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RISK-BASED EVALUATION OF OPTIMAL STRATEGIES IN E-COMMERCE

The article is dedicated to the development and implementation of a strategy for reducing potential risks in the field of online trade. The main risks of e-commerce are analyzed, such as cybercrime, technical issues, legal matters, financial threats, and reputational losses. Special attention is given to methods and tools that allow for effective identification, assessment, and mitigation of these risks. Various methods of analyzing and assessing risks related to business processes in e-commerce companies are presented, as risk management is one of the most important tasks for any company. This issue is crucial for ensuring the successful operation of a business entity. For trading companies, particularly in the e-commerce sector, it is essential to conduct risk assessments and analyses even before risks materialize, in order to take timely measures to minimize them.

Relevance of the topic. In the context of the growth of digital technologies and the increasing volume of electronic transactions, the issue of protecting businesses and their customers from potential threats is becoming increasingly relevant.

The purpose of the article. The aim of the research is to systematize the indicators used for the quantitative assessment of business risks in e-commerce, based on probability-statistical methods, to build interval estimates of the effectiveness of each strategy, and to determine the type of risk for each strategy using various methods.

Research methods. The article outlines the sequence of actions in risk analysis and assessment. The possibility of using different methods for analyzing the risks of business processes is discussed.

Scientific novelty. An algorithm has been developed to minimize risks in e-commerce, offering a systematic approach to identifying, assessing, and managing risks. The algorithm consists of several key stages: risk identification, impact assessment, development of a management strategy, and monitoring the effectiveness of the implemented measures. The algorithm has been tested on real e-business cases, which confirmed its effectiveness in reducing the likelihood of negative events and minimizing potential losses. Implementing the proposed measures significantly improved risk management in the cases examined.

Keywords: e-commerce, risks, cyber security, risk management, minimization, strategy
JEL classification*: D81, L86, G32*

Статтю присвячено розробці та реалізації стратегії зниження потенційних ризиків у сфері онлайн-торгівлі. Проаналізовано основні ризики електронної комерції, такі як кіберзлочинність, технічні проблеми, юридичні питання, фінансові загрози та репутаційні втрати. Особлива увага приділяється методам та інструментам, які дозволяють ефективно ідентифікувати, оцінювати та зменшувати ці ризики. Це питання є визначальним для забезпечення успішної діяльності суб'єкта господарювання. Для торгових компаній, особливо в секторі електронної комерції, важливо проводити оцінку та аналіз ризиків ще до того, як ризики матеріалізуються, щоб вчасно вжити заходів для їх мінімізації. У статті викладено послідовність дій при аналізі та оцінці ризиків. Обговорюється можливість використання різних методів аналізу ризиків бізнес-процесів.

Актуальність теми. В умовах зростання цифрових технологій та збільшення обсягів електронних транзакцій питання захисту бізнесу та його клієнтів від потенційних загроз стає все більш актуальним.

Мета статті. Метою дослідження є систематизація показників, які використовуються для кількісної оцінки бізнес-ризиків в електронній комерції, на основі ймовірнісно-статистичних методів, побудова інтервальних оцінок ефективності кожної стратегії та визначення типу ризику для кожної з них.

Методи дослідження. Представлено різні методи аналізу та оцінки ризиків, пов'язаних з бізнес-процесами в компаніях електронної комерції, оскільки управління ризиками є одним із найважливіших завдань будь-якої компанії.

Наукова новизна. Розроблено алгоритм для мінімізації ризиків в електронній комерції, що пропонує системний підхід до ідентифікації, оцінки та управління ризиками. Алгоритм складається з кількох ключових етапів: ідентифікація ризиків, оцінка впливу, розробка стратегії управління та моніторинг ефективності впроваджених заходів. Алгоритм був протестований на реальних кейсах електронного бізнесу, які підтвердили його ефективність у зниженні ймовірності негативних подій та мінімізації потенційних втрат. Впровадження запропонованих заходів значно покращило управління ризиками у розглянутих випадках.

Ключові слова: електронна комерція, ризики, кібербезпека, управління ризиками, мінімізація, стратегія

JEL classification*: D81, L86, G32*

Problem statement. In e-commerce, as in any business, sellers and consumers face various types of risks: the risk of counterfeit websites and hacker attacks, fraud (misuse of financial and personal data), the risk of product quality mismatches, which reduce trust in online shopping, and others. Additionally, e-commerce entrepreneurs need to select products whose sale will yield the highest profit (product range, volume), the target customer audience, the sales strategy, the market segment in which they will operate, the website, and so on. Each area of activity carries its own risks: something could go wrong, the wrong choices might be made, the wrong strategy or audience might be targeted.

For businesses, it is important not to avoid risk entirely, but to foresee possible situations and make the best decision using a set of criteria that satisfy the entrepreneur's primary interests. Since this decision largely determines the success and profitability of a business, particularly in e-commerce, or even its existence, considering potential risks and the algorithms for minimizing them is highly relevant. Successful risk management in e-commerce requires a systematic approach, continuous market monitoring, and quick adaptation to changes in technology and market conditions, which determines the importance of the chosen topic.

Analysis of recent research and publications. The sources on risks in e-commerce cover various aspects such as cybersecurity, legal issues, technical problems, and more. Reports from companies like Symantec, McAfee, or organizations like the European Union Agency for Cybersecurity (ENISA) provide data on cybersecurity levels and protection methods. Organizations like Verizon or IBM offer reports and statistical data on fraud and cybercrime.

Regulations in the field of data protection (such as the General Data Protection Regulation (GDPR) in the EU, and the California Consumer Privacy Act (CCPA) in California) are governed by legislative acts. It is important to consider laws on personal data protection, rules for e-commerce, and consumer rights protection. Legal and regulatory risks may include penalties for non-compliance or legal disputes with customers. Continuous changes in legislation may require frequent updates to policies and procedures.

In addition to reports, recommendations, legislative acts, and statistical data, a significant amount of literature is dedicated to the topic of risks in e-commerce. Among the foreign sources from recent years, the following are noteworthy:

− R. Lowe's article [2], dedicated to financial risks in e-commerce and strategies for their minimization;

− Starovoytov's book [3], which provides an overview of the main cyber threats to e-commerce and analyzes various methods of managing them, with a particular focus on new protection technologies and security practices;

− T. Chikwendu and S. Okoli's article [4], which recommends an easily applicable approach to managing cyber risks, particularly suitable for small and medium-sized businesses, as they typically lack the skills and experience required to deploy effective cyber solutions;

− L. Johnson and K. Brown's study [5], which discusses key risk management strategies for businesses in e-commerce, covering financial, technical, and legal aspects;

− R. Davis and S. Clark's article [6], dedicated to legal and regulatory challenges in e-commerce, including compliance with data protection requirements and other regulatory standards;

− N. Urrea, B. Vishkaya, and P. Giovanni's work [7], which proposes a practical action plan for quickly mitigating risks on e-commerce platforms;

− T. Tuomi's master's thesis [8], in which the author builds a practical model for risk minimization for specific enterprises.

