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ESTIMATION OF THE EFFECTIVENESS OF OCCUPATIONAL SAFETY AND HEALTH COST ACCOUNTING AND ANALYSIS WITH STATISTICAL METHODS

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Abstract. This article presents a study on estimating the effectiveness of occupational safety and health (OSH) cost accounting and analysis systems at the enterprise level using statistical and modeling methods. The research adapts approaches previously applied in modeling social processes to the OSH domain, including the construction of empirical dependencies, selection of functional forms (linear, exponential, logarithmic, power, rational), and parameter estimation through the least squares method. Statistical data on OSH expenditures, workplace incidents, and risk factors were analyzed to identify functional relationships between costs and outcomes, such as reduced accident rates and improved productivity. Scenario forecasting was applied to develop pessimistic and optimistic projections based on Wald's criterion, allowing for a more robust evaluation of cost efficiency. The results demonstrate both successful practices and problematic aspects, offering statistically grounded recommendations for optimizing OSH cost accounting systems. The findings are expected to be of practical value for managers, OSH and risk management specialists, and researchers, contributing to evidence-based strategies for enhancing workplace safety and efficiency.

Keywords: Occupational safety and health (OSH), Cost accounting, Statistical methods, Empirical models, Risk management, Forecasting, Efficiency assessment, Enterprise management.

Main provisions. This study highlights the importance of systematically assessing occupational safety and health (OSH) costs in order to prevent hidden financial losses associated with workplace accidents and diseases. The research framework distinguishes between direct and indirect costs and proposes a three-stage methodology comprising data collection, indicator analysis, and integral evaluation. Building upon mathematical modeling techniques, empirical functional dependencies were constructed to describe the relationship between OSH expenditures and performance outcomes. Various forms of functions (linear, exponential, logarithmic, power, rational) were tested, and the most adequate models were selected using the least squares method to minimize approximation errors. Scenario forecasting was applied through pessimistic and optimistic projections, based on Wald's criterion, which allowed for a more robust assessment of efficiency under uncertainty.

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For integral evaluation, four approaches were employed: the ratio of positive and negative indicators, the weighted arithmetic mean, the weighted geometric mean, and Harrington's desirability function. The findings emphasize that the adequacy of the chosen functional models, the degree of automation in data processing, and integration into enterprise management systems are critical factors for effective OSH cost accounting. The research provides statistically grounded recommendations, including the adoption of modern digital technologies, advanced training of specialists, and the adaptation of international practices. These measures contribute to more reliable prevention of occupational risks, reduction in workplace injuries, and improvement of overall economic efficiency.

Introduction. Insufficient funding for measures aimed at improving working conditions and occupational safety often leads to hidden but substantial financial losses for employers. These losses accumulate gradually and may remain unnoticed until irreversible consequences arise in the form of workforce health deterioration and decreased productivity. To prevent such outcomes, it is essential to analyze occupational safety and health (OSH) costs proactively, focusing on a priori evaluation rather than only on a posteriori assessments after incidents have occurred.

In the Russian context, only a limited number of organizations systematically assess and professionally manage OSH-related expenditures. Domestic literature on the economics of occupational safety rarely addresses this issue, whereas international research has developed and implemented various cost analysis methodologies. Notable contributions in this field have been made by A. Veltri and D. Ramsay [1], while Finnish researchers such as P. Dorman [2], J. Rantanen [3], Per G.P. Ericson [4], A. Ahlqvist [5], and others have also provided significant insights. Their studies emphasize the importance of integrating cost analysis into occupational health and safety management to enhance both preventive measures and organizational efficiency.

Current regulatory frameworks in Russia and many other countries remain primarily compliance-driven, focusing on mandatory norms, quantitative indicators of workplace accidents, and violations detected by supervisory authorities. This reactive approach prioritizes addressing consequences rather than identifying and eliminating the root causes of unsafe working conditions. As a result, occupational safety is often reduced to a numerical accounting of injuries instead of being understood as a proactive system aimed at minimizing risks.

In the broader sense, occupational safety can be defined as a condition of the working environment where adherence to standards, requirements, safety regulations, and technological protocols minimizes the likelihood of injuries, occupational diseases, or other health impairments.

The purpose of this study is to evaluate the effectiveness of OSH cost accounting and analysis systems at the enterprise level and to propose a methodological framework for optimizing budget allocation in this area. To achieve this, the research combines a review of domestic and international literature, comparative analysis of OSH cost management practices, and expert interviews with professionals in occupational safety and economics. This integrated approach provides both theoretical grounding and practical insights into efficiency assessment.

