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FORMATION OF ORGANIZATIONAL SUPPORT FOR THE MANAGEMENT OF THE ECONOMIC SECURITY OF ENGINEERING ENTERPRISES: METHODICAL AND PRACTICAL ASPECTS

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Abstract. Difficult conditions of functioning and the severity of forecasting possible changes in the conduct of business stimulate a search for new ways to improve economic security management for engineering enterprises. The purpose of our article is to develop a methodological framework for the formation of organizational support for the management of economic security of an engineering enterprise with subsequent practical application. The subjects of the study are the activities of the top engineering enterprises in Ukraine for the period 2010–2017. Based on the analysis of engineering enterprises of Ukraine, we are in the results of the study allow us to estimate the potential losses from the realization of certain threats, as well as directly assess their impact on the activities of the enterprise. Developed methodological bases for the formation of organizational support for managing the process of ensuring the economic security of the engineering enterprise, providing for assessing the level of influence of threats, determining the optimal set of measures to improve organizational support in accordance with the results of calculating the integral level of threats, which allows planning possible costs for organizational support of protective actions as a whole at the enterprise, and in the context of the main structural units their subsequent optimization.

Keywords: security, economic security, engineering enterprise, threat, organizational support, system.

JEL Classification: D21, D81, L62, G32.

Introduction

The specifics of the activities of the engineering enterprises of Ukraine, together with the existing problems of the growth of the aggressiveness of the external environment, have led to the aim of developing a methodological basis for the formation of organizational support for economic security management for the engineering enterprise with subsequent practical application.

The aim of our research is to strive to develop a methodological basis for the formation of organizational support for the management of the economic security of a engineering enterprise. To do this, it is necessary to identify the key threats and types of losses that the management of the enterprise may suffer as a result of their impact.

Thanks to mathematical methods, we determine and calculate the integral level of threats, which allows you to plan the possible costs of organizational support for events in the enterprise.

The methodology of empirical research includes: observation, induction, deduction, testing, evaluation. All this was used on the example of 10 domestic engineering enterprises in order to form an organizational support for the management of the economic security of enterprise.

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The novelty of our research is the development of a methodological basis for the formation of organizational support for managing the process of ensuring the economic security of a engineering enterprise, which involves assessing the level of influence of threats, determining the optimal set of measures to improve organizational support according to the results of calculating the integral level of threats, which allows you to plan the possible costs of organizational support for events in the enterprise as a whole, and in the context of the main structural divisions – their subsequent optimization.

1. Literature review

General provisions for the formation of a mechanism of economic security were laid down in the last century, but even today they are constantly being improved (Stavytskyi 2017). A significant contribution to the development of the concept of the essence of "security" in modern society has made N. Lasan (2010). Menggang Li (2013) made a significant contribution to the development of industrial security theory. Scientists pay attention to developing issues of maintaining a sufficient level of economic security of an enterprise, in particular: Z. Zhivko (2013) focused on developing methodological foundations for managing an enterprise's economic security system, in particular by proposing a procedure for monitoring an enterprise's economic security, identified and hierarchically rationalized the impact of threats on economic security of Ukrainian enterprises; M. Karaim (2014) scientifically substantiated theoretical and methodological principles and developed practical recommendations for the application of anti-crisis technologies in the management of the economic security of an engineering enterprise; M. Kopitko (2015) has developed a theoretical and methodological approach, methodological foundations and practical recommendations for the integrated provision of the economic security of transport engineering enterprises; V. Franchuk (2010) paid attention to the development of theoretical, methodological, conceptual foundations of the organization the system of economic security of joint stock companies.

It is worth noting the modern scientific contribution to the development of financial security of the enterprise as a component of the economic security of G. Blakyta, T. Ganushchak (2018). Key principles of the concept of economic security of enterprises in modern Ukrainian science, laid B. B. Dub (2016). Modern analysis of economic security issues for industrial enterprises was carried out by M. Bublyk, V. Koval and O. Redkva (2017).

In developing the methodological foundations of the formation of organizational support for the management of the economic security of an engineering enterprise, for our research, a discrete assessment scale was used, which was used by such scientists as V. Burkov, E. Gratsianskyi, S. Dzyubko, A. Shepkin (2001) and T. Saati (1993). In addition, the results of the work of T. Saati (1993) allowed us to form matrices of pairwise comparisons to reduce the impact of threats on the economic security of engineering enterprises. Also, one should pay tribute to the contribution of M. Bartish and I. Dudzyanyi (2009) and his method of multi-criteria evaluation of alternatives.

A. Modenov and M. Vlasov (2018) considers the principles of formation of the organizational structure of an enterprise ensuring the economic safety of an enterprise. Abandoning the functional approach of building the organizational structure, it is proposed to use a process approach, which allows to minimize the number of structural units and thereby enhance management efficiency.

A. Lanioglo and T. Polajeva (2017) studied the essence and stages of an integrated system for ensuring the economic security of an enterprise.

Significant contribution to the study of the essence of the concept of economic security of the enterprise brought research N. Avanesova and Y. Chuprin (2017).

G. Goncharov (2015) considered the problems of improving the system of institutional and organizational support for the economic security of small businesses. An analysis of the existing system. His assessment is also being carried out, and directions are offered along with tools for further improvement.

Paying tribute to the scientific and practical significance of the work of leading scientists, it should be noted that in modern scientific literature and the practice of managing machine-building enterprises, important issues of organizational support for managing their economic security are not sufficiently investigated.