Among recent research by Ukrainian scholars, the following studies are notable: S. Savchenko's work [10] discusses the dynamics of views on the phenomenon of risk, its essence as an economic category, the main properties and functions of risk, and the influence of subjective factors on risk selection. In works [1], [9] and [11] general principles of risk classification are explored, including the identification of various risk zones: a risk-free zone, a minimal risk zone, a low-risk zone, an acceptable risk zone, a critical risk zone, and a catastrophic risk zone. Article [12] is dedicated to the application of risk management to improving the competitiveness of an enterprise.

In addition, these works describe the main types of business risks, including: political risks, social risks, environmental risks, administrative and legal risks, production risks (technical, direct production, transport), marketing and commercial risks (realization risks), financial risks (related to investments, purchasing power of money, insufficient financing, unforeseen expenses, and budget overruns in production), and risks related to external economic activity.

These works provide a comprehensive understanding of various risk categories that businesses may face, as well as strategies for managing and mitigating these risks.

The aim of research. The aim of the study is to systematize the indicators used for the quantitative assessment of entrepreneurial risks in the field of e-commerce based on statistical methods, encompassing both absolute and relative values. Additionally, the study intends to develop interval assessments of the effectiveness of each strategy and determine the risk type for each strategy using various methods.

To achieve this goal, the following tasks should be addressed:

1. Conduct a review of current methods used for risk assessment in e-commerce, particularly statistical methods. Identify their advantages and limitations, specifically in the context of the unique risks inherent in this sector. This may include the analysis of statistical approaches such as forecasting methods, correlation and regression analysis,

as well as other techniques for evaluating the probability and magnitude of risks.

2. Identify key indicators that characterize both absolute and relative risk values in e-commerce. These may include indicators such as: loss levels (absolute indicators), relative risk (e.g., risk per unit of profit), variation coefficients, potential loss values, and the probability of their occurrence. These indicators should be integrated into a unified evaluation system to allow for a comprehensive risk assessment.

3. Develop a methodology for evaluating the effectiveness of each strategy in e-commerce using interval data that reflects both risks and opportunities. Interval analysis methods should be applied to account for the variability of results and uncertainties in decision-making.

4. Analyze and classify risks into different categories, such as financial, operational, and strategic risks. Evaluate these risks using coefficients of potential losses from the implementation of strategies and standard deviation and linear variation coefficients. This will allow for the categorization of risks based on their impact on the business and facilitate monitoring and management.

5. Provide practical recommendations for businesses in e-commerce on managing identified risks, optimizing strategies, and improving overall effectiveness. These recommendations may include strategies for minimizing financial losses, optimizing operational processes, or improving strategic management based on risk analysis.

Methods. To achieve the set goal, a number of scientific methods were applied:

− **Comparative method** – used to compare different risk minimization strategies applied in e-commerce, based on the experience of various companies and authors. This method allows for an analysis of the advantages and limitations of different approaches to risk management.

− **Generalization method** – employed to integrate the obtained results and formulate general recommendations for minimizing risks in e-commerce. This method ensures that diverse findings are synthesized into a coherent set of strategies applicable to various business contexts.

− **Empirical method** – used to collect and analyze real-world data on the risks faced by businesses in e-commerce, as well as to evaluate the effectiveness of the risk minimization techniques employed. This method provides insight into practical applications of risk management strategies.

− **Statistical analysis** – applied to process the collected data, identifying key trends, risk levels, and the effectiveness of various risk minimization approaches. It aids in revealing patterns and assessing the overall risk landscape in e-commerce.

− **Modeling method** – utilized to create risk models that predict potential outcomes of risky situations and develop optimal strategies for avoiding or mitigating negative impacts. This approach supports decision-making by simulating various risk scenarios.

− **Forecasting** – applied to predict future challenges and risks in e-commerce based on current trends and the results of the research. This method helps anticipate upcoming risks and prepare businesses for potential disruptions.

Results

1. Risk analysis

A significant number of socio-economic situations related to decision-making have the characteristic that they involve two or more parties with different (sometimes opposing) interests. Each party has the opportunity to achieve its goal using various methods, depending on the actions of the opposing side. These situations are referred to as **conflict situations** and are characterized by the following features: the presence of interested parties, the existence of possible actions on their part, and the interests of the parties involved.

In e-commerce, all possible risks can be divided into the following types (Table 1).

Classical theory defines risk as the average value of potential losses or damages that may arise from a particular decision. In neoclassical theory, risk is understood as a deviation from the goal, i.e., from the planned outcomes (financial, strategic, reputational,

Table 1

E-Commerce Risks*

№	Risk Title	Explanation	Mitigation Measures
1.	Data Protection and Cybersecurity	Malicious actors may attempt to access sensitive customer data such as financial information, personal details, and logins. It is crucial to use reliable protection systems and regularly update them.	Reports from companies like Symantec, McAfee, or organizations such as ENISA (European Union Agency for Cybersecurity) provide data on cybersecurity levels and protection methods.
2.	Fraud	Online stores may become targets of fraudulent schemes such as fake transactions or the use of stolen credit cards. It is important to implement systems to verify and authenticate transactions.	Organizations like Verizon or IBM provide reports and statistical data on fraud and cybercrime that should be carefully monitored.
3.	Logistics	E-commerce often relies on suppliers and logistics companies, which may lead to delivery delays or order fulfillment errors.	The use of artificial intelligence can help streamline logistics processes.
4.	Technical Issues	Websites may face technical failures or hosting problems that affect the availability and functionality of online stores.	Technical risks depend on the reliability of third-party services (hosting, payment systems). A recovery plan and business continuity measures are necessary. This can be aided by publications from hosting providers, analytics on technological incidents, discussions in IT communities: forums, technical blogs, IT infrastructure studies.
5.	Regulations	Compliance with legislation and regulatory requirements in different countries can be challenging. Violations may result in fines or legal issues.	Data protection regulations (GDPR in the EU, CCPA in California) are governed by legislative acts. It is essential to consider laws regarding personal data protection, e-commerce rules, and consumer rights protection. Legal and regulatory risks may include fines for non-compliance or legal disputes with customers. Constant changes in legislation may require frequent updates to policies and procedures.
6.	Customer Conflicts	Product returns, misunderstandings in product descriptions, or poor product quality can lead to conflicts with customers and damage the company's reputation. Negative reviews or customer service issues may harm the company's image (reputational risks).	Monitoring and analyzing reviews, as well as promptly responding to them on social media platforms, is an important task for any e-commerce business.
7.	Hacker Attacks	Break-ins, website attacks (DDoS attacks), and other forms of cybercrime can damage the business and its reputation. Major threats include phishing, viruses, malware, and attacks on infrastructure (DDoS attacks). Security risks can range from small attacks to large-scale cyber incidents affecting entire companies or industries.	There are specialized protection programs against such attacks, which should not be skimped on.
8.	Competition	The large number of online stores may complicate market entry and customer attraction. Small businesses may find it difficult to compete with larger players.	Each business has its own strategy for addressing this challenge.

End of Table 1

№	Risk Title	Explanation	Mitigation Measures
9.	Financial Risks	E-commerce entrepreneurs must choose products whose sale will generate the highest profit (assortment, volume), the target audience, the sales strategy, the market segment they will operate in, the website, and so on. Each activity point carries its own risks: making incorrect decisions, choosing the wrong strategy or audience, and thus "losing money".	To minimize financial risks, it is important to constantly monitor analytics from financial consultants, banks specializing in e-commerce, and agencies tracking financial losses from fraud in e-commerce. Security technology costs may be significant but are not critical for protecting the business.

*Source: compiled by the authors

etc.). In the modern interpretation, risk is no longer solely associated with potential losses during the execution of an economic decision, but also with the danger of deviation from the set goal. Thus, today risk is defined not so much as potential losses, but as the absence of significant positive economic outcomes, and it is a financial category characterizing the change in financial results during decision-making.

E-commerce, like all other forms of business, brings a range of risks in addition to its numerous advantages. These risks can be categorized into two types: dynamic and static. Dynamic risk depends on changes in external conditions, such as currency fluctuations or changes in the value of equity, which may be caused by economic and political factors. Static risk arises from the actions of the firm itself, with factors including the skill level of staff, the ability to make rational decisions, and the technical support of the company.

The level of risk is influenced by both objective and subjective factors. Objective factors depend on the external environment, while subjective factors depend on the internal aspects of the firm's operations. To analyze risk, the following sequence should be followed:

1. Identify the objective and subjective factors influencing each type of risk.
2. Analyze the identified factors.
3. Evaluate the feasibility of implementing a strategy while considering various types of risk.
4. Determine the upper acceptable limit of risk.
5. Develop measures to reduce the risk.

Tasks related to risk are divided into three classes [1]:

1. Deterministic tasks under certainty.
2. Statistical tasks under risk. These involve known probabilities of events or a probability distribution function, and, accordingly, elements of probability theory and mathematical statistics are used.
3. Tasks under complete uncertainty, when only possible event outcomes are known, but their probabilities and the distribution function are unknown.

For the first class of tasks, methods of optimization of deterministic problems are applied:

1. Expected value criterion, when the optimum (maximum or minimum) of indicators, such as profit, sales volume (maximization tasks), or cost, expenses, etc. (minimization tasks), needs to be found.
2. Critical level criterion, which allows one to determine not the optimal values but boundary limits (e.g., minimum price).
3. Most probable event criterion, where a random variable is replaced by a deterministic one, which has the highest probability of realization.

For the second and third classes of tasks, game theory under risk and uncertainty is applied. This theory is typically objective (instability of the economic situation, actions of business partners and competitors, demand for goods, government policy, equipment failure, currency exchange rate, environmental factors, etc.), but it can also be subjective, meaning it may depend on the individual psycho-physical parameters of the

decision-maker (DM) or their insufficient information. In these tasks, the probability distribution may be known or unknown, and the external environment may be in one of several possible states. The choice of solution depends on the objective reality, which is called in the mathematical model the "nature (external environment)". The mathematical model of such situations is called a "game with nature". In solving such games, "nature" is not necessarily antagonistic to the player; it can also support the player's actions, as it assumes its states randomly. Therefore, the player must choose strategies that, considering the possible states of "nature", will yield good results. Game theory with "nature" is called statistical decision theory.

In the theory of games with "nature," depending on the information available, two situations are considered. In one of them, either the probabilities with which nature accepts each of its possible states are known, or these probabilities are unknown but their relative values are known, or the probabilities of nature's states are determined by experts (the DM). In these cases, we speak of "decision-making under risk." In the other case, the probabilities of possible states of nature are unknown, and there is no way to obtain such information. In this case, we speak of "decision-making under uncertainty," and the DM can only make certain hypotheses regarding the state of the external environment. There are several methods for selecting the best strategy under these conditions, which are focused on use under risk and uncertainty.

Risk analysis is usually based on the following assumptions: losses from various types of risks are independent of one another; damages from one risk do not necessarily increase the probability or magnitude of losses from another; and the maximum possible losses arising from the occurrence of a specific risk should not exceed the financial capabilities of the enterprise. There are both objective factors (external environment) and subjective factors (specifics of the firm itself) that affect the level of risk.

To analyze risk, several stages need to be completed:

1. Identify objective and subjective factors that influence each type of risk.
2. Analyze these factors to understand their impact on the level of risk.
3. Evaluate the probability of success or failure of a strategy, considering the various risks involved.
4. Establish the acceptable level of risk, which the business is willing to tolerate.
5. Implement measures to reduce risk.

Both qualitative and quantitative methods of analysis are used in this process. Qualitative analysis focuses on identifying risk factors, risk zones, and potential threats.

Within qualitative analysis, two key aspects are highlighted:

− The first aspect is comparing expected positive outcomes with possible negative consequences.

− The second aspect is the evaluation of how decisions made under conditions of uncertainty and conflict will impact the interests of the enterprise.

Several key risk zones can be identified in the context of business operations:

1. Risk-Free Zone – no losses are expected during business operations.
2. Minimal and Low-Risk Zone – where losses may be smaller than the expected profit.
3. Acceptable Risk Zone – where possible losses do not exceed the expected profit. In the worst case, the business may lose all of its profit, but under favorable conditions, the losses will be minimal.
4. Critical Risk Zone – where losses may exceed profit but do not surpass revenue.
5. Catastrophic Risk Zone – the most dangerous zone, where losses may exceed revenue and potentially even reach the value of the business's assets.

The main criteria for defining these zones include the following indicators: profit, revenue, risk coefficient, own funds of the enterprise, and losses. Within the acceptable risk zone, using net profit and calculated profit as criteria, it is also possible to highlight a "sufficiently acceptable" zone and a zone of elevated risk [12].

Quantitative risk analysis is a crucial component of enterprise management, as it

allows for the evaluation of the probability and magnitude of potential losses, as well as for determining the overall risk level for a specific business activity. Its primary goal is to complement qualitative analysis with precise calculations, enabling more effective decision-making.

Key parameters for assessing the degree of risk include:

1. Probability of loss occurrence – this refers to the likelihood that a specific risk will materialize. The higher the probability, the greater the risk.

2. Magnitude of potential losses – this refers to the amount of damage that may occur as a result of the risk realization. The greater the potential loss, the higher the risk.

The degree of riskiness depends on various factors, such as the size of the enterprise, the number of employees, the value of assets, market share, production volume, etc. Entrepreneurial activity always carries a certain threat of loss, as it is associated with expenses and may lead to additional unforeseen costs in the event of an unfavorable outcome.

Losses are defined as the random decrease in business profit due to adverse conditions, miscalculations, or deviations from the plan. When evaluating risk, it is important to consider the potential losses of resources, which can be random, unforeseen, and potentially possible. These may include financial, material, social, moral-psychological, environmental, sales, or time losses.

The evaluation of the magnitude of losses and the probability of their occurrence should be conducted for each type of loss over a defined period. Only random losses, which cannot be predicted or calculated in advance, are considered in the analysis. If losses can be predicted, they should be treated as unavoidable costs and accounted for in the calculations.

Depending on the type of activity (production, commercial, financial), different types of losses are distinguished and evaluated separately for each segment of the enterprise's business activity [11].

Risk is a significant economic category, and the degree of its impact on an enterprise can be regulated through the formulation and implementation of strategies, as well as through the risk management mechanism. Without considering and managing risks, conducting business activities becomes impossible.

Risk management is a set of economic, organizational, and technical measures aimed at identifying the types, sources, and factors of risk, evaluating their magnitude, and developing and implementing actions to reduce risks and prevent negative consequences. Within this activity, risk management includes two main subsystems:

a) object of management – these are the risks themselves and their sources;

b) subject of management – these are the bodies responsible for risk management (e.g., specialized departments within a company).

For the effective functioning of risk management, a dedicated risk management body should be established. As a process, risk management involves several stages:

1. Assessment of the business situation at the enterprise and identification of risks.

2. Quantitative and qualitative risk analysis.

3. Risk degree regulation – choosing directions and methods of regulation and their implementation.

4. Evaluation of the results of risk regulation and their adjustment, if necessary.

The main methods of risk management include the following directions (Table 2).

These methods not only reduce the likelihood of negative consequences but also allow for more effective management of business operations, focusing on lowering the risk level and increasing potential profits [11], [12].

An important task in risk research for assessing its degree is the use of both qualitative and quantitative analysis methods, particularly the application of indicator systems based on probability-statistical methods, as well as the use of comprehensive quantitative risk assessment to determine its type. This enables the adoption of the most well-founded management decisions [1], [9], [11].

Table 2

Risk Management Approaches*

№	Name	Comment
1	Risk Avoidance	This involves avoiding doubtful partners, suppliers, or risky projects and decisions.
2	Risk Compensation	Includes strategic planning, monitoring the socio-economic environment, forecasting economic situations, active marketing, and other measures that help minimize possible negative consequences.
3	Risk Retention	A strategy in which the company does not take measures to compensate for losses but creates reserve funds (cash or physical), self-insurance funds, or attracts external funding through loans or grants.
4	Risk Transfer	This includes risk insurance, factoring agreements, guarantees, and hedging (e.g., exchange deals), which allow the transfer of part of the risk to other parties.
5	Risk Reduction	This can be achieved through diversification (spreading assets across different areas), obtaining additional information for better forecasting of situations, and limiting risks (e.g., setting limits on losses).

Source: compiled by the authors

2. Quantitative and Qualitative Risk Analysis Using probability-statistical Methods

The system of criteria for quantitative risk assessment based on probability-statistical methods includes various variation indicators, which are divided into absolute and relative values.

Absolute values include: expected value of effectiveness, variance, semi-variance, semi-quadratic deviation, standard deviation, expected values of favorable and unfavorable deviations from planned economic indicators, average linear deviation, skewness and kurtosis coefficients, and the range of variation.

Relative values include: the probability of losses or income reduction compared to the forecasted variant, the risk coefficient, the quadratic coefficient of variation, the semi-variance coefficient, the linear coefficient of variation, the expected loss coefficient, variation coefficients of skewness and kurtosis, the oscillation coefficient, and the relative risk coefficient.

In addition, an interval evaluation of the effectiveness of strategies is conducted, the risk type is determined, and the range of variation is assessed.

To quantitatively assess risk, all possible outcomes of a certain event or strategy and the probabilities of their occurrence must be determined. The absolute magnitude of risk is characterized by the size of the forecasted losses (damages), expressed in material or monetary terms. The risk assessment for the business entity is carried out, taking into account the most important indicator – profit or losses.

Let us assume that the player has *m* possible strategies (possible action alternatives, and "nature" can take one of *n* states of the external environment: P_j ($j = \overline{1,n}$). These can be considered as its "strategies" (nature's hypotheses). The set of nature's states $\{P_1,...,P_n\}$ is formed either based on the analysis of its possible states or through the analysis and intuition of experts (decision-makers). The given payoff (loss) matrix $A = (a_{ij})_{m\times n}$, is as follows, where a_{ij} – represents the profit (or loss) when implementing the *i*-th strategy under the j-th state of nature, q_j – is the probability of the occurrence of the *j*-th state of "nature",

$$j = 1,...,n;\ \sum_{i=1}^{n} q_j = 1.$$

Statistical games with "nature" are described using a payoff matrix $A = (a_{ij})_{m\times n}$. $a_{ij} = \varphi(A_i, P_j)$, where a_{ij} represents the gain (or loss) of the player when they choose strategy A_i, and "nature" (or the opponent) is in state P_j. The function

$\varphi(A_i, P_j)$ is the utility function of the corresponding alternative. The elements a_{ij} can be understood as both the profit/income and the costs/losses of the player when choosing the *i*- th strategy A_i and when "nature" is in state P_j. In such games, the player has no control over the opponent's strategy choice, but they aim to maximize their gain (or minimize their loss) considering the probability of each strategy being chosen by the opponent. The player's gain depends on which strategy the opponent chooses, so in statistical games, it is crucial to calculate the probability of winning based on the chosen strategy, as well as to use optimization methods to determine the best strategy.

In game theory with "nature" two situations are considered:

1. The probabilities of potential states of nature are known, or their relative values, or the probabilities of the states of nature are set by experts (the decision maker, or the person who makes the decision – PMD). In these situations, decisions are made under conditions of risk.

2. The probabilities of possible states of nature are unknown, and there is no way to obtain such information. In this case, decisions are made under conditions of uncertainty. To choose the best strategy under these conditions, several methods have been developed [1], [9], [12].

I. Let's consider the evaluation of the riskiness of strategies based on variability indicators, which consist of absolute and relative values [12].

Absolute indicators.

1. Mathematical Expectation of Effectiveness (the most likely value of profit or loss) $M_i = \sum_{j=1}^{n} a_{ij} \cdot q_j$ *i*-th strategy, $i = \overline{1,m}.$ The larger (smaller) the value of this indicator, the better the *i*-th strategy.

2. Dispersion $D_i = \sum_{j=1}^{n} (a_{ij} - M_i)^2 \cdot q_j$ or $D_i = \sum_{j=1}^{n} a_{ij}^2 \cdot q_j - M_i^2, \quad i = \overline{1,m}.$ It is the weighted average of the squared deviations of profit (or loss) a_{ij} values from the expected effectiveness of the *i*-th strategy M_i. It serves as an indicator of how much the profit or loss values for this strategy are dispersed (spread out) around the mean value (expected value). A high variance indicates that the results may significantly differ from the average, suggesting a high level of uncertainty and risk.

3. Standard deviation $\sigma_i = \sqrt{D_i}$, $i = \overline{1,m}.$ It demonstrates the degree of dispersion of profit (or loss) values a_{ij}, relative to the expected effectiveness M_i of this strategy, $i = \overline{1,m}, \ j = \overline{1,n}$. The smaller this indicator, the more reliable the corresponding strategy is.

4. Semivariation $SV_i = \sum_{j=1}^{n} \alpha_j \cdot q_j \cdot (a_{ij} - M_i)^2$, where α_j – threshold deviation indicator $M_i, \quad i = \overline{1,m}, \ j = \overline{1,n}, \ M_i$ – mathematical expectation of efficiency *i*-th strategy. Additive semivariation SV_i^+ determines the variance of those profit (or loss) values a_{ij}, which are greater than the mathematical expectation of efficiency *i*-th strategy M_i, $i = \overline{1,m}, \ j = \overline{1,n}.$ When calculating it, they take $\alpha_j = 1,$ if $a_{ij} > M_i,$ and $\alpha_j = 0,$ if $a_{ij} \le M_i, \quad i = \overline{1,m}, \ j = \overline{1,n}.$ The higher the value of the positive semivariance, the greater the expected profit (or loss) from implementing the corresponding strategy. Negative semivariance SV_i^- determines the variance of those profit (or loss) values a_{ij}, which do not exaggerate the mathematical expectation of efficiency *i*-th strategy M_i, $i = \overline{1,m}, \ j = \overline{1,n}.$ When calculating it, on the contrary – $\alpha_j = 1,$ if $a_{ij} \le M_i,$ and $\alpha_j = 0,$ if $a_{ij} > M_i, \quad i = \overline{1,m}, \ j = \overline{1,n}.$ That is, the smaller the negative semi-variance, the smaller the predicted decrease in profit (or increase in losses) from implementing the chosen strategy.

5. Semiquadratic deviation $SSV_i = \sqrt{SV_i}$. Similarly, the positive and negative semi-quadratic deviations are calculated: SSV_i^+ and SSV_i^-: $SSV_i^+ = \sqrt{SV_i^+}, \ SSV_i^- = \sqrt{SV_i^-}, \quad i = \overline{1,m}.$ The positive semi-quadratic deviation SSV_i^+ determines the standard deviation of those

profit (or loss) values a_{ij}, that exceed the mathematical expectation of the effectiveness of the i-th strategy M_i, $i=\overline{1,m}$, $j=\overline{1,n}$. That is, the larger the positive semi-quadratic deviation, the greater the absolute value of the actual expected profit (or loss) will be when implementing the corresponding strategy. The negative semi-quadratic deviation SSV_i^- defines the mean squared deviation of those profit (or loss) values a_{ij}, that do not exceed the mathematical expectation of the effectiveness of the i-th strategy M_i, $i=\overline{1,m}$, $j=\overline{1,n}$. The smaller the negative semi-quadratic deviation, the smaller the expected reductions in profit (or losses) from implementing the corresponding strategy.

6. The expected value of favorable and unfavorable deviations relative to the planned economic indicator Z or relative to the mathematical expectation of the effectiveness ($Z = M_i$); $V_{Zi} = \sum_{j=1}^{n} \alpha_j \cdot q_j \cdot (a_{ij} - Z)$, where α_j – threshold deviation indicator Z, $i=\overline{1,m}$, $j=\overline{1,n}$. When calculating the positive conditional mathematical expectation of deviations V_{Zi}^+ we take $\alpha_j = 1$, if $a_{ij} > Z$, and $\alpha_j = 0$, if $a_{ij} \le Z$, $i=\overline{1,m}$, $j=\overline{1,n}$. The greater the value of V_{Zi}^+, the greater the expected profit (or loss) from implementing this strategy. When calculating the negative conditional expected value of deviations V_{Zi}^- the opposite is true, – $\alpha_j = 1$, if $a_{ij} \le Z$, and $\alpha_j = 0$, if $a_{ij} > Z$, $i=\overline{1,m}$, $j=\overline{1,n}$. The greater the value of $\left|V_{Zi}^-\right|$, the greater the expected profit (or loss) from implementing this strategy.

7. Average linear deviation $d_i = \sum_{j=1}^{n} \left|a_{ij} - M_i\right| \cdot q_j$, $i=\overline{1,m}$. The smaller it is, the more reliable the corresponding strategy will be.

8. Asymmetry coefficient

$$As_i = \frac{1}{\sigma_i^3} \sum_{j=1}^{n} (a_{ij} - M_i)^3 \cdot q_j, \; i=\overline{1,m}.$$

In the case where it equals zero, the probability density function of the random variable will be symmetrical relative to its expected value. If $As_i > 0$ ($As_i < 0$), then the asymmetry is right-sided (or left-sided). If $\left|As_i\right| < 0{,}1$, then the distribution is almost symmetrical; if $0{,}1 \le \left|As_i\right| < 0{,}3$, then asymmetry is insignificant; if $0{,}3 \le \left|As_i\right| < 0{,}5$, then asymmetry is moderate; if $0{,}5 \le \left|As_i\right|$, then asymmetry is significant. The larger the value of the skewness coefficient for the profit (or loss) matrix, the smaller (or larger) the risk of the corresponding strategy will be.

9. Coefficient of excess

$$Ex_i = \frac{1}{\sigma_i^4} \sum_{j=1}^{n} (a_{ij} - M_i)^4 \cdot q_j - 3, \qquad i=\overline{1,m}.$$

When $Ex_i \ge 0$ ($Ex_i < 0$), the distribution is considered to be peaked (or flat-topped). The higher the value of the excess coefficient (the concentration of the performance indicator values near its expected value) for the profit (or loss) matrix, the more reliable the corresponding strategy will be.

10. Range of variation $R_i = \max_j a_{ij} - \min_j a_{ij}$, $i=\overline{1,m}$. The larger it is, the greater the risk of the corresponding strategy.

Relative indicators.

11. Quadratic coefficient of variation $V_{\sigma i} = \frac{\sigma_i}{M_i}$, $i=\overline{1,m}$. The lower its value for the profit matrix, the better the ratio between risk and effectiveness of the strategy.

12. Risk coefficient $K_{Ri} = \frac{SSV_i^-}{SSV_i^+}$, $i=\overline{1,m}$. This coefficient for the profit (or loss) matrix shows how many times the possible decrease in profit (or loss) can exceed the possible increase in profit (or loss). The smaller (or in the case of losses, the larger) its value, the lower the risk of choosing the corresponding strategy.

13. Coefficient of semivariance

$$K_{Si} = \frac{SSV_i^-}{M_i} \text{ or } K_{Si} = \frac{SSV_i^+}{M_i} \; i=\overline{1,m}.$$

It defines the ratio of negative semivariance (for the profit matrix) or positive semivariance (for the loss matrix), which takes into account only negative deviations from the expected value. The smaller this coefficient is, the less risky the strategy is.

14. Linear coefficient of variation $V_{di} = \frac{d_i}{M_i}, \quad i = \overline{1,m}.$ The lower its value for the profit matrix, the better the ratio between risk and effectiveness of the strategy.

15. Expected Loss Ratio $K_{Zi} = \frac{\left|V_{Zi}^-\right|}{V_{Zi}^+ + \left|V_{Zi}^-\right|}$ – for the profit matrix or $K_{Zi} = \frac{V_{Zi}^+}{V_{Zi}^+ + \left|V_{Zi}^-\right|}$ – for the loss matrix, $i = \overline{1,m}.$ This ratio determines the ratio of the amount of expected losses to the sum of expected profits and expected losses. $K_{Zi} \in [0;1],$ and if $K_{Zi} = 0,$ there are no expected additional losses; if there are no expected additional profits.

16. Coefficient of variation of asymmetry $VAs_i = \frac{lAs_i}{M_i}, \quad i = \overline{1,m},$ where

$$lAs_i = \begin{cases} 1/(As_i + 1), & As_i > 0; \\ 1 - As_i, & As_i \le 0. \end{cases}$$

The smaller it is, the less (or more) risky the strategy is for the profit matrix and the loss matrix, respectively.

17. Coefficient of variation of kurtosis $VEx_i = \frac{lEx_i}{M_i}, \quad i = \overline{1,m},$ where

$$lEx_i = \begin{cases} 1/(Ex_i + 1), & Ex_i > 0; \\ 1 - Ex_i, & Ex_i \le 0. \end{cases}$$ The smaller it is, the less risky the strategy is for the profit matrix.

18. Oscillation coefficient $V_{Ri} = \frac{R_i}{M_i}, \quad i = \overline{1,m}.$ The smaller it is, the less risky the corresponding strategy is for the profit matrix.

19. The coefficient of relative risk is the ratio of the size of losses to a specific base depending on the specifics and type of the assessed risk.

II. Now, let's consider the interval estimation of the effectiveness of strategies, which involves determining the range of possible outcomes for each strategy. This range allows for evaluating the level of risk associated with choosing a particular strategy. To do this, the boundary *i*-th error is calculated, which is the absolute risk indicator. The boundary error indicates the maximum possible deviations of the strategy's result from its average value. In other words, it shows how much the results can change depending on various conditions and factors.

$\Delta_i = \frac{t_\gamma \cdot \sigma_i}{\sqrt{n}},$ if $n > 30$, and $\Delta_i = \frac{t_\gamma \cdot s_i}{\sqrt{n}},$ if $n \le 30$, where $\sigma_i -$ standard deviation, $s_i -$ corrected standard deviation: $s_i = \sigma_i \cdot \sqrt{\frac{n}{n-1}}, \quad i = \overline{1,m}.$ $t_\gamma = t(\alpha = 1 - \gamma, \nu = n - 1)$ is found using the table of critical points of the Student distribution for a two-sided critical region depending on the sample size *n* and reliability γ, $\alpha -$ significance level, $\nu -$ number of degrees of freedom, γ – he confidence that the actual profit (or loss) will be within the corresponding confidence interval.

The marginal error shows how the strategy's performance will vary within a given confidence level. The smaller the marginal error (or marginal deviation), the more reliable and safer the strategy is. If we add or subtract the marginal error Δ_i to the mathematical expectation of the efficiency of the *i*-th strategy M_i we get the limits within which the actual profit (or loss) for this strategy can fluctuate: $a_i^{\max} = M_i + \Delta_i, \; a_i^{\min} = M_i - \Delta_i,$ $i = \overline{1,m}.$ These limits help to assess within what limits the results of the strategy may vary, and thus determine the level of risk associated with its implementation. If $a_i^{\min}$ takes a negative value, then instead of the expected profit (or loss) we have the amount of expenses (or profit). The smaller the value of the marginal error (marginal deviation), the safer and more reliable the strategy is. To assess the risk, the range of variation is used, which is calculated on the basis of the marginal limits $a_i^{\min}$ та $a_i^{\max}$: $R_i^v = a_i^{\max} - a_i^{\min}, \; i = \overline{1,m}.$ The larger it is, the riskier the strategy is.

One of the methods for determining the type (level or zone) of risk is to estimate the coefficient of possible losses from the implementation of the strategy. This coefficient is calculated as the ratio of the minimum value of the efficiency of the *i*-th strategy $a_i^{\min}$ (the worst possible result) to the mathematical expectation of the efficiency of the i-th strategy M_i: $K_{vi} = \frac{a_i^{\min}}{M_i}, \; i = \overline{1, m}.$

When $K_{vi} \geq 0,9,$ the risk is minimum; when $0,75 \leq K_{vi} < 0,9,$ the risk is small; when $0 \leq K_{vi} < 0,75,$ the risk is acceptable; when $-0,3 \leq K_{vi} < 0,$ the risk is considered critical (justified); and if $K_{vi} < -0,3,$ so the risk is assessed as catastrophic (unacceptable), $i = \overline{1, m}.$

The second method of determining the type of risk is based on the analysis of the value of the quadratic and linear coefficients of variation. These coefficients estimate the level of dispersion of results (profits or losses) relative to the average value, which gives an idea of the degree of variability and, accordingly, the level of risk.

According to a certain scale, the type of risk is determined by the value of the coefficient of variation according to this principle.

− [0; 0,1) – minimal risk: this indicates a very low level of fluctuations in results. The strategy is almost risk-free.

− [0,1; 0,25) – low risk: the risk is slightly higher, but still at a low level. Results may fluctuate, but within limits that do not threaten serious losses.

− [0,25; 0,5) – acceptable risk: the risk is already becoming noticeable, but is considered acceptable for the enterprise. Fluctuations in results may be significant, but they do not go beyond the acceptable limits.

− [0,5; 0,75) – critical risk: the risk increases significantly, and significant losses are possible. The strategy requires special attention, since large fluctuations in results can significantly affect the financial condition.

− [0,75; 1] – catastrophic risk: this is the highest level of risk. The risk of catastrophic losses, where fluctuations in results are very large and can lead to serious financial problems or even bankruptcy.

This method allows you to classify strategies and business processes by risk level, which helps to make more effective decisions about choosing the optimal strategies for the enterprise.

Risk types are also obtained in this way:

a) risk-free zone: $H = 0$;

b) minimum risk zone: $Ex < Pr$, $H \in (0; 0,1]$;

c) low risk zone: $Ex < Pr$, $H \in (0,1; 0,25]$;

d) acceptable risk zone: $Ex \leq Pr$, $H \in (0,25; 0,5]$;

e) critical risk zone: $Ex > Pr$, $Ex \leq Rv$, $H \in (0,5; 0,75]$;

h) catastrophic risk zone: $Ex > Rv$, $Ex \leq Of$, $H \in (0,75; 1]$,

where H – is the risk coefficient (ratio of possible losses to the size of the enterprise's own funds), Pr – is profit, Rv – is revenue, Ex – is losses, Of – is the own funds of the trading enterprise.

Economic risk assessment involves creating a risk curve that displays the probability of a certain level of loss or profit in the form of a graph. This is a complex process, so risk is often assessed using quantitative indicators. The construction of such a curve includes several stages:

1. Determining zones of different risk levels, where losses do not exceed specified values. This helps to identify which losses are acceptable and which are unacceptable.

2. Determining the dependence of losses on their level - at this stage, they analyze how losses change depending on different conditions and scenarios. This allows one to understand how risky a certain decision can be.

3. Constructing a profit probability distribution curve, which shows the probability of obtaining a specific level of profit in different situations. Such a curve helps to assess not only the probability of profit, but also the degree of risk associated with these profits.

4. Constructing a risk curve - at the final stage, the risk curve itself is created. It is the result of combining the profit probability

curve and the defined risk zones. The risk curve reflects the overall level of risk for the enterprise, depending on the probability of loss and profit.

These stages help enterprises clearly assess possible risks and develop strategies to minimize or manage them.

There are several methods for quantifying the degree of risk, each of which has its own practical application (Table 3).

When making decisions under conditions of uncertainty and conflict, risk is often assessed using utility theory and statistical solutions in game theory. For a more comprehensive approach, fuzzy set and fuzzy logic methods are used, as well as innovative approaches such as neural networks, chaos theory**, and** catastrophe theory.

As for the quantitative assessment of investment project risks, the following methods are used for this: the discount rate adjustment method – adjusts the discount rate based on the assessment of the project's risk; sensitivity analysis – assesses how changes in the main project parameters (e.g. cost, demand) affect the result; scenario method – considers various possible scenarios of events to assess the risk; decision tree method and simulation modeling – are used to build models and simulations that allow assessing the probability and scale of various risks.

Quantifying risks can also be done through profit variability analysis, which helps to determine how fluctuations in a company's income can affect its financial results.

3. Implementation of the risk assessment methodology

Let us consider the implementation of the above risk assessment methodology based on the probabilistic-statistical method. It should be noted that the above risk assessment methodology based on the probabilistic-statistical method in practice always makes sense to use for risk assessment when choosing a particular strategy. But if the mathematical expectations of efficiency (the most probable values of profit or loss) for different strategies differ sufficiently, then when choosing the optimal strategy, the indicator of mathematical expectation of efficiency often comes to the fore, which, with a significant difference between the mathematical expectations of the efficiency of strategies, often has priority over risk indicators.

Table 3

Methods for quantifying the degree of risk in an enterprise*

№	Method	Description
1	Probability-statistical method	Uses data on past results to assess the probability of future events. This allows one to determine the degree of variability and the probability of losses or profits.
2	Method of expert assessments	Is based on the opinions and experience of experts. This is useful when there is no or insufficient accurate statistical data. Is based on the opinions and experience of experts. This is useful when there is **no or insufficient** accurate statistical data
3	Analytical and calculation method	Includes the construction of various mathematical models for risk analysis and assessment.
4	Normative method	Provides for the use of established standards or regulations to determine acceptable levels of risk.
5	Cost-benefit analysis method	Assesses risks based on the ratio of costs and possible benefits, helping to determine the optimal level of risk for the enterprise.
6	Analog method	Uses the experience of other enterprises or projects with similar conditions to assess risks.
7	Decision tree method	Allows you to evaluate different decision options and their likely consequences, which helps in choosing the least risky option.
8	Rating method	Assesses risks using ratings that are determined based on assessments of various risk factors.

Source: compiled by the autjors based on [1], [9], [11], [12]

Let the company "F." engage in electronic trade abroad. In our case, the "nature" of B_j is the client base (audience): B_1 – women, B_2 – youth, B_3 – creative elite, B_4 – children, B_5 – businessmen. And the strategies of A_i are niche markets: A_1 – books, A_2 – furniture, A_3 – dietary supplements, A_4 – toys, A_5 – kitchenware, A_6 – sports equipment. The approximate profits (gains) a_{ij}, that will be obtained when implementing each strategy A_i depending on the client base B_j, calculated by the marketer, are given in Table 4 (in thousand UAH) $(i = 1, m,\ j = 1, n,\ m = 6,\ n = 5)$.

It is necessary to: 1) investigate the effectiveness of each strategy (i.e., which niche markets A_i are better to choose for a particular client base (audience) B_j); 2) investigate the riskiness of each strategy based on variation indicators; 3) make an interval assessment of the effectiveness of each strategy and determine the type of risk of each of them; 4) conclude which strategy should be followed and why. Using the above formulas for calculating absolute and relative indicators, we obtain tables of indicators in Excel (Tables 5–7). In the calculations of the expected value of favorable and unfavorable deviations relative to the planned economic indicator Z, we take the mathematical expectation of the efficiency of the i-th strategy as this indicator: $Z = M_i$.

Discussion. In tables 5–7, the values of the indicators corresponding to the best strategies are highlighted in bold. According to the mathematical expectation of efficiency, the strategies are arranged in order of deterioration: A_5 (kitchenware), A_6 (sports equipment), A_2 (furniture), A_3 (dietary supplements), A_1 (books), A_4 (toys).

As for the quantitative assessment of the riskiness of strategies based on variation indicators consisting of absolute and relative values, according to the values of the indicators in tables 5–6, the strategies are arranged in order of deterioration: A_3 (dietary supplements), A_6 (sports equipment), A_5 (kitchenware), A_4 (toys), and A_2 (furniture), and finally A_1 (books).

According to the interval assessment of the effectiveness of the strategies according to Table 7, the undoubtedly best strategy is A_3 (dietary supplements).

A qualitative risk analysis was also conducted to determine the risk type of each strategy.

According to the first method of determining the risk type of a strategy, which is based on the assessment of the coefficient of possible losses from the implementation of the strategy according to Table 7, it was found that all strategies correspond to the permissible risk. The best strategy is A_3 (dietary supplements), in second place is A_4 (books), in third place is A_6 (sports equipment), in fourth place is A_1 (toys), in fifth place is A_2 (furniture), in sixth place is A_5 (kitchenware).

Table 4

Profits when choosing niche markets for the corresponding customer base*

A_i \ B_j	Profits				
	B_1	B_2	B_3	B_4	B_5
A_1	215	195	166	126	103
A_2	173	203	185	174	84
A_3	224	152	134	195	126
A_4	198	164	143	203	105
A_5	182	226	177	144	87
A_6	235	177	143	165	114
q_j	0,14	0,28	0,15	0,18	0,25

*Source: compiled by the authors

Table 5

Absolute indicators*

M_i	D_i	σ_i	SV_i^+	SV_i^-	SSV_i^+	SSV_i^-	V_{zi}^+	V_{zi}^-	d_i	As_i	Ex_i	R_i
158,03	1788,349	42,289	846,608	941,741	29,097	30,688	19,523	-19,523	39,046	-0,099	-1,599	112
161,13	2113,133	45,969	625,874	1487,26	25,017	38,565	19,283	-19,283	38,565	-0,942	-0,813	119
160,62	1201,876	34,668	775,141	426,735	27,841	20,658	15,062	-15,062	30,123	0,710	-0,960	98
157,88	1334,566	36,532	602,280	732,286	24,541	27,061	15,452	-15,452	30,904	-0,242	-1,276	98
162,98	2700,240	51,964	1192,15	1508,08	34,528	38,834	22,411	-22,411	44,823	-0,281	-1,245	139
162,11	1440,818	37,958	807,396	633,422	28,415	25,168	14,894	-14,894	29,788	0,480	-0,435	121

*Source: compiled by the authors

Table 6

Relative indicators*

$V_{\sigma i}$	K_{Ri}	K_{Si}	V_{di}	K_{zi}	VAs_i	VEx_i	V_{Ri}
0,2676	1,0547	0,1942	0,2471	0,5000	0,0070	0,0164	0,7087
0,2853	1,5415	0,2393	0,2393	0,5000	0,0121	0,0113	0,7385
0,2158	**0,7420**	**0,1286**	0,1875	0,5000	**0,0036**	0,0122	**0,6101**
0,2314	1,1027	0,1714	0,1957	0,5000	0,0079	0,0144	0,6207
0,3188	1,1247	0,2383	0,2750	0,5000	0,0079	0,0138	0,8529
0,2342	0,8857	0,1553	**0,1838**	0,5000	0,0042	**0,0089**	0,7464

*Source: compiled by the authors

Table 7

Interval estimate

$t_{0,99}$	S_i	Δ_i	$a_i^{\min}$	$a_i^{\max}$	R_i^v	K_{vi}	Type of risk
4,6041	47,2804	97,3510	60,6790	255,3810	194,7020	0,3840	allowable
4,6041	51,3947	105,8224	55,3076	266,9524	211,6448	0,3432	allowable
4,6041	38,7601	79,8076	80,8124	240,4276	159,6151	0,5031	allowable
4,6041	40,8437	84,0977	73,7823	241,9777	168,1954	0,4673	allowable
4,6041	58,0973	119,6232	43,3568	282,6032	239,2464	0,2660	allowable
4,6041	42,4385	87,3814	74,7286	249,4914	174,7627	0,4610	allowable

*Source: compiled by the authors

According to the second method of determining the type of risk by the quadratic coefficient of variation, strategies A_3, A_4, A_6 correspond to low risk, and strategies A_1, A_2, A_5 to acceptable risk (strategies are listed in order of deterioration); according to the linear coefficient of variation, strategies A_6, A_3, A_4, A_2, A_1 correspond to low risk, and strategy A_5 to acceptable risk (strategies are listed in order of deterioration).

Although in terms of mathematical expectation of efficiency (profit value), strategy A_3 is slightly inferior to strategies A_6, A_5, A_2, the trading company is recommended to choose the third strategy A_3 (dietary supplements) from the point of view of

riskology and, as a backup option, the sixth strategy A_6 (sports equipment) or, at worst A_5.

The given risk assessment methodology was effectively implemented using the MS Excel spreadsheet. The initial data are statistical data that correspond to market strategies, business plans, etc. Computer implementation of the given methodology makes it possible to conduct quantitative risk analysis – calculate absolute and relative risk indicators and qualitative analysis - obtain an interval assessment of the effectiveness of the strategy and the type of risk, which is calculated for greater reliability using various methods.

This algorithm allows one to choose the best strategy and thereby increase competitiveness.

Conclusions. The work conducted a comprehensive analysis of risks arising in the field of electronic commerce. The main types of risks were identified, including financial, technical, legal, and reputational. Understanding and classifying these risks are critically important for their effective management. The tasks and methods of risk analysis are highlighted, and the characteristics of risk zones in electronic commerce are given.

A systematization of indicators for the quantitative assessment of business risks based on probabilistic and statistical methods has been carried out. These indicators include both absolute and relative values of variation. However, none of these indicators, either separately or together, can fully reflect the riskiness of a particular decision. They should be applied comprehensively, since they are interrelated and complementary. It is also important to take into account the specifics of a particular task and the significance of each probability-statistical indicator in the context of the overall enterprise risk system.

A quantitative assessment of risks has been carried out, based on the calculation of a system of absolute and relative variation indicators, and a qualitative analysis of risks has been carried out with the obtaining of an interval assessment of the effectiveness of the strategy and the type of risk, which is calculated for greater reliability using various methods.

An algorithm for minimizing risks in e-commerce has been developed, which provides a systematic approach to identifying, assessing and managing risks. The algorithm consists of several key stages: risk identification, assessment of their impact, development of a management strategy and monitoring the effectiveness of the implemented measures. The algorithm has been tested on real e-business cases, which confirmed its effectiveness in reducing the likelihood of negative events and reducing potential losses. The implementation of the proposed measures has significantly improved risk management in the above cases.

To further improve the algorithm, it is recommended to implement automated risk monitoring systems and use modern technologies, such as artificial intelligence and big data, to predict potential threats. It is also important to take into account the specifics of individual business models and adapt the algorithm to the individual needs of the company.

It is necessary to further improve the concept of a system of quantitative indicators for assessing the degree of risk, which will allow for a more accurate reflection of its complexity and multifacetedness. It is also important to develop and apply economic and mathematical methods and risk models, as well as create software complexes for assessing, analyzing and managing risks. This will facilitate effective management decisions to minimize risks.

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RISK-BASED EVALUATION OF OPTIMAL STRATEGIES IN E-COMMERCE

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The article focuses on the development and implementation of a comprehensive strategy to reduce potential risks in online trade. With the growth of digital technologies and the increasing volume of electronic transactions, the need to protect businesses and their customers from potential threats has become more critical. The aim of the research is to systematize the indicators used for the quantitative assessment of business risks in e-commerce, utilizing probability-statistical methods. It also seeks to build interval estimates of the effectiveness of various strategies and determine the type of risk associated with each strategy through different methods.

The main risks in e-commerce, such as cybercrime, technical issues, legal matters, financial threats, and reputational losses, are thoroughly analyzed. The article places particular emphasis on the methods and tools that enable effective identification, assessment, and mitigation of these risks.

Various risk analysis and assessment methods for business processes in e-commerce companies are discussed, as risk management is a critical task for any company. For e-commerce businesses, it is crucial to conduct risk assessments and analyses even before risks materialize, allowing them to take proactive measures to minimize these risks. The article details the steps involved in risk analysis and assessment, highlighting the value of different methods for analyzing business process risks.

An algorithm has been developed to minimize risks in e-commerce, providing a systematic approach to identifying, assessing, and managing risks. This algorithm includes several key stages: risk identification, impact assessment, strategy development, and monitoring the effectiveness of implemented measures. It has been tested on real-world e-business cases, which demonstrated its effectiveness in reducing the likelihood of negative events and minimizing potential losses. The implementation of the proposed measures has significantly improved risk management in the examined cases.

To further enhance the algorithm, it is recommended to implement automated risk monitoring systems and leverage modern technologies, such as artificial intelligence and big data, to predict potential threats. Additionally, it is important to consider the specific needs of individual business models and adapt the algorithm accordingly to suit each company's requirements.

Further development of a system of quantitative indicators for assessing the degree of risk is necessary, allowing for a more accurate reflection of its complexity and multifaceted nature. The article also stresses the importance of developing and applying economic and mathematical methods and risk models, as well as creating software tools for risk assessment, analysis, and management. These efforts will support better management decisions aimed at minimizing risks and improving overall business resilience.

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