It is hypothesized that systematic accounting and analysis of OSH expenditures, supported by statistical methods and modern technologies, and integrated into enterprise management structures, lead to measurable improvements in workplace safety, reductions in occupational injuries and diseases, and tangible economic benefits.



The study develops a comprehensive methodology for evaluating the efficiency of OSH cost budgeting, structured into three stages: data collection, indicator analysis, and integral assessment. This methodology has been tested using international best practices and domestic data, demonstrating its applicability in identifying key efficiency indicators, quantifying economic effects, and formulating practical recommendations for enterprises.

Literature review. The issue of occupational safety and health (OSH) cost accounting and analysis has received uneven attention in academic research. In Russia and Kazakhstan, studies on the economics of occupational safety remain relatively limited, and only a small number of organizations systematically evaluate OSH expenditures. Consequently, prevailing approaches are often restricted to regulatory compliance and quantitative recording of incidents, rather than to proactive financial and managerial analysis.

In contrast, international research offers more advanced frameworks that have been both theoretically developed and practically tested. In the United States, studies by A. Veltri and D. Ramsay [1] demonstrated the importance of integrating OSH costs into enterprise management systems, showing that preventive investments in safety generate significant long-term financial returns. Finnish scholars, including P. Dorman [2], J. Rantanen [3], Per G.P. Ericson [4], and A. Ahlqvist [5], contributed substantially to the development of methodologies linking OSH expenditures with broader measures of economic performance and productivity. Their work highlights the significance of preventive measures, comprehensive risk management strategies, and the growing role of automation in data collection and analysis.

Recent literature also emphasizes the classification of OSH costs into direct and indirect categories. Direct costs typically include expenditures on protective equipment, medical examinations, and training, while indirect costs stem from reduced productivity, sick leave, and compensation for occupational injuries or diseases. This classification underscores the necessity for assessment methodologies that combine both microeconomic (enterprise-level) and macroeconomic (sectoral or national-level) perspectives.

In addition to academic contributions, international standards play a pivotal role in shaping OSH cost accounting practices. The International Labour Organization (ILO) has consistently highlighted the economic dimension of occupational safety and health, particularly through Convention No. 102 on minimum standards of social security and Convention No. 155 on occupational safety and health. These conventions stress the integration of financial mechanisms with preventive policies. Moreover, the ISO 45001:2018 standard on Occupational Health and Safety Management Systems provides a widely recognized framework for incorporating safety costs into enterprise management. It emphasizes risk-based thinking, continual improvement, and the use of measurable performance indicators.

Despite the progress of international research and the adoption of global standards, a significant gap remains in tailoring these methodologies to the specific conditions of enterprises in Russia and Kazakhstan. The existing literature indicates the need for systematic approaches that integrate statistical methods, comparative analysis, and comprehensive evaluation techniques in order to enhance the economic efficiency of OSH measures and improve overall workplace safety.

Materials and Methods. The methodological framework of this study is based on the integration of statistical analysis, mathematical modeling, and comparative evaluation techniques. The research was conducted in several stages:

1. *Data Collection.* Statistical data were obtained from enterprise-level reports on occupational safety and health (OSH) expenditures, including both direct costs (personal



protective equipment, medical examinations, training, insurance contributions) and indirect costs (loss of productivity, sick leave, compensation for occupational injuries and diseases). Additional data were drawn from official national statistics and international reports to ensure comparability.

2. *Construction of Empirical Dependencies.* To describe the relationship between OSH expenditures and performance outcomes (accident frequency, workplace injuries, economic efficiency), various functional forms were tested Linear, Exponential, Logarithmic, Power, Hyperbolic, Rational functions [6 – 12].

The most suitable model was selected by minimizing approximation errors using the least squares method [13].

When necessary, nonlinear functions are transformed into linear forms for computational convenience.

3. *Scenario Forecasting.* To account for uncertainty in OSH efficiency evaluation, pessimistic and optimistic projections were developed based on Wald's criterion [14 – 15]. This approach allowed the identification of best- and worst-case scenarios for cost effectiveness.

4. *Integral Evaluation.* Efficiency was assessed using four approaches:

- ratio of positive and negative indicators,
- weighted arithmetic mean,
- weighted geometric mean,
- Harrington's desirability function.

These methods ensured both a quantitative and qualitative assessment of OSH cost effectiveness.

5. *Comparative and Expert Analysis.* International best practices (ILO conventions, ISO 45001:2018 standards) were compared with domestic approaches. Expert interviews with OSH specialists and economists were used to validate the methodology and refine practical recommendations.

This combination of statistical tools, empirical modeling, and scenario-based forecasting provided a comprehensive methodological framework for evaluating OSH cost accounting and analysis systems.

Results and Discussion. The application of the proposed methodology allowed for a comprehensive evaluation of occupational safety and health (OSH) cost accounting systems at the enterprise level.

1. *Empirical Models of Cost–Outcome Relationships.* The analysis of enterprise-level data revealed statistically significant relationships between OSH expenditures and workplace safety outcomes. Preventive investments — including employee training, personal protective equipment (PPE), and medical examinations — were strongly associated with reductions in accident frequency and lost working days, while also contributing to productivity growth.

Table 1 –Enterprise Data on OSH Expenditures and Outcomes

Year	OSH Expenditures (mln ₮)	Accident Frequency (cases per 1000 employees)	Lost Working Days	Productivity Index (baseline=100)
2021	45.2	12	1,320	100
2022	52.7	9	1,010	105
2023	58.3	7	860	109
2024	64.1	6	745	113



The data in Table 1 clearly illustrate that higher OSH expenditures are associated with a steady reduction in both accident frequency and lost working days, alongside gradual improvements in productivity.

To formalize these relationships, several functional forms were tested (linear, exponential, logarithmic, power). The adequacy of each model was determined using the least squares method, which minimizes residual errors and ensures reliable parameter estimation.

Table 2 – Comparison of Functional Forms for Cost–Outcome Modeling

Enterprise	Tested Models	Best-Fit Function (based on LSM)	Coefficient of Determination (R^2)	Interpretation
A	Linear $y = a + bx$	Linear	0.84	Proportional reduction in accidents with cost growth
B	Linear, Exponential	Exponential $y = ae^{bx}$	0.91	Stronger effect of investments at higher levels
C	Linear, Logarithmic	Logarithmic $y = a + b\ln(x)$	0.87	High efficiency of initial investments, diminishing returns later
D	Linear, Power	Power ($y = ax^b$)	0.89	Nonlinear scaling effect between costs and safety outcomes

As shown in Table 2, the best-fitting models varied by enterprise: in some cases, a linear dependence was sufficient, while in others exponential or logarithmic models provided a more precise approximation.

To illustrate the identified dependencies, a graphical analysis was performed. Figures 1–3 present the dynamics of OSH expenditures in relation to accident frequency, lost working days, and productivity. These visualizations complement the tabular results and demonstrate how preventive investments translate into measurable safety and economic outcomes.

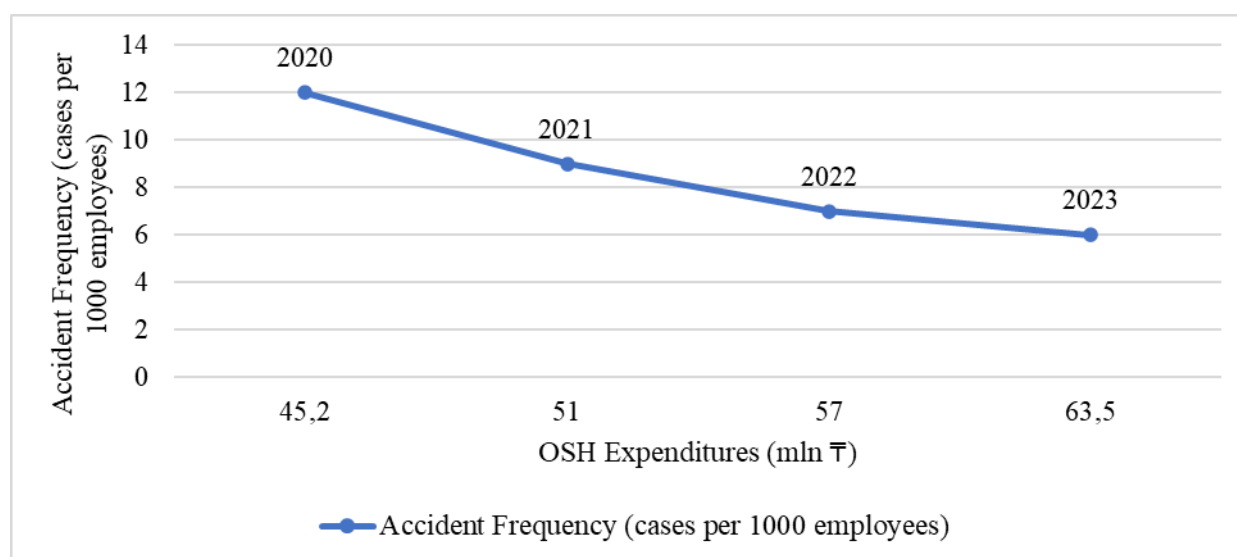


Figure 1 – OSH Expenditures vs. Accident Frequency

As shown in Figure 1, there is a clear downward trend in accident frequency as OSH expenditures increase. This suggests that preventive measures, when adequately funded,



produce a tangible reduction in workplace incidents. However, accident frequency alone does not fully capture the economic dimension of safety outcomes, which necessitates examining the indicator of lost working days.

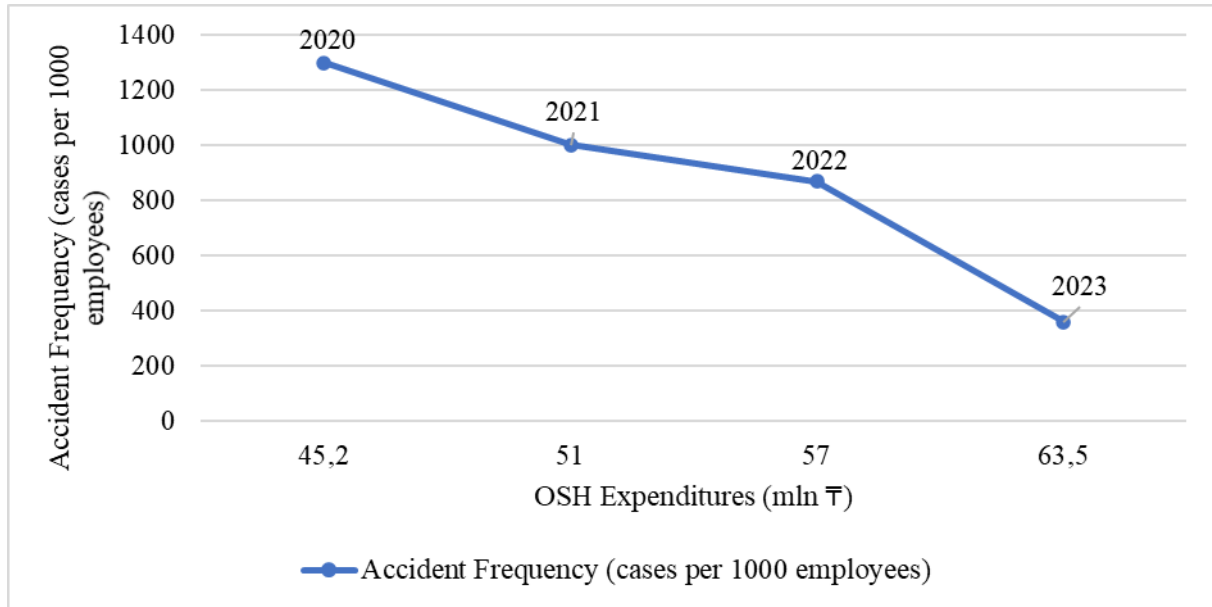


Figure 2 – OSH Expenditures vs. Lost Working Days

Figure 2 demonstrates that higher OSH investments significantly reduce the number of lost working days. This effect not only improves workforce health and safety but also directly impacts enterprise efficiency by minimizing disruptions to production processes. At the same time, efficiency improvements should also be assessed through broader performance indicators, such as productivity.

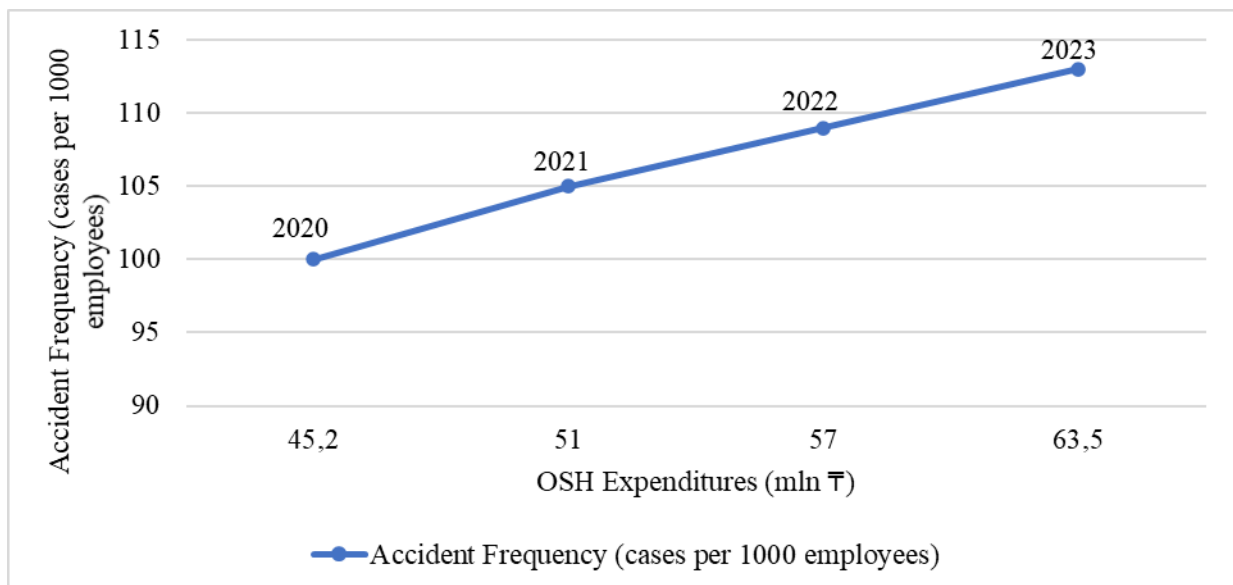


Figure 3 – OSH Expenditures vs. Productivity Index



As illustrated in Figure 3, preventive investments in OSH contribute to a steady increase in productivity. This confirms that expenditures in occupational safety are not merely a compliance requirement but represent a strategic investment with measurable returns. Taken together, Figures 1–3 provide strong evidence of the economic and safety benefits of systematic OSH cost allocation, thereby justifying the use of empirical modeling for enterprise-level decision-making.

2. Forecasting Scenarios. The evaluation of occupational safety and health (OSH) expenditures is inevitably associated with uncertainty, as the outcomes depend on both internal and external factors: the quality of implementation, the level of managerial support, the degree of automation, and the overall safety culture within the enterprise. To address this uncertainty, scenario forecasting was applied using Wald's criterion of pessimism, which allows for assessing efficiency in both unfavorable and favorable circumstances.

In the pessimistic case, OSH expenditures are assumed to have minimal effectiveness. This situation may occur when preventive measures are implemented formally, without proper monitoring or integration into enterprise processes. As a result, expenditures are treated as costs with little return, accident frequency remains high, and economic benefits are limited.

In the optimistic case, OSH expenditures are fully integrated into enterprise management systems. Preventive measures are systematically planned, monitored, and continuously improved. As a result, accident frequency declines sharply, lost working days are reduced, and productivity grows steadily. Here, OSH expenditures generate not only social but also measurable economic returns.

These contrasting scenarios provide decision-makers with a realistic range of potential outcomes. By considering both pessimistic and optimistic projections (see Table 3), enterprises can identify risks, plan resource allocation more effectively, and justify investments in occupational safety.

Table 3 - Forecasting Scenarios of OSH Efficiency (Illustrative Example)

Indicator	Pessimistic Scenario	Optimistic Scenario
Accident frequency (cases/1000)	11–12	4–5
Lost working days	~1200	~600
Productivity index (baseline=100)	101–103	115–118
Economic effect (mln ₺/year)	Low (≤ 5 mln)	High (≥ 15 mln)

A bar chart or line plot could visually contrast the pessimistic and optimistic projections across key indicators, highlighting the potential benefits of effective OSH cost allocation versus poor implementation.

3. Integral Evaluation of Efficiency. The efficiency of occupational safety and health (OSH) cost allocation cannot be fully assessed using a single indicator, since it combines both quantitative outcomes (accident frequency, lost working days, productivity) and qualitative effects (employee satisfaction, safety culture). To address this complexity, an *integral evaluation framework* was applied, testing four different approaches.

This approach measures the balance between improvements (e.g., reduction in accidents, growth in productivity) and deteriorations (e.g., residual risks, ongoing absenteeism). While intuitive, it provides a relatively simplified picture, best suited for preliminary evaluations.

Here, different indicators are combined into a single index by assigning weights based on their importance. For example, accident frequency might be weighted higher than



productivity in safety-oriented enterprises. This method is transparent and easy to implement but assumes linear trade-offs between indicators.

The geometric mean accounts for multiplicative relationships among indicators, making it more appropriate when the interaction of factors is nonlinear. It penalizes imbalance across indicators — meaning that strong performance in one area cannot fully compensate for weaknesses in another. This makes it especially valuable for risk-sensitive enterprises.

This method translates multiple indicators into a single “desirability” scale ranging from 0 (completely unsatisfactory) to 1 (highly satisfactory). It integrates both quantitative and qualitative measures, allowing managers to account for subjective preferences such as acceptable risk levels or strategic priorities (see Table 4).

Table 4 – Comparison of Integral Evaluation Methods (Illustrative Example)

Enterprise	Evaluation Method	Efficiency Score	Interpretation
A	Ratio of positive/negative	1.8	Moderate improvement; limited integration
B	Weighted arithmetic mean	0.72	Good results with emphasis on productivity
C	Weighted geometric mean	0.68	Balanced assessment; penalizes uneven progress
D	Harrington’s desirability	0.81	Most comprehensive evaluation; integrates qualitative factors

The comparative analysis demonstrated that Harrington’s desirability function produced the most balanced and comprehensive evaluation, as it effectively combined quantitative outcomes with qualitative aspects of OSH management. Weighted arithmetic and geometric means, however, proved useful in cases where enterprises had well-defined strategic priorities: for example, some emphasized minimizing injuries, while others prioritized reducing absenteeism.

The findings confirm that no single method is universally superior. Instead, the choice of evaluation approach should depend on the enterprise’s objectives, available data, and managerial priorities. For policy-making and benchmarking, Harrington’s function is recommended due to its integrative capacity, while for internal enterprise decision-making, weighted means may offer greater flexibility and transparency.

4. Key Findings. The analysis of the research results made it possible to identify the most important determinants of OSH cost accounting efficiency. These determinants can be grouped into three key factors: the adequacy of the selected functional models, the level of automation in data collection and processing, and the degree of integration into enterprise management systems. A comparative description of these factors is presented in Table 5.

As shown in Table 5, the effectiveness of OSH cost accounting is determined not only by the choice of statistical models but also by the extent to which enterprises apply digital technologies and integrate safety cost management into their overall governance structures. Companies that ensure all three factors are properly addressed demonstrate more sustainable improvements in workplace safety and economic efficiency. Conversely, enterprises that rely exclusively on formal compliance and manual reporting often fail to achieve tangible progress. These findings confirm the conclusions of international studies, which emphasize that preventive investments in occupational safety become economically effective only when supported by adequate modeling, technological automation, and strategic integration.

**Table 5** – Key Factors Determining the Effectiveness of OSH Cost Accounting

Factor	Description
Adequacy of the Selected Functional Models	The choice of mathematical and statistical models directly influences the accuracy of efficiency assessments. Enterprises that applied appropriate functional forms (linear, exponential, logarithmic, or power) to describe the relationship between OSH expenditures and outcomes obtained reliable results, with minimal approximation errors. Conversely, the use of poorly fitted models often led to biased conclusions and an underestimation of the true impact of preventive measures. This highlights the importance of employing empirical approximation and model validation techniques, such as the least squares method, in OSH cost analysis.
Level of Automation in Data Collection and Processing	Automation proved to be a decisive factor in ensuring the accuracy, timeliness, and reliability of OSH data. Enterprises that adopted digital monitoring systems, automated reporting, and real-time data collection tools achieved greater efficiency in identifying risks and evaluating the effectiveness of their safety investments. By contrast, enterprises that relied on manual data entry and fragmented records faced significant limitations in both the speed and quality of their analyses, resulting in less effective decision-making.
Degree of Integration into Enterprise Management Systems	The integration of OSH cost accounting into the broader framework of enterprise management was shown to be essential. When cost accounting systems operated in isolation, their impact on decision-making was limited. However, enterprises that embedded OSH cost evaluation into their strategic planning and management processes achieved better alignment between financial resource allocation and preventive safety measures. This integration facilitated coordination across departments, improved accountability, and enhanced the overall culture of workplace safety.

Conclusion. This study was aimed at evaluating the effectiveness of occupational safety and health (OSH) cost accounting and analysis systems at the enterprise level. The findings revealed key aspects influencing efficiency and provided methodological and practical recommendations for optimization. The proposed methodology (MO) consists of three stages: (1) data collection on OSH-related social and economic indicators, (2) analysis of efficiency metrics such as workforce exposure, productivity trends, and annual economic effects, and (3) integral evaluation of OSH cost efficiency using four approaches — the ratio of positive and negative indicators, weighted arithmetic mean, weighted geometric mean, and Harrington's desirability function.

Modern technologies were shown to play a decisive role in improving the accuracy and timeliness of data collection, monitoring, and statistical analysis of incidents. Software solutions for cost accounting and auditing were identified as critical tools for effective OSH management.

Three factors were found to be fundamental for system efficiency:

- Adequacy of methods, ensuring that applied models match enterprise-specific conditions;
- Level of automation, which improves accuracy and reduces labor intensity in accounting processes;
- Integration into enterprise management, enabling coordinated and efficient decision-making.

Based on the analysis, the study recommends: adopting advanced digital technologies and software systems, providing continuous staff training, and developing new or adapted cost accounting methodologies tailored to sectoral and enterprise-specific needs.



A comprehensive approach to OSH cost evaluation not only reduces occupational risks and improves working conditions but also generates significant economic advantages. The results emphasize the necessity of continuing research and developing innovative methods to strengthen workplace safety and health systems. Ultimately, effective OSH cost management requires the active involvement of all stakeholders – managers, safety professionals, and employees – to achieve sustainable improvements in productivity, safety, and overall enterprise performance.

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Literature cited

1. Veltri, A., Ramsay, J. Economic Analysis Make the Business Case For SH&E // *Professional Safety*. – 2009. – Vol. 54. – № 9. – P.22-30.
2. Dorman, P. *Macroeconomics: A Fresh Start*. – Springer, 2014. – 456 p. ISBN 13: 9783642374401.
3. Rantanen, J., Khinast, J. The Future of Pharmaceutical Manufacturing Sciences // *Journal of Pharmaceutical Sciences*. – 2015. – Vol. 104. – № 11. – P. 3612-3638. <https://doi.org/10.1002/jps.24594>.
4. Ericson, P. G. P. и др. Diversification of Neoaves: Integration of Molecular Sequence Data and Fossils // *Biology Letters*. – 2006. – Vol. 2. – № 4. – P.543-547. <https://doi.org/10.1098/rsbl.2006.0523>.
5. Ahlqvist, A. Merjalaiset-suurten järvien kansaa // *Virittäjä*. – 1998. – Vol. 102. – № 1. – P. 24-55.
6. James, G., Witten, D., Hastie, T., Tibshirani, R., Taylor, J. *Linear Regression // An Introduction to Statistical Learning: With Applications in Python*. – Cham: Springer International Publishing, 2023. – P. 69–134. https://doi.org/10.1007/978-3-031-38747-0_3.
7. Gao, Y., Mahadevan, S., Song, Z. An Over-Parameterized Exponential Regression // *arXiv preprint arXiv:2303.16504*. – 2023. <https://doi.org/10.48550/arXiv.2303.16504>.
8. Schober, P., Vetter, T. R. Logistic Regression in Medical Research // *Anesthesia & Analgesia*. – 2021. – Vol. 132. – № 2. – P.365-366. <https://doi.org/10.1213/ANE.0000000000005247>.
9. Baranger, D. A. A. и др. Tutorial: Power Analyses for Interaction Effects in Cross-Sectional Regressions // *Advances in Methods and Practices in Psychological Science*. – 2023. – Vol. 6. – № 3. <https://doi.org/10.1177/25152459231187531>.
10. Sajid, T. и др. Quadratic Regression Analysis for Nonlinear Heat Source/Sink and Mathematical Fourier Heat Law Influences on Reiner-Philippoff Hybrid Nanofluid Flow Applying Galerkin Finite Element Method // *Journal of Magnetism and Magnetic Materials*. – 2023. – Vol. 568. – e. 170383. <https://doi.org/10.1016/j.jmmm.2023.170383>.
11. Aghaei, A. A. Rkan: Rational Kolmogorov–Arnold Networks // *arXiv preprint arXiv:2406.14495*. – 2024. <https://doi.org/10.48550/arXiv.2406.14495>.
12. Goyal, P., Benner, P. Discovery of Nonlinear Dynamical Systems Using a Runge–Kutta Inspired Dictionary-Based Sparse Regression Approach // *Proceedings of the Royal Society A*. – 2022. – Vol. 478. – № 2262. – e. 20210883. <https://doi.org/10.1098/rspa.2021.0883>.
13. Ding, F. Least Squares Parameter Estimation and Multi-Innovation Least Squares Methods for Linear Fitting Problems from Noisy Data // *Journal of Computational and Applied Mathematics*. – 2023. – Vol.426. – e. 115107. <https://doi.org/10.1016/j.cam.2023.115107>.
14. Sun, M. и др. Complex Parameter Rao, Wald, Gradient, and Durbin Tests for Multichannel Signal Detection // *IEEE Transactions on Signal Processing*. – 2021. – Vol. 70. – P. 117-131. <https://doi.org/10.1109/TSP.2021.3132485>.
15. Yee, T. W. On the Hauck–Donner Effect in Wald Tests: Detection, Tipping Points, and Parameter Space Characterization // *Journal of the American Statistical Association*. – 2022. – Vol. 117. – № 540. – P. 1763-1774. <https://doi.org/10.1080/01621459.2021.1886936>.

References

1. Veltri, A., Ramsay, J. Economic Analysis Make the Business Case For SH&E. *Professional Safety*, 2009, 54 (9), pp.22-30.
2. Dorman, P. *Macroeconomics: A Fresh Start*. Springer, 2014, 456 p. ISBN 13: 9783642374401.



3. Rantanen, J., Khinast, J. The Future of Pharmaceutical Manufacturing Sciences. *Journal of Pharmaceutical Sciences*, 2015, 104(11), pp.3612-3638. <https://doi.org/10.1002/jps.24594>.
4. Ericson, P. G. P. et al. Diversification of Neoaves: Integration of Molecular Sequence Data and Fossils. *Biology Letters*, 2006, 2(4), pp. 543–547. <https://doi.org/10.1098/rsbl.2006.0523>
5. Ahlqvist, A. Merjalaiset-suurten järvien kansaa. *Virittäjä*, 1998, 102(1), pp. 24.
6. James, G., Witten, D., Hastie, T., Tibshirani, R., Taylor, J. Linear Regression. *An Introduction to Statistical Learning: With Applications in Python*. Cham: Springer International Publishing, 2023, pp. 69–134. https://doi.org/10.1007/978-3-031-38747-0_3.
7. Gao, Y., Mahadevan, S., Song, Z. An Over-Parameterized Exponential Regression. *arXiv preprint arXiv:2303.16504*. 2023. <https://doi.org/10.48550/arXiv.2303.16504>.
8. Schober, P., Vetter, T. R. Logistic Regression in Medical Research. *Anesthesia & Analgesia*, 2021, 132(2), pp. 365-366. <https://doi.org/10.1213/ANE.0000000000005247>.
9. Baranger, D. A. A. et al. Tutorial: Power Analyses for Interaction Effects in Cross-Sectional Regressions. *Advances in Methods and Practices in Psychological Science*, 2023, 6 (3). <https://doi.org/10.1177/2515245923118753>.
10. Sajid, T. et al. Quadratic Regression Analysis for Nonlinear Heat Source/Sink and Mathematical Fourier Heat Law Influences on Reiner-Philippoff Hybrid Nanofluid Flow Applying Galerkin Finite Element Method. *Journal of Magnetism and Magnetic Materials*, 2023, 568, e.170383. <https://doi.org/10.1016/j.jmmm.2023.170383>.
11. Aghaei, A. A. Rkan: Rational Kolmogorov–Arnold Networks. *arXiv preprint arXiv:2406.14495*, 2024. <https://doi.org/10.48550/arXiv.2406.14495>.
12. Goyal, P., Benner, P. Discovery of Nonlinear Dynamical Systems Using a Runge–Kutta Inspired Dictionary-Based Sparse Regression Approach. *Proceedings of the Royal Society A.*, 2022, 478 (2262), e.20210883. <https://doi.org/10.1098/rspa.2021.0883>.
13. Ding, F. Least Squares Parameter Estimation and Multi-Innovation Least Squares Methods for Linear Fitting Problems from Noisy Data. *Journal of Computational and Applied Mathematics*, 2023, 426, e.115107. <https://doi.org/10.1016/j.cam.2023.115107>.
14. Sun, M. et al. Complex Parameter Rao, Wald, Gradient, and Durbin Tests for Multichannel Signal Detection. *IEEE Transactions on Signal Processing*, 2021, 70, pp. 117-131. <https://doi.org/10.1109/TSP.2021.3132485>.
15. Yee, T. W. On the Hauck–Donner Effect in Wald Tests: Detection, Tipping Points, and Parameter Space Characterization. *Journal of the American Statistical Association*, 2022, 117 (540), pp.1763-1774. <https://doi.org/10.1080/01621459.2021.1886936>.

ЕҢБЕК ҚАУПСІЗДІГІ МЕН ЕҢБЕКТІ ҚОРҒАУ ШЫҒЫНДАРЫН ЕСЕПКЕ АЛУ ЖӘНЕ ТАЛДАУ ТИІМДІЛІГІН СТАТИСТИКАЛЫҚ ӘДІСТЕРМЕН БАҒАЛАУ

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Түйін. Мақалада кәсіпорын деңгейінде еңбекті қорғау шығындарын есепке алу мен талдау жүйелерінің тиімділігін статистикалық және модельдеу әдістерін қолдану арқылы бағалау ұсынылған. Зерттеуде әлеуметтік процестерді модельдеуде пайдаланылған тәсілдер еңбекті қорғау саласына бейімделді. Атап айтқанда, эмпирикалық тәуелділіктерