \qquad (27)$$

$$=\sigma_x\sqrt{\frac{\pi}{2}}\left[1-\Phi\left(\frac{a-\overline{x}}{\sigma_x}\right)\right],$$

where $\Phi(y)=\sqrt{\frac{2}{\pi}}\int_0^y e^{-\frac{z^2}{2}}dz$ is the Laplace function.

Substituting (27) into (26), we finally find

$$\overline{\tau}(a)=\pi\frac{\sigma_x}{\sigma_v}e^{\frac{(a-\overline{x})^2}{2\sigma_x^2}}\left[1-\Phi\left(\frac{a-\overline{x}}{\sigma_x}\right)\right]. \qquad (28)$$

Substituting (22) into (21) and calculating the integral, we consistently find

$$\overline{s}(a)=\frac{1}{\overline{\nu}(a)}\int_a^{\infty}\frac{x}{\sigma_x\sqrt{2\pi}}e^{-\frac{(x-\overline{x})^2}{2\sigma_x^2}}dx-a\cdot\overline{\tau}(a);$$

$$\int_a^{\infty}\frac{x}{\sigma_x\sqrt{2\pi}}e^{-\frac{(x-\overline{x})^2}{2\sigma_x^2}}dx=\left|\begin{array}{cc} z=\dfrac{x-\overline{x}}{\sigma_x} & dz=\dfrac{dx}{\sigma_x} \\ x=a\to z=\dfrac{a-\overline{x}}{\sigma_x} & x=\overline{x}+\sigma_x z \\ x=\infty\to z=\infty & \end{array}\right|=$$

$$=\int_{\frac{a-\overline{x}}{\sigma_x}}^{\infty}\frac{\overline{x}+\sigma_x z}{\sqrt{2\pi}}e^{-\frac{z^2}{2}}dz;$$

$$\int_{\frac{a-\overline{x}}{\sigma_x}}^{\infty}\frac{\overline{x}+\sigma_x z}{\sqrt{2\pi}}e^{-\frac{z^2}{2}}dz=\frac{\overline{x}}{\sqrt{2\pi}}\int_{\frac{a-\overline{x}}{\sigma_x}}^{\infty}e^{-\frac{z^2}{2}}dz+\frac{\sigma_x}{\sqrt{2\pi}}\int_{\frac{a-\overline{x}}{\sigma_x}}^{\infty}ze^{-\frac{z^2}{2}}dz;$$

$$\int_{\frac{a-\overline{x}}{\sigma_x}}^{\infty}e^{-\frac{z^2}{2}}dz=\int_{\frac{a-\overline{x}}{\sigma_x}}^{0}e^{-\frac{z^2}{2}}dz+\int_0^{\infty}e^{-\frac{z^2}{2}}dz=\int_0^{\infty}e^{-\frac{z^2}{2}}dz-\int_0^{\frac{a-\overline{x}}{\sigma_x}}e^{-\frac{z^2}{2}}dz=$$

$$=\sqrt{\frac{\pi}{2}}\left[1-\Phi\left(\frac{a-\overline{x}}{\sigma_x}\right)\right];$$

$$\int_{\frac{a-\overline{x}}{\sigma_x}}^{\infty}ze^{-\frac{z^2}{2}}dz=\left|\begin{array}{cc} t=\dfrac{z^2}{2} & dt=zdz \\ z=\dfrac{a-\overline{x}}{\sigma_x}\to t=\dfrac{1}{2}\left(\dfrac{a-\overline{x}}{\sigma_x}\right)^2 & z=\infty\to t=\infty \end{array}\right|=$$

$$=\int_{\frac{1}{2}\left(\frac{a-\overline{x}}{\sigma_x}\right)^2}^{\infty}e^{-t}dt=-e^{-t}\Big|_{\frac{1}{2}\left(\frac{a-\overline{x}}{\sigma_x}\right)^2}^{\infty}=e^{-\frac{1}{2}\left(\frac{a-\overline{x}}{\sigma_x}\right)^2};$$

$$\int\int_{\frac{a-\overline{x}}{\sigma_x}}^{\infty}\frac{\overline{x}+\sigma_x z}{\sqrt{2\pi}}e^{-\frac{z^2}{2}}dz=\frac{\overline{x}}{\sqrt{2\pi}}\sqrt{\frac{\pi}{2}}\left[1-\Phi\left(\frac{a-\overline{x}}{\sigma_x}\right)\right]+\frac{\sigma_x}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{a-\overline{x}}{\sigma_x}\right)^2};$$

$$\int_a^{\infty}\frac{x}{\sigma_x\sqrt{2\pi}}e^{-\frac{(x-\overline{x})^2}{2\sigma_x^2}}dx=\frac{\overline{x}}{2}\left[1-\Phi\left(\frac{a-\overline{x}}{\sigma_x}\right)\right]+\frac{\sigma_x}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{a-\overline{x}}{\sigma_x}\right)^2};$$

$$\overline{s}(a)=\frac{1}{\overline{\nu}(a)}\left\{\begin{array}{c}\dfrac{\overline{x}}{2}\left[1-\Phi\left(\dfrac{a-\overline{x}}{\sigma_x}\right)\right]+ \\ \dfrac{\sigma_x}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{a-\overline{x}}{\sigma_x}\right)^2}\end{array}\right\}-a\overline{\tau}(a). \qquad (29)$$

Taking into account (26 and 29), the formula (30), which determines the average area bounded by the realization of the stationary random function *X(t)* above the given level *a* during the emission, is given by the formula

$$\overline{s}(a)=\frac{\sigma_x^2\sqrt{2\pi}}{\sigma_v}+\frac{(\overline{x}-a)\sigma_x\pi}{\sigma_v}\left[1-\Phi\left(\frac{a-\overline{x}}{\sigma_x}\right)\right]e^{-\frac{1}{2}\left(\frac{a-\overline{x}}{\sigma_x}\right)^2}, \qquad (30)$$

where $\sigma_x^2=K_x(0)$; $\sigma_v^2=-\frac{d^2}{d\tau^2}K_x(\tau)\big|\tau=0$; $K_x(\tau)$ is autocorrelation function.

In order to find the statistical characteristics of realizations of random processes, it is natural to use the principles of processing research material developed in mathematical statistics. For this, it is necessary to go to the sequence of implementation of a random variable obtained by discretization of a random process

$$x_1, x_2, ..., x_i, ..., x_n, \qquad (31)$$

where $x_i = x(i\cdot\Delta)$; $n\cdot\Delta = T$.

Then the estimate of the mathematical expectation, that is, the average, is found according to the formula

$$\overline{x}=\frac{1}{n}\sum_{i=1}^{n}x_i. \qquad (32)$$

The sample variance is determined by the formula

$$\sigma_x^2=\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\overline{x})^2, \qquad (33)$$

and the standard deviation is

$$\sigma_x=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\overline{x})^2}. \qquad (34)$$

In turn, the sample estimate of the autocorrelation function is given by the formula

$$\tilde{R}_x(k)=\frac{1}{\sigma_x(n-1)}\sum_{i=1}^{n-k}(x_i-\bar{x})(x_{i+k}\bar{x}),\quad k=0,2,\ldots,m. \tag{35}$$

To find the analytical formula $R_x(\alpha,\tau)$, it is necessary to approximate formula (35) by minimizing the functional

$$F(\alpha)=\sum_{k=1}^{m}(R_x(\alpha,k\cdot\Delta)-\tilde{R}_x(k))^2\to\min_{\alpha}. \tag{36}$$

Given that

$$F(\alpha_0)=\min_{\alpha}\sum_{k=1}^{m}(R_x(\alpha,k\cdot\Delta)-\tilde{R}_x(k))^2,$$

the analytical formula of the autocovariance function will be written in the form

$$K_x(\alpha_0,\tau)=\sigma_x^2\cdot R(\alpha_0,\tau). \tag{37}$$

Then, according to (30), we obtain

$$K_x(\alpha_0,0)=\sigma_x^2\cdot R_x(\alpha_0,0)=\sigma_x^2.$$

Further,

$$\sigma_v^2=-\frac{d^2}{d\tau^2}K_x(\alpha_0,\tau)\Big|\tau=0=-\sigma_x^2\cdot\frac{d^2}{d\tau^2}R_x(\alpha_0,\tau)\Big|\tau=0=$$
$$=-\sigma_x^2\frac{d^2}{d\tau^2}(e^{-\alpha_0\cdot\tau}(1+\alpha_0\cdot\tau))\Big|\tau=0;$$
$$\frac{d}{d\tau}(e^{-\alpha_0\cdot\tau}(1+\alpha_0\cdot\tau))=-\alpha_0e^{-\alpha_0\cdot\tau}(1+\alpha_0\cdot\tau)+\alpha_0e^{-\alpha_0\cdot\tau}=$$
$$=-\alpha_0^2\tau e^{-\alpha_0\cdot\tau};$$
$$\frac{d^2}{d\tau^2}(e^{-\alpha_0\cdot\tau}(1+\alpha_0\cdot\tau))=\frac{d}{d\tau}(-\alpha_0^2\tau e^{-\alpha_0\cdot\tau})=-\alpha_0^2\frac{d}{d\tau}(\tau e^{-\alpha_0\cdot\tau})=$$
$$=-\alpha_0^2(e^{-\alpha_0\cdot\tau}-\tau\alpha_0e^{-\alpha_0\cdot\tau})=-\alpha_0^2e^{-\alpha_0\cdot\tau}(1-\alpha_0\tau);$$
$$\sigma_v^2=-\sigma_x^2\cdot\left[-\alpha_0^2e^{-\alpha_0\cdot\tau}(1-\alpha_0\tau)\right]$$
$$\Big|\tau=0=\alpha_0^2\cdot\sigma_x^2. \tag{38}$$

All subsequent calculations and construction of tables and graphs were carried out using Mathcad.

The proposed methodology was developed using relevant statistical information on the activities of JSC "PivdGZK" [20, 21].

Consider the value of the economic indicator – net income from the sale of products in the period from 2018 to 2022 [20, 21]. The graph displaying the initial information "Data" and the graph of the approximation of the values of the indicator of net income from the sale of products under the name "Model" are presented in Fig. 1.

The mathematical model of net income from product sales is represented by a polynomial of the fourth order

$$y_m(t)=34.52\cdot t^4-1.636\cdot t^3+25{,}555\cdot t^2-$$
$$-29{,}288\cdot t+20{,}000{,}000. \tag{39}$$

The mathematical model (39) is found according to the data displayed on the "Data" graph using the method of least squares. At the same time, the coefficient of determination was $R^2=0.999$, which indicates a very high relationship, according to the Chaddock scale. Deviations are calculated as the difference between the corresponding values presented in the "Data" and "Model" graphs

$$x(t)=y(t)-y_m(t). \tag{40}$$

To calculate the deviations, the random processes presented in the "Data" and "Model" graphs were discretized according to the formula

$$t_i=2{,}017+i\cdot\Delta;\quad i=0,1,\ldots,36;\quad \Delta=\frac{1}{12}, \tag{41}$$

that is, with a discreteness of one month.

Next, we find the numerical characteristics of the indicator net income from the sale of products according to formulas (31, 32 and 33) taking into account discretization

$$\bar{x}=\frac{1}{36}\sum_{i=1}^{36}x_i=31{,}383; \tag{42}$$

$$\sigma_x^2=\frac{1}{35}\sum_{i=1}^{36}(x_i-31{,}833)^2=8{,}917{,}631{,}808; \tag{43}$$

$$\sigma_x=\sqrt{\frac{1}{35}\sum_{i=1}^{36}(x_i-31{,}833)^2}=94{,}433. \tag{44}$$

Fig. 2 presents the deviation graph (40), the average value of the deviation, as well as the upward deviation limit, which is half of the standard value of the deviation from the average value.

The analysis of the graph in Fig. 2 shows that the deviation of the indicator of net income from the sale of products is a stationary random sample sequence. A visual analysis of the graph in Fig. 2 proves that there are outliers – the deviation of the values of the indicator of net income from the sale of products above the specified limit. Therefore, it can be concluded that an increase in the number of emissions worsens economic security.

Instead, the sample estimate of the autocorrelation function is given by the formula

$$\tilde{R}_x(k)=\frac{1}{3.12117E+11}\sum_{i=1}^{n-k}(x_i-31{,}383)(x_{i+k}-31{,}383),$$
$$k=0,1,\ldots,m. \tag{45}$$

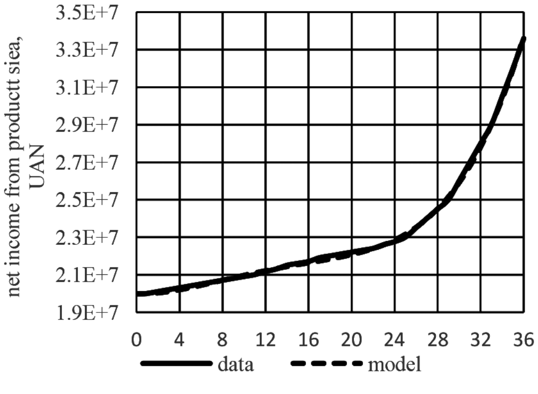

Fig. 1. Graphs of initial data and model values of net income from product sales

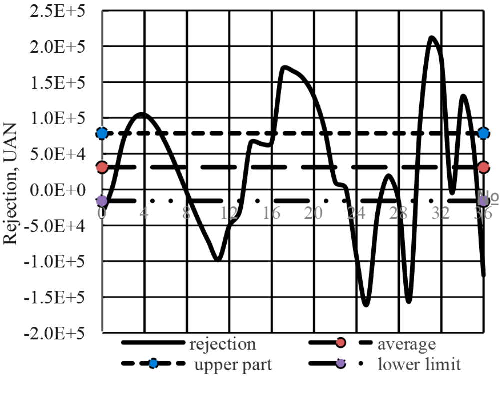

Fig. 2. Graphs of deviation of net income from product sales, average deviation, limits of deviation

The following was chosen as the structure of the analytical formula

$$R_x(\tau) = e^{-\alpha\cdot|\tau|}(1+\alpha\cdot|\tau|), \tag{46}$$

where α is a parameter.

To approximate the functions (45 and 46) using the parameter α, the minimization of the functional (36) was applied. As a result, we get $\alpha_0 = 1.412$, and formula (46) takes the following form

$$R_x(\tau) = e^{-1.412\cdot|\tau|}(1+1.412\cdot|\tau|). \tag{47}$$

According to formulas (37 and 47), the analytical formula of the autocovariance function takes the form

$$K_x(\tau) = 8{,}917{,}631{,}808\cdot e^{-1.412\cdot|\tau|}(1+1.412\cdot|\tau|). \tag{48}$$

Then, according to (38), we get

$$\sigma_v^2 = \alpha_0^2\cdot\sigma_x^2 = 1.412^2\cdot 8{,}917{,}631{,}808 = 17{,}779{,}474{,}911. \tag{49}$$

Given that $a = 78{,}599$, and using formula (26) we find the average number of emissions per unit of time

$$\bar{\nu}(78{,}599) = 0.198. \tag{50}$$

In turn, the number of emissions that occur in a given time interval (0.36) makes up the value

$$\bar{n}(78{,}599) = \bar{\nu}(78{,}599)\cdot 36 = 0.198\cdot 36 = 7.14 \approx 7. \tag{51}$$

Next, we will find out that the average duration of the emission, according to (29), will be the value

$$\bar{\tau}(78{,}599) = 0.942. \tag{52}$$

And, finally, the average area limited by the implementation of the stationary random function $X(t)$ above the given level $a = 78{,}599$ during the emission is found according to the formula (30) and is the value

$$\bar{s}(78{,}599) = 123{,}186. \tag{53}$$

Next, we will consider such an economic indicator as the cost price in the period from 2018 to 2022 [20, 21]. The graph of the values of the indicator of the cost of goods sold under the name "Data" and the graph of the corresponding approximation under the name "Model" are presented in Fig. 3.

The mathematical model of the cost indicator is represented by a polynomial of the fifth order.

$$\begin{aligned} y_m(t) = {}& -1.006\cdot t^5 + 91.334\cdot t^4 - 2{,}667.8\cdot t^3 + \\ & + 24{,}905\cdot t^2 + 44{,}348.9\cdot t + 6{,}719{,}563. \end{aligned} \tag{54}$$

Mathematical model (54) is found similarly according to (39). At the same time, the coefficient of determination was $R^2 = 0.9967$, which indicates a very high relationship, according to the Chaddock scale.

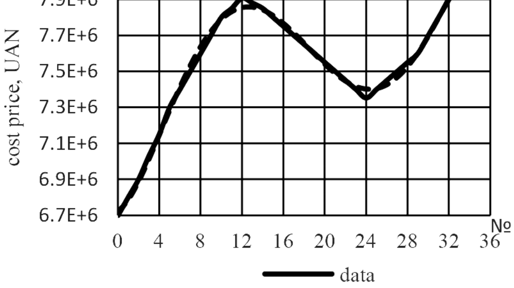

Fig. 3. Graphs of input data and model values of the cost of goods sold

To calculate the deviations, random processes presented on the "Data" and "Model" graphs were discretized according to formula (41), i. e., with a discreteness of one month.

Next, we find the numerical characteristics of the cost according to formulas (32–34) taking into account discretization (43)

$$\bar{x} = \frac{1}{36}\sum_{i=1}^{36} x_i = 836; \tag{55}$$

$$\sigma_x^2 = \frac{1}{35}\sum_{i=1}^{36}(x_i - 836)^2 = 419{,}394{,}409; \tag{56}$$

$$\sigma_x = \sqrt{\frac{1}{35}\sum_{i=1}^{36}(x_i - 836)^2} = 20{,}479. \tag{57}$$

Deviations are calculated as the difference between the corresponding numerical values of the "Data" and "Model" graphs, respectively

$$x(t) = y(t) - y_m(t). \tag{58}$$

Fig. 4 shows the deviation graph (58), the average value of the deviation, as well as the limit of the deviation, which is half of the standard value of the deviation of the values of the cost indicator from the average value.

The analysis of the deviation graph (58) shows that the deviation value of the cost of goods sold indicator is a stationary random sampling sequence. The graph (Fig. 5) shows that there are outliers in the deviation values of the cost indicator beyond the specified limit. This gives reason to note that the increase in the number of emissions worsens economic security.

The selective estimate of the autocorrelation function is found according to the formula

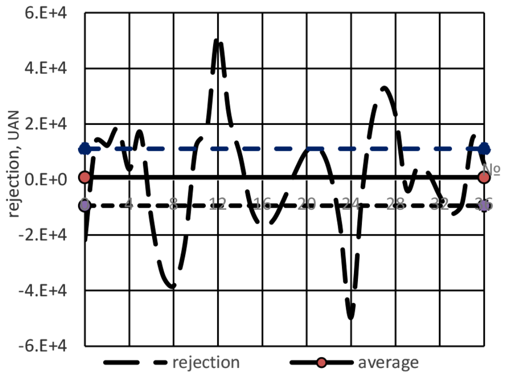

Fig. 4. Schedules of deviations of the cost of goods sold; average value; deviation limits

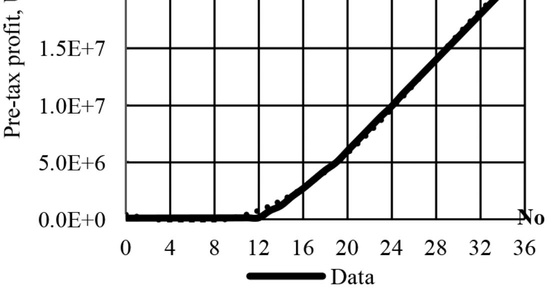

Fig. 5. Graphs of input data and model values of the pre-tax profit indicator

$$\tilde{R}_x(k)=\frac{1}{14{,}678{,}804{,}303}\sum_{i=1}^{n-k}(x_i-836)(x_{i+k}-836),\quad k=0,1,\ldots,m. \tag{59}$$

Structure (47) was chosen as the analytical formula. To approximate the functions (59 and 45) using the parameter α, the minimization of the functional (37) was applied. As a result, we get $\alpha_0 = 1.986$, and formula (48) takes the form

$$R_x(\tau)=e^{-1.986\cdot|\tau|}(1+1.986\cdot|\tau|). \tag{60}$$

According to formulas (38 and 60), the analytical formula of the autocovariance function takes the form

$$K_x(\tau)=419{,}394{,}409e^{-1.986\cdot|\tau|}(1+1.986\cdot|\tau|). \tag{61}$$

According to (37), we have

$$\sigma_v^2=\alpha_0^2\cdot\sigma_x^2=1.986^2\cdot 419{,}394{,}409=1{,}654{,}173{,}750. \tag{62}$$

Given that a = 11,075 and using formula (26) we find the average number of emissions per unit of time

$$\bar{\nu}(11{,}075)=0.279. \tag{63}$$

In turn, the number of emissions that occur in a given time interval (0.36) makes up the value

$$\bar{n}(11{,}075)=\bar{\nu}(11{,}075)\cdot 36=0.279\cdot 36=10.04\approx 10. \tag{64}$$

Further, the average duration of the emission, according to (29), will be the value

$$\bar{\tau}(11{,}075)=0.669. \tag{65}$$

And, finally, the average area limited by the implementation of the stationary random function $X(t)$ above the given level a = 1,1075 during the emission is found according to formula (31) and is the value

$$\bar{s}(11{,}075)=18{,}993. \tag{66}$$

Instead, consider such an economic indicator as profit before taxation in the period from 2018 to 2022 [20, 21]. The graph of the values of the pre-tax profit indicator under the name "Data" is presented in Fig. 5. In turn, the graph of the corresponding approximation is called "Model". The mathematical model of the pre-tax profit indicator is represented by a polynomial of the fourth order

$$y_m(t)=-29.5717\cdot t^4+1{,}602.83\cdot t^3-1{,}751.34\cdot t^2-\\-169{,}961.79\cdot t+429{,}796. \tag{67}$$

The mathematical model (67) was formed similarly to (54). The coefficient of determination was $R^2 = 0.9987$, according to the Chaddock scale – a very high connection.

To calculate the deviations, random processes presented on the "Data" and "Model" graphs were discretized according to formula (41), i. e., with a discreteness of one month.

Next, we find the numerical characteristics of the tax before taxation according to formulas (32–34) taking into account discretization (41)

$$\bar{x}=\frac{1}{36}\sum_{i=1}^{36}x_i=117; \tag{68}$$

$$\sigma_x^2=\frac{1}{35}\sum_{i=1}^{36}(x_i-117)^2=74{,}653{,}494{,}491; \tag{69}$$

$$\sigma_x=\sqrt{\frac{1}{35}\sum_{i=1}^{36}(x_i-117)^2}=273{,}228. \tag{70}$$

Deviations are calculated as the difference between the corresponding numbers of the "Data" and "Model" graphs

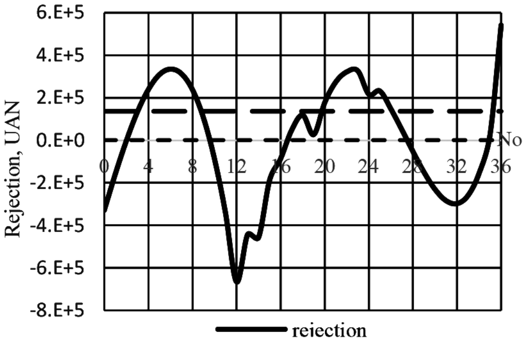

Fig. 6. Schedules of pre-tax profit deviation; average value; deviation limits

$$x(t) = y(t) - y_m(t). \tag{71}$$

Fig. 6 shows the deviation graph (71), the average value of the deviation, as well as the limit of the deviation, which is half of the standard value of the deviation of the pre-tax tax from the average value.

Analysis of the deviation graph (71) shows that the deviation of the values of the cost indicator is a stationary random sample sequence. A visual analysis of the graph gives grounds for asserting that there are outliers in the values of the cost indicator beyond the specified limit. Therefore, it can be concluded that an increase in the number of emissions worsens economic security.

The selective estimate of the autocorrelation function is found by the formula

$$\tilde{R}_x(k)=\frac{1}{74{,}653{,}494{,}491}\sum_{i=1}^{n-k}(x_i117)(x_{i+k}117),\quad k=0,1,\ldots,m. \tag{72}$$

Structure (47) was selected as an analytical dependence. To approximate the functions (61 and 47) using the parameter α, the minimization of the functional (36) was applied. As a result, we get that

$\alpha_0 = 0.871$, and formula (47) takes the form

$$R_x(\tau)=e^{-0.871\cdot|\tau|}(1+0.871\cdot|\tau|). \tag{73}$$

According to (38), we get

$$\sigma_v^2=\alpha_0^2\cdot\sigma_x^2=0.871^2\cdot 74{,}653{,}494{,}491=56{,}635{,}201{,}714. \tag{74}$$

Given that a = 136,731 and using formula (26), we find the average number of emissions per unit of time

$$\bar{\nu}(136{,}731)=0.122. \tag{75}$$

In turn, the number of emissions that occur in a given time interval (0.36) makes up the value

$$\bar{n}(136{,}731)=\bar{\nu}(136{,}731)\cdot 36=0.122\cdot 36=4.39\approx 4. \tag{76}$$

Further, the average duration of the emission, according to (29), will be the value

$$\bar{\tau}(136{,}731)=1.526. \tag{77}$$

And, finally, the average area limited by the implementation of the stationary random function $X(t)$ above the given level a = 136,731 during the emission is found according to the formula (31) and is the value

$$\bar{s}(136{,}731)=577{,}805. \tag{78}$$

We will present the obtained results regarding the characteristics of emission values of PivdGZK JSC enterprise indicators in the Table. The results presented in the Table allow us to draw conclusions about economic security for each of the pro-

Table

Calculation and analytical values of emissions of enterprise activity indicators

Emissions Indexes	The average amount or one month $\overline{v}(a)$	The amount for four years $\overline{n}(a)$	The average duration $\overline{\tau}(a)$	The average area bounded by the function above a given level $\overline{s}(a)$
net income from product sales	0.198	7.14	0.942	123,186
cost of goods sold	0.279	10.04	0.669	18,993
pre-tax profit	0.122	4.39	1.526	577,805

duction characteristics. The analysis of those given in the Table of the calculation results shows that the largest average number of emissions both for one month and for a given time interval (4 years) correspond to the cost price indicator. The largest values of both the average emission duration and the average area bounded by a random function above a given level correspond to the pre-tax profit indicator.

Thus, regarding the evaluation of the economic safety of the JSC "PivdGZK" enterprise, we can note: the economic indicator cost of sold products – the value of the average number of emissions both for one month and for four years is the most dangerous; profit before taxation – the value of the average duration of the emission and the average area of the emission, which is limited by a function above a given level, indicates economic danger. The obtained results should be used when making management decisions to ensure the economic security of the enterprise.

Conclusions. Having systematized the experience of scientific research in the field of assessing the economic security of an industrial enterprise, we can note that the result of ensuring the economic security of an enterprise is the stability of the functioning of all its components. The issue of economic security of an industrial enterprise is considered on the basis of a systemic approach. Under the economic security of an industrial enterprise, it is proposed to consider information about emissions in connection with a random process in time, which determines the value of a certain economic indicator characterizing its activity.

From a new point of view, problematic issues regarding the assessment of economic security at enterprises are considered, based on the statistical analysis of the values of economic indicators. As a tool for analyzing situations that have developed at enterprises, the possibility of applying a statistical approach based on the theory of emissions is substantiated. The proposed methodology allows for an analysis of economic security based on selected economic indicators.

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Оцінювання економічної безпеки промислового підприємства в парадигмі системно-синергетичного підходу

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Мета. Оцінювання синтезу рівнів економічної безпеки промислового підприємства задля запобігання можливих загроз.

Методика. У дослідженні використовуються методологічні принципи системно-синергетичного підходу, а саме підприємство розглядається як системний об’єкт, що перебуває під впливом внутрішніх і зовнішніх збурень. Статистичні методи аналізу щодо значень викидів певних показників, які характеризують функціонування промислового підприємства. Обгрунтована можливість застосування статистичного підходу, заснованого на теорії викидів.

Результати. Дослідженні та проаналізовані проблемні питання забезпечення прийняття рівня економічної безпеки на промислових підприємствах. Як інструмент для аналізу ситуацій, що склалися на підприємствах, обгрунтована можливість використання статистичного підходу, заснованого на теорії викидів. Синтез рівнів економічної безпеки пропонується визначати на засадах системно-синергетичного підходу.

Наукова новизна. Набуло подальшого розвитку питання визначення економічної безпеки як інформації про викиди певного економічного показника, представленого як випадковий часовий процес. Передбачене визначення ймовірності виходу ординат процесу за заданий рівень і знаходження ймовірнісних характеристик часу перебування ординат випадкового процесу вище за цей рівень.

Практична значимість. Аналіз результатів визначення економічної безпеки досліджено на підприємстві АТ «ПівдГЗК». Проаналізовані значення наступних економічних показників: чистий дохід від реалізації продукції; собівартість реалізованої продукції; прибуток до оподаткування. Результати розрахунків показали, що найбільша середня кількість викидів як за один місяць, так і за заданий інтервал часу припадають на собівартість. Середня тривалість викиду й середня площа викиду, що обмежена функцією вище заданого рівня, стосується такого економічного показника як прибуток до оподаткування. Такі показники здійснюють негативний вплив на економічну безпеку підприємства. Проведений аналіз надає підстави відповідним службам для реалізації управлінських дій із запобігання можливих загроз для економічної безпеки підприємства.

Ключові слова: *економічна безпека, випадковий процес, викиди, показник, статистичний підхід*

The manuscript was submitted 03.03.24.