2. Research model

One of the key tasks of the subjects of economic security is to monitor the level of impact of threats and apply protective measures adequate to the situation, can be defined as a vector optimization task, or as a normal scalar optimization task, focusing on the integral assessment of the level of threat impact. In the following, we used another method, which provides the implementation of an integrated assessment of the impact of threats. Despite the fact that a threat can be identified by two groups of factors (a probability vector and a loss vector), it is necessary make an intergration at first (convolution) according to the probabilities of each type of loss (for example, determine the expected value for each type of loss, that is, the expected loss as received financial losses and unused opportunities, that is, lost profits, etc.), and then determine the integral estimate of the expected losses. However, one can do the opposite: first, to obtain an integral estimate of losses, and then to determine the mathematical probability of the occurrence of such events. In the approach to solving the problem of improving organizational support considered below, the first option is used to manage the impact of threats, in which the integral assessment of threats is taken as an integral assessment of the expected losses of various activities.

Below we propose the universal tool for the formation the organizational support in the ESEE system, which minimizes the magnitude of losses from the realization of external and internal threats, and then helps to maintain the level of necessary security for development.

In accordance with the task, it is necessary to solve the following problem: the need to define a set of measures $\{x_i\}$ with varying parameters of the control object (subjects of the ESEE) so that the threat (integral assessment of the influence of external and internal threats) is not more than specified, and the cost of implementing all the measures that is, the costs of formation the organizational support were minimal. The current problem is discrete and quite complex from a mathematical point of view. As a rule, such tasks are related to *NP*-complete and are solved using the search procedure. The solution of the task is divided into several main stages: assessment of the level of impact of threats on ESEE; Determination of the optimal set of measures to improve the organizational support of guarantees ESEE.

Each of the defined stages is interconnected with the previous one and is a component of integral set of measures to reduce the impact of threats in order to ensure the necessary level of the ESEE as a socio-economic system. All four stages (involvement of experts to adjust the procedures for aggregating the tree of possible losses; determining the optimal set of necessary measures that change the parameters of organizational support management ESEE; customization of simulation models of the implementation of threats; selection of an effective set of management mechanisms for a given enterprise ESEE) are proposed to be combined into a computer decision support system, which contains the entire set of developed algorithms, which should allow to dynamically simulate various strategies for providing the required level of ESEE.

In addition, for the operation of the system, it is necessary to determine the acceptable level of the impact of threats, as well as the dynamic distribution of funds while the conducting a combination of protective measures.

To obtain baseline data for assessing the level of influence of ESEE threats, we suggest using an expert assessment system, for which it is necessary to form a group of experts, as well as to use objective statistical and analytical data of both a particular enterprise and the development trends of the domestic engineering industry and the national economy.

When considering the financial, personnel, material and informational consequences of the realization of a certain threat or set of threats that may lead to an increase in the level of danger, it is advisable to operate with the concepts of direct, indirect, total and general losses. By direct losses as a result of the realization of a certain threat, we mean the losses of all structural divisions of an enterprise that are related to what is happening or processes. Direct losses are expenses, losses, damage caused and entailed a decrease, or the impossibility of further use of fixed assets, current assets, as well as costs associated with the restriction of development and the elimination of the consequences of increasing danger. The costs of eliminating the consequences of increasing danger include the wage costs of additionally hired specialists, third-party services, payment of penalties, the creation of new protective mechanisms, the restoration of lost consumer and customer confidence through the signing of new agreements and the provision of additional guarantees, discounts, services, court costs and the like. The amount of expenditures on eliminating the consequences of increasing danger due to the realization of a certain threat depends on the specifics and scale of the economic activity of the engineering enterprise.

Indirect losses from the growth of danger are losses, diseconomies and additional expenses, the company's divisions will incur, are indirectly involved in the situation, or the enterprise as a whole, if a certain external threat is realized, which does not directly concern the activity of the enterprise. Indirect losses can be attributed as the loss of markets due to changes in the political situation, the decline in the purchasing power of the population, the result of scientific and technological progress, which led to a significant improvement in the technology of manufacturing industrial products and the like. Direct and indirect losses in aggregate form a total loss.

It is important to note that the magnitude of the general losses as a result of the realization of a certain threat can be considered as final only at a certain time stage, because its consequences will be felt in subsequent periods. Thus, the indicator of total losses, being finite at a specific point in time, is intermediate compared to some final indicator, which will be determined in the distant future. The latter will be called the general losses and understand by them the sum of all losses, losses and expenses of the enterprise, caused by the increase in danger as a result of the realization of external and internal threats. Of course, it is impossible to call a clear period after which the magnitude of the losses will not change or these changes will be relatively small. This term, first of all, will depend on the type and scale of activity of a particular enterprise, as well as on the nature of the threat realization.

All types of direct losses that the enterprise may incur through the realization of a threat we are grouped into four groups: financial, material, personnel and informational. Therefore, considering the structure of direct losses, it is advisable to single out direct financial, direct material, direct personnel and direct informational losses.

At this stage, it is advisable to emphasize once again that the proposed list of direct losses in the context of the main groups is indicative and expedient, since it is not tied to a particular enterprise and the effect of any threat.

Analysis of the sequence of occurrence of interrelated events in the implementation of a certain threat shows that, as we move along their chain, firstly, the influence of the primary event weakens, and, secondly, the difficulty of estimating indirect losses increases. Based on these considerations, in assessing indirect losses, it is advisable to use expert judgment based on the results of the calculation of direct losses, without detailing and analyzing the individual components. If we consider indirect losses carefully, it is advisable to analyze them in individual areas of the enterprise.

Thus, the structure of losses from the realization of the threat depends on the form in which the source data is presented in the form of indicators of losses (losses or lost profits) or expected losses. This structure is a tree with an integral loss estimate at the initial vertex, and various types of losses at the lower vertices. To obtain an integral loss estimate, it is necessary to set the parameters of the aggregation procedure (convolution) at each base node of the tree. There are various aggregation procedures (linear, adaptive, multiplicative, generalized additive, etc.). When aggregating heterogeneous indicators (for example, financial, material, personnel and information losses), it is advisable to apply the so-called matrix convolutions.

It is first necessary to determine the values of indicators with respect to a discrete scale of assessments that have been used by leading scientists such as V. Burkov, E. Gratsianskyi, S. Dzyubko, A. Shepkin (2001), E. Semenyuk, T. Olyanyshen, V. Senkivskyi, O. Melnikov, Y. Kotlyarevskyi (2012) and T. Saati (1993). Each value of a discrete scale corresponds to a certain qualitative characteristic of threats or losses (for clarity, we will consider the losses from the realization of threats as an integral indicator, and we will call local threats as output indicators the expected losses by type, we will call local threats). Obviously, each qualitative value of a local threat corresponds to a certain interval of quantitative values of the corresponding expected losses (Table 1).

Table 1. Scale threat assessments and losses from their implementation (source: developed by author)

Evaluation value	Assessment	Substantive explanation
1	Minimal	There is no threat
2	Low	Low threat
3	Average	Significant threat
4	High	Clear threat
5	Maximum	Absolute threat

The method of forming an integral assessment of losses from the realization of threats is based on the methodology of forming integrated assessments, which defines the system of formal and expert procedures described in the works of V. Burkov, E. Gratsianskyi, S. Dzyubko, A. Shepkin (2001). This methodology can be used for a wide class of assessment tasks. For the object being evaluated, the set of parameters $\{a_i\}$ is determined. To obtain a comprehensive assessment, the parameters are pairwise compared with each other using convolution matrices. The obtained characteristics, in turn, are again compared in pairs with each other using the convolutional matrices of the next level. The procedure is repeated until one characteristic remains, which will be a comprehensive assessment of the object. To implement the abovementioned procedure, it is necessary to determine the pairs of characteristics that will be compared, as well as the corresponding convolution matrices. In addition, it is necessary to construct convolution matrices in such a way that estimates of all the characteristics at all levels can be obtained from the estimates determined at a low level.

The advantage of the binary structure is that it allows to solve the problem of integrated assessment with *N* criteria through a multi-step aggregation procedure. Moreover, at each step aggregation is carried out only by two criteria. This simplifies the task of choosing the rules of aggregation, since it corresponds to the real possibilities of a person in issuing consistent consistent information.

Setting up an assessment procedure (with the existing assessment tree and a fixed set of initial indicators) consists of a number of tasks: selection of normalization transformations; determination of the type and parameters of individual evaluation functions; selection of rating scales; select the type of aggregation procedures (convolution) and adjust their parameters; selection of methods for the transition from continuous to discrete scales; implementation of the assessment procedure.

3. Data

The authors carried out an analytical study in two planes: the first one included the analysis of the development trends of the engineering industry in Ukraine in the period 2010–2017; the second is aimed to the studying the economic activities of the leading Ukrainian engineering enterprises. The group of engineering enterprises under study included: PJSC "Smelyansky engineering factory", PJSC "Drogobychsky engineering factory", PJSC "Korostensky engineering factory", PJSC "Berislavsky engineering factory", PJSC "Berdichevsky engineering factory "Progress"", PJSC "Monastyrishensky engineering factory", PJSC "Verkhnedneprovsky engineering factory", PJSC "Poltava engineering factory", PJSC "Karlovsky engineering factory", PJSC "Grebenkovsky engineering factory". The result of the analytical study was the determination of the combination of external and internal threats that most significantly affect the economic security of engineering enterprises in Ukraine. Among the internal threats highlighted: the further application of cost technologies, accompanied by an increase in the resource intensity of engineering products; use of physically and morally worn fixed assets; critically low capacity utilization; management system is not adapted to market conditions; inefficient cash flow management; the lack of large-scale investment projects, low rates of development, implementation and release of new products, a significant curtailment of innovation and investment activities. External threats include: general destabilization of the economy; political instability; depreciation and fluctuations of the national currency; the imperfection of government programs to support industry; substantial dependence of the engineering on foreign markets; growing competition from foreign producers; significant reduction in demand and insufficient development of the domestic market.

A certain set of threats forms the information basis for the development of the methodological basis for the formation of organizational support for managing the economic security of an engineering enterprise. In the development of such methodological support, the process of managing the economic security of Ukrainian engineering enterprises can significantly improve than enhancing their protection from the negative impact of external and internal threats.

To determine the integral assessment of losses from the realization of threats, a binary convolution tree is constructed, in which each non-upside vertex is a logical convolution matrix that accumulates information from matrices of the previous level. We will consider the algorithm for determining the integral threat assessment using the example of the threat tree fragment shown in Figure 1.

4. Results and discussions

We construct three logical convolution matrices. The first matrix (Table 2) provides a generalized assessment of financial and material threats, defined as material and financial losses.

The second matrix (Table 3) provides a generalized assessment of the implementation of personnel and informational threats, that is, an assessment of personnel and informational losses.

Finally, the third matrix (Table 4) provides an integrated assessment of the realization of threats by aggregating complex estimates of material and financial, personnel and informational losses.

Table 2. Logical matrix of convolution of financial and material threats (source: developed by author)

		Financial threats a_1				
		1	2	3	4	5
Material threats a_2	1	1	2	2	3	3
	2	1	2	3	3	3
	3	2	2	3	4	4
	4	3	3	3	4	5
	5	3	4	4	4	5

Table 3. Logical matrix of convolution of personnel and informational threats (source: developed by author)

		Personnel threats a_3				
		1	2	3	4	5
Informational threats a_4	1	1	1	2	3	3
	2	1	1	2	3	3
	3	1	1	2	3	3
	4	1	2	2	3	4
	5	2	2	3	4	4

Table 4. Logical matrix of convolution of direct losses from implementing threats (source: developed by author)

		Material and Financial threats A_1				
		1	2	3	4	5
Personnel and Informational threats A_2	1	1	1	2	3	4
	2	1	2	2	3	4
	3	2	2	3	4	5
	4	2	2	3	4	5
	5	2	2	3	4	5

Convolution logic matrices define the procedure for aggregating local threats into an integral assessment of losses

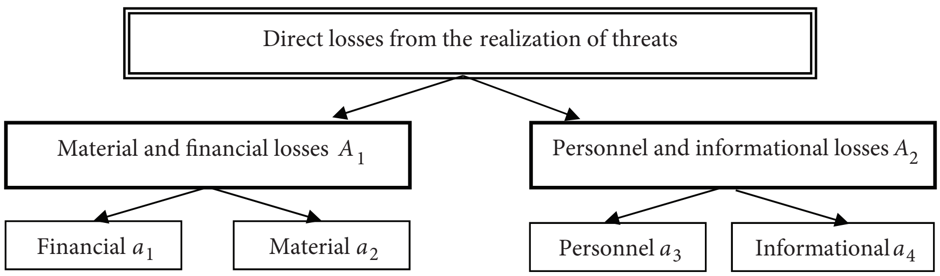

Figure 1. Binary tree structure of threats (direct losses) (source: developed by author)

from the realization of threats, and thereby fix the priorities and policies of enterprise management regarding losses of various types. The formation of convolutional logical matrices is a responsible procedure performed by employees of the enterprise security service.

Thus, each type of hazard is characterized by a probability distribution of possible loss values. The task is to determine, on the basis of these data, the probability distribution of the possible values of the integral estimate of losses from the realization of threats.

We assume that the losses from the realization of threats are independent random variables. Denote p_{ij} probability j value for losses a_i, $i=\overline{1,4}$, $j=\overline{1,5}$. Probability distribution p_{ij} of possible values of enterprise losses *ai* are given in Table 5.

Table 5. Distribution of the probabilities of values p_{ij} possible losses a_i (source: developed by author)

Pij	p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}
p_{1j}	0.1	0.1	0.2	0.2	0.4
p_{2j}	0.1	0.1	0.2	0.2	0.4
p_{3j}	0.4	0.2	0.2	0.1	0.1
p_{4j}	0.4	0.2	0.2	0.1	0.1

Based on the logical matrix of convolution of financial and material threats (Table 3), we generalize the probabilities of loss for various cases (Table 6).

By the denomination the probability of estimating j by q_{ij}. Applying the formula of total perceptibility it is possible to estimate the number of probable minimum material and financial losses and taking into account the data in Table 6 (1):

$$q_{11} = p11p21 + p12p21, \tag{1}$$

where p_{11} is the probability of the absence of financial threats; p_{12} is the probability of occurrence of weak financial threats; p_{21} is the probability of the absence of material threats.

Table 6. The likehood of financial and material threats for different cases (source: developed by author)

End of Table 6

Assessment j	Case	Cases of probability of occurrence of threats	Probability of losses q_{ij}	Probability of threats p_{ij}
1	2	3	4	5
1	1	financial threats a_1 and material threats a_2 absent $j = 1$	q_{11}	$p_{11} \times p_{21}$
	2	financial threats a_1 weak $j = 2$, material threats a_2 absent $j = 1$		$p_{12} \times p_{21}$
2	1	financial threats a_1 weak $j = 1$, material threats a_2 weak $j = 2$	q_{12}	$p_{11} \times p_{22}$
	2	financial threats a_1 absent $j = 1$, material threats a_2 significant $j = 3$		$p_{11} \times p_{23}$
	3	financial threats a_1 material threats a_2 weak $j = 2$		$p_{12} \times p_{22}$
	4	financial threats a_1 significant $j = 3$, material threats a_2 absent $j = 1$		$p_{13} \times p_{21}$
	5	financial threats a_1 significant $j = 3$, material threats a_2 weak $j = 2$		$p_{13} \times p_{22}$
3	1	financial threats a_1 absent $j = 1$, material threats a_2 явні $j = 4$	q_{13}	$p_{11} \times p_{24}$
	2	financial threats a_1 absent $j = 1$, material threats a_2 absolute $j = 5$		$p_{11} \times p_{25}$
	3	financial threats a_1 weak $j = 2$, material threats a_2 significant $j = 3$		$p_{12} \times p_{23}$
	4	financial threats a_1 weak $j = 2$, material threats a_2 explicit $j = 4$		$p_{12} \times p_{24}$
	5	financial threats a_1 weak $j = 2$, material threats a_2 absolute $j = 5$		$p_{12} \times p_{25}$
	6	financial threats a_1 material threats a_2 significant $j = 3$		$p_{13} \times p_{23}$
	7	financial threats a_1 explicit $j = 4$, material threats a_2 absent $j = 1$		$p_{14} \times p_{21}$
	8	financial threats a_1 explicit $j = 4$, material threats a_2 weak $j = 2$		$p_{14} \times p_{22}$
	9	financial threats a_1 explicit $j = 4$, material threats a_2 significant $j = 3$		$p_{14} \times p_{23}$
	10	financial threats a_1 absolute $j = 5$, material threats a_2 absent $j = 1$		$p_{15} \times p_{21}$
4	1	financial threats a_1 significant $j = 3$, material threats a_2 explicit $j = 4$	q_{14}	$p_{13} \times p_{24}$
	2	financial threats a_1 significant $j = 3$, material threats a_2 absolute $j = 5$		$p_{13} \times p_{25}$
	3	financial threats a_1 material threats a_2 explicit $j = 4$		$p_{14} \times p_{24}$
	4	financial threats a_1 absolute $j = 5$, material threats a_2 weak $j = 2$		$p_{15} \times p_{22}$
	5	financial threats a_1 absolute $j = 5$, material threats a_2 significant $j = 3$		$p_{15} \times p_{23}$
	6	financial threats a_1 absolute $j = 5$, material threats a_2 high $j = 4$		$p_{15} \times p_{24}$
5	1	financial threats a_1 explicit $j = 4$, material threats a_2 absolute $j = 5$	q_{14}	$p_{14} \times p_{25}$
	2	financial threats a_1 material threats a_2 absolute $j = 5$		$p_{15} \times p_{25}$

The probability of occurrence of low material and financial losses q_{12} occurs in such cases (2):

$$q_{12} = p_{11}p_{22} + p_{11}p_{23} + p_{12}p_{22} + p_{13}p_{21} + p_{13}p_{22}, \quad (2)$$

where p_{13} is the probability of occurrence of significant financial threats; p_{22} is the probability of occurrence of weak material threats; p_{23} is the probability of occurrence of significant material threats.

The probability of occurrence of the average material and financial losses q_{12} is calculated (3):

$$q_{13} = p_{11}p_{24} + p_{11}p_{25} + p_{12}p_{23} + p_{12}p_{24} + p_{12}p_{25} + p_{13}p_{23} + p_{14}p_{21} + p_{14}p_{22} + p_{14}p_{23} + p_{15}p_{21}, \quad (3)$$

where p_{14} is the probability of occurrence of obvious financial threats; p_{15} is the probability of occurrence of absolute financial threats; p_{24} is the probability of occurrence of obvious material threats; p_{23} is the probability of occurrence of absolute material threats.

The likelihood of high losses q_{14} occurs in the following cases (4):

$$q_{14} = p_{13}p_{24} + p_{13}p_{25} + p_{14}p_{24} + p_{15}p_{22} + p_{15}p_{23} + p_{15}p_{24}. \quad (4)$$

The probability of occurrence of maximum losses (5):

$$q_{15} = p_{14}p_{25} + p_{15}p_{25}. \quad (5)$$

We determine the probability of personnel informational losses q_{2j} according to the formulas given below.

The probability of occurrence of the minimum personnel and informational losses p_{21} occurs in such cases (6):

$$q_{21} = p_{31}p_{41} + p_{31}p_{42} + p_{32}p_{41} + p_{32}p_{42} + p_{33}p_{41} + p_{33}p_{42} + p_{34}p_{41}, \quad (6)$$

where p_{31} is the probability of lack of personnel threats; p_{32} is the probability of occurrence of weak personnel threats; p_{33} is the probability of occurrence of significant personnel threats; p_{34} is the probability of occurrence of obvious personnel threats; p_{41} is the probability of the absence of informational threats; p_{42} is the probability of occurrence of weak informational threats.

The likelihood of low social losses (7):

$$q_{22} = p_{31}p_{43} + p_{32}p_{43} + p_{33}p_{43} + p_{34}p_{42} + p_{34}p_{43} + p_{35}p_{41} + p_{35}p_{42}, \quad (7)$$

where p_{35} is the probability of occurrence of absolute material threats; p_{43} is the probability of occurrence of significant informational threats.

The likelihood of average personnel informational losses (8):

$$q_{23} = p_{31}p_{44} + p_{31}p_{45} + p_{32}p_{44} + p_{32}p_{45} + p_{33}p_{44} + p_{33}p_{45} + p_{34}p_{44} + p_{35}p_{43}, \quad (8)$$

where p_{44} is the probability of occurrence of obvious informational threats; p_{45} – the probability of occurrence of absolute informational threats.

The probability of occurrence of high personnel and informational losses (9):

$$q_{24} = p_{34}p_{45} + p_{35}p_{44} + p_{35}p_{45}. \quad (9)$$

The probability of occurrence of maximum personnel and informational losses $q_{25} = 0$.

Substituting the values of p_{ij} with Table 11 into formulas (1–9), we obtain the results, and put them in Table 7.

Table 7. Probability of material and financial and social losses (source: developed by author)

p_{ij}	p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}
p_{1j}	0.02	0.08	0.3	0.36	0.24
p_{2j}	0.52	0.26	0.19	0.03	0

The method of constructing an integrated threat assessment based on the aggregation of local threats (expected losses) can be applied without significant changes to the construction of an integrated assessment of losses from the realization of threats as a mathematical expectation of an integrated assessment of losses. For this, it suffices to consider the losses as initial indicators rather than local threats, but the losses themselves, giving each value of losses an appropriate probability.

Knowing the probability distribution of the possible values of material, financial and personnel and informational losses based on the matrix of integral threats, it make possible to determine the probability distribution of the possible values of the integral threats of the enterprise.

The probability of integral estimates of direct losses from the realization of threats Q_j is determined as follows:

for direct losses when there are no threats (10)

$$Q_1 = q_{11}q_{21} + q_{11}q_{22} + q_{12}q_{21}, \quad (10)$$

for direct losses from the realization of weak threats (11)

$$Q_2 = q_{11}q_{23} + q_{12}q_{22} + q_{12}q_{23} + q_{13}q_{21} + q_{13}q_{22} + q_{14}q_{21} + q_{14}q_{22} + q_{15}q_{21} + q_{15}q_{22}; \quad (11)$$

for direct losses from the realization of significant threats (12)

$$Q_3 = q_{11}q_{24} + q_{12}q_{24} + q_{13}q_{23} + q_{14}q_{23} + q_{15}q_{23}; \quad (12)$$

for direct losses from the realization of obvious threats (13)

$$Q_4 = q_{11}q_{25} + q_{12}q_{25} + q_{13}q_{24} + q_{14}q_{24} + q_{15}q_{24}; \quad (13)$$

for direct losses from the realization of absolute threats (14)

$$Q_5 = q_{13}q_{25} + q_{14}q_{25} + q_{15}q_{25}. \quad (14)$$

Substituting the values of q_{ij} with and Table 7 in the formulas (10–14), we obtain the results, put in Table 8.

Table 8. Probability of integral assessments of direct losses from implementing threats (source: developed by author)

Q_1	Q_2	Q_3	Q_4	Q_5
0.0572	0.7418	0.174	0.027	0

Now it is possible to estimate the integral threat $R = \sum_{j=1}^{5} jQ_j$ as the average of the integral estimates of direct losses from the realization of the threats Q_j (15):

$$R = 1Q_1 + 2Q_2 + 3Q_3 + 4Q_4 + 5Q_5. \quad (15)$$

Substituting the values of Q_j in the formula (15), we obtain (16):

$$R = 1 \times 0.0572 + 2 \times 0.7418 + 3 \times 0.174 + 4 \times 0.027 + 5 \times 0 = 2.1708. \quad (16)$$

In this case, the level of threats is between low and medium on the selected rating scale (Table 1).

That is, if you know how to define an integral threat, then you can set and solve threat management tasks, the resulting document of which is the developed program for reducing threats to the required level with minimal losses.

At the second stage, an optimal set of measures is determined that can change the parameters of the object in such a way that the integral impact of the threats is not more than the specified, and the expenses on the organizational support of the ESEE support process are minimal. The task is solved on the basis of the tree of possible losses already built at the first stage. To do this, it is necessary to determine how to change the primary parameters of the object (in this case, the subject of the ESEE), that is, to improve its organizational support of the process of ensuring economic security so that the magnitude of the integral impact of threats becomes acceptable, or one that allows the existence and further development of the enterprise. After that, any change in each primary parameter of organizational support will be associated with a specific event (or group of events), which has a value. To determine the optimal combination of such measures, a multi-criteria evaluation of alternatives will be applied.

In accordance with the given basic positions of the direction (functional subsystems), the reduction of the influence of the ESEE threats and their mathematical notation includes: financial – b_1; material – b_2; personnel – b_3; informational – b_4.

Thus, the set of directions for reducing the impact of the ESEE threats is the set $Q = \{b_1, b_2, b_3, b_4\}$.

The solution of this problem is based on the research of O. Aref'yeva and A. Shtangret (2011), Z. Zhivko (2013), Yu. Ivanov (2014) at the micro and macro level using systems analysis methods.

For the solution of the problem the interaction of the directions of reducing the influence of the ESEE threats is determined on the basis of expert assessments, therefore the preference of one direction of reducing the influence of threats in relation to another *bij* cannot always be calculated accurately. Numbers b_{ij} M. Syavavko (2007) names the ranks of advantages. The greater the rank of the advantage, the greater the degree of its belonging to the set of true values. Since the directions of reducing the impact of threats that we study have a certain functional load, it can be argued that the degree of its significance is a function of the weight of the level.

A solution to the situation when it is not always possible to accurately calculate b_{ij} could be the use of T. Saati (1993) of the matrix theory asserted briefly below.

If the numbers $\lambda_1, \ldots, \lambda_n$ satisfy the equations $B_x = \lambda_x$, that is, the eigenvalues of the matrix B, with $b_{ii} = 1$ for all i and, then $\sum_{i=1}^{n} \lambda_i = n$.

If we consider that $Bg = ng$ – this means only one thing: the value of the eigenvector of the matrix B is equal to n, all the others are zeros; that is, in the case of consistency of expert judgments, the maximum eigenvalue of the matrix B is equal to n. The quotient of dividing the sum of the components of an eigenvector by the number of components (arithmetic average) will determine the approximation to the number $\lambda_{\max}$, which is called the maximum or principal eigenvalue. This value becomes the main characteristic that is used to establish the degree of consistency of expert judgments regarding pairwise comparisons of ways to reduce the impact of threats in tasks with linguistically vague criteria, which are solved using the theory of fuzzy sets.

We also affirm that with a slight change in the *bij* elements of the inversely symmetric matrix B, the eigenvalue of its vector also changes insignificantly, that is, the eigenvalue $\lambda_{\max}$ will be close to n, and other eigenvalues will slightly differ from zero. It follows that the deviation $\lambda_{\max}$ from n can serve as a measure of consistency, or the adequacy of expert judgments regarding the ways to reduce the impact of threats, depending on their importance for ensuring the ESEE. The deviation from consistency is called the *IU* consistency index and is expressed by the value $IU = \frac{\lambda_{\max} - n}{n-1}$. The value of *IU* should not exceed 10% of its reference value.

To determine the priority scale, we construct a square inverse-symmetric matrix of pairwise comparisons, the order of which is determined by the number of analyzed parameters proposed by T. Saati (1993) (Table 10). Since, in the general case, such matrices are inconsistent, the establishment of the pair-wise advantages of ways to reduce the impact of ESEE threats between them occurs with the help of the scale of the relative importance of objects – Table 9.

For two ways of reduction the impact of threats, which are compared with each other, depending on their importance and degree of influence on the ESEE, have the value of the corresponding element of the pairwise comparisons

Table 9. Scale relative importance of the direction of reduction by the influence of threats (source: developed by author)

Importance assessment	Comparison criteria	Help in choosing criteria
1	Directions are equal	No advantage b_1 over b_2
3	One direction is dominated by another	There is a reason for the presence of weak advantages b_1 over b_2
5	One direction prevails another	There is a reason for the significant advantage of b_1 over b_2
7	One direction is far superior to the another	There is a reason for the presence of a clear advantage of b_1 over b_2
9	One direction absolutely prevails another	Absolute advantage of b_1 over b_2 Is beyond doubt
2, 4, 6, 8	Intermediate values	Auxiliary comparative assessments

matrix in position ($b1$, $b2$) in Table 9. Put the set of estimates of importance as a result of comparing the directions of reducing the impact of threats in the matrix B, decorated in the form of a table (Table 10). According to the conditions in Table 9, the diagonal elements of the matrix are equal to one.

Table 10. Matrix of pairwise comparisons direction of the influence of threats ESEE (source: developed by author)

b_i	b_1	b_2	b_3	b_4
b_1	1	3	7	5
b_2	1/3	1	5	3
b_3	1/7	1/5	1	1/3
b_4	1/5	1/3	3	1

To establish the degree of consistency in the numerical values of pairwise comparisons of the directions of reducing the impact of threats given by the matrix, as T. Saati (1993) notes in his work, the priority vector of the matrix for which we first calculate the main eigenvector, and then normalizes it. So, we find the product of the elements of each row and calculate the root of the 4th degree. Get the vector (17):

$$S = (3.201;\ 1.495;\ 0.312;\ 0.668). \qquad (17)$$

Normalizing the vector S, for which we divide its components by the sum of the values of all the components, will result in the following vector (18):

$$S_n = (0.563;\ 0.263;\ 0.055;\ 0.117). \qquad (18)$$

The normalized S_n vector determines the numerical priorities of the directions for reducing the influence of the ESEE threats, and clarifies the formal result of solving the problem.

We calculate the consistency estimate of the weight values of the parameters. Multiply the matrix of pairwise comparisons by the vector S_n. We get (19):

$$S_{n1} = (2.328;\ 1.079;\ 0.227;\ 0.483). \qquad (19)$$

Let us find the components of the eigenvector λ_{max}: divide the components of the vector S_{n1} into the corresponding components of the vector S_n. We get (20):

$$S_{n2} = (4.129;\ 4.099;\ 4.134;\ 4.104). \qquad (20)$$

The approximate value for $\lambda_{max} = 4.117$, where λ_{max} is the arithmetic mean of the component S_{n2}.

The evaluation of the solution obtained is determined by the consistency index IU, which was discussed above. In our case, $IU = 0.039$. The value of the consistency index is usually, as noted by V. Lyamecz and Tevyashev (2004), compared with the reference values of the consistency index, the so-called random consistency index WI, which depends on the number of objects, are compared (Table 11).

For our case, $WI = 0.900$. Additionally, the results are evaluated in terms of WU consistency, the value of which is obtained from the expression $WU = IU / WI$.

Since $IU = 0.039$, then, accordingly, $WU = 0.043$. The results of pairwise comparisons can be considered satisfactory if $WU \leq 0.1$. Consequently, the level of convergence of the process is sufficient, and the consistency of expert judgments regarding the weights of the directions of reducing the impact of ESEE threats is appropriate.

Next, we calculate the weight values for various scenarios taking into account financial, material, personnel and informational directions for reducing the impact of ESEE threats. To do this, we determine the possibility of providing ESEE by using the method of pairwise comparisons for the most part of the variants. In our case, there will be three scenarios for changing the state of the EBMP: optimistic – A realistic – B and pessimistic – C. Further calculations are performed using a computer program, as noted by I. Gileta et al. (2012). To find the value of the utility functions uij for options A, B, C, taking into account the financial direction of reducing the threat level of the ESEE, we construct a matrix of pairwise comparisons in the form of Table 12.

Table 11. Table magnitude random coherence index (source: developed by author)

Number of objects	3	4	5	6	7	8	9	10
Reference index value	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The consistency of the results is carried out by the priority vectors λ_{max}, the consistency index *IU* and the consistency relation *WU*. We obtain the following results.

Table 12. Matrix of pairwise comparisons scenarios with reference to the financial direction of decreasing the level of threats ESEE (source: developed by author)

Financial	A	B	C
A	1	7	9
B	1/7	1	3
C	1/9	1/3	1

$$\lambda_{max} = 3.080;\ IU = 0.040;\ WU = 0.069.$$

The usefulness of alternatives in the financial direction:

$$u_{11} = 0.785;\ u_{12} = 0.148;\ u_{13} = 0.065.$$

Next, we define the utility function *uij* for variants *A, B, C*, taking into account the material direction of reducing the level of ESEE threats and construct a matrix of pairwise comparisons (Table 13). The consistency of the results is accomplished by the priority vectors λ_{max}, the consistency index *IU* and the consistency relation *WU*.

Table 13. Matrix of pairwise comparisons scenarios with reference to the material direction of decreasing the level of threats ESEE (source: developed by author)

Material	A	B	C
A	1	5	7
B	1/5	1	3
C	1/7	1/3	1

$$\lambda_{max} = 3.065;\ IU = 0.032;\ WU = 0.056.$$

The usefulness of alternatives in the material direction:

$$u_{21} = 0.730;\ u_{22} = 0.188;\ u_{23} = 0.080.$$

Now we define the utility function u_{ij} for options *A, B, C*, taking into account the personnel direction of reducing the level of ESSE threats and construct a matrix of pairwise comparisons (Table 14). The consistency of the results is accomplished by the priority vectors λ_{max}, the consistency index *IU* and the consistency relation *WU*.

Table 14. Matrix of pairwise comparisons scenarios with reference to the personnel direction of decreasing the level of threats ESEE (source: developed by author)

Personnel	A	B	C
A	1	1	3
B	1	1	1
C	1/3	1	1

$$\lambda_{max} = 3.018;\ IU = 0.091;\ WU = 0.016.$$

The usefulness of alternatives in the personnel direction:

$$u_{31} = 0.549;\ u_{32} = 0.240;\ u_{33} = 0.209.$$

Last, we define the utility function u_{ij} for variants *A, B, C*, taking into account the information direction of reducing the level of ESEE threats (Table 15). The consistency of the results is accomplished by the priority vectors λ_{max}, the consistency index *IU* and the consistency relation *WU*.

$$\lambda_{max} = 3.029;\ IU = 0.145;\ WU = 0.025.$$

The usefulness of alternatives in the informational direction:

$$u_{41} = 0.658;\ u_{42} = 0.185;\ u_{43} = 0.156.$$

Table 15. Matrix of pairwise comparisons scenarios with reference to the informational direction of decreasing the level of threats ESEE (source: developed by author)

Informational	A	B	C
A	1	3	5
B	1/3	1	1
C	1/5	1	1

The values of the utility functions u_{ij} obtained as a result of the calculations for variants *A, B, C,* taking into account the various directions for reducing the level of the ESSE threats to facilitate further calculations, are presented in the form Table 16.

Table 16. The value of utility of alternatives for different directions reducing the level of threats (source: developed by author)

u_{ij}	u_{1j}	u_{2j}	u_{3j}
u_{i1}	0.785	0.730	0.549
u_{i2}	0.148	0.188	0.240
u_{i3}	0.065	0.080	0.209

The calculations were performed correctly, because the value of the vector of priorities λ_{max}, the index of consistency *IU* and the relation of consistency *WU* for each of the matrices are within the normal range. According to the proposed M. Bartish (2009) method for multi-criteria evaluation of alternatives, we have: u_{ij} – the utility of the *j* alternative (j = 1, 2, 3) in the ith variant (i = 1, ..., 4); U_j is the multifactor utility evaluation of the j^{th} alternative, and (21):

$$U_j = \sum_{i=1}^{4} s_i u_{ij};\ j = 1,2,3, \tag{21}$$

where u_{ij} is the utility of the *j* alternative by the *i* option.

In accordance with this, we have the following options for calculating the values of the utility function of alternatives (22):

$$U_1 = s_1u_{11} + s_2u_{21} + s_3u_{31} + s_4u_{41},$$

$$U_2 = s_1u_{12} + s_2u_{22} + s_3u_{32} + s_4u_{42},$$
$$U_3 = s_1u_{13} + s_2u_{23} + s_3u_{33} + s_4u_{43}. \quad (22)$$

Substituting in the expressions (22) the values obtained above (Table 16), we get:

$$U_1 = 0.563 \times 0.785 + 0.263 \times 0.730 + 0.055 \times 0.549 + 0.117 \times 0.658 = 0.741;$$
$$U_2 = 0.563 \times 0.148 + 0.263 \times 0.188 + 0.055 \times 0.240 + 0.117 \times 0.185 = 0.167;$$
$$U_3 = 0.563 \times 0.065 + 0.263 \times 0.080 + 0.055 \times 0.209 + 0.117 \times 0.156 = 0.086.$$

According to the method used to ensure the ESEE, it is advisable to use the alternative U_1, for which the value of the utility function is maximum. In this case, to ensure the ESEE, the financial and material direction of reducing the impact of threats is a priority, the informational direction is a bit less weight, and the personnel direction is even less important. The first two indicators are general economic and their growth during the crisis is unlikely. At the same time, the information direction requires comparatively lower material costs, and in the personnel direction, it is clear that in our conditions it is the first thing that unfortunately is sacrificed.

So, thanks to our methodology, it is possible to determine which alternative option the company's management should choose in order to reduce the impact of threats. For example, for the majority of Ukrainian machine-building enterprises should use the financial and material ways to reduce the influence of threats.

Conclusions

In order to improve the organizational support for the management of economic security of an engineering enterprise, methodical bases were proposed to determine the optimal set of necessary measures that change the financial, material, personnel and information parameters of organizational support in order to reduce the negative impact of threats, provide for calculating the effectiveness of each possible decision to minimize costs and monitor the effectiveness of the formation of the body from the structural units to the most efficient use of resources to ensure the necessary level of security.

Improving the management of economic security of an engineering enterprise is possible through increasing the efficiency of organizational support by forming the basis for countering the influence of external and internal threats by defining (using graph theory, matrix analysis and the method of pairwise comparisons for the most part) of the set of measures which threat (integral assessment of the influence of external and internal threats) should not exceed the established level, and the costs of implementation should be minimal, including the costs of forming organizational support.

The importance of the scientific base in the development and implementation of comprehensive protective measures, the basis of which should be the organizational support that is most adapted to the reality of running a business, can significantly improve the efficiency of managing the economic security system of each engineering enterprise, should be the basis for the restoration and development of domestic engineering.

The theoretical significance of the research lies in the formation of a scientific approach to the development of theoretical and methodological foundations, which together solve the important scientific task of achieving compliance with the theoretical principles of organizational and methodological support for managing the economic security of enterprises, based on the use of organizational support that allows an adequate response to changing business conditions and makes providing the necessary level of development for security of engineering enterprises.

The practical significance of the results obtained lies in the fact that the proposals and recommendations formulated as a result of the study allow engineering enterprises to ensure effective management of economic security, based on the use of organizational support adapted to business conditions.

Summing up, we note that thanks to our proposed method of forming organizational support for managing economic security of an engineering enterprise, including an assessment of possible losses from the realization of threats and an assessment of their impact, we can significantly increase the overall state of economic security. In addition, our research allows us to determine which alternative option the company's management should choose in order to reduce the impact of threats.

Author contributions

The authors contributed equally.

Disclosure statement

The authors do not have any conflict of interest.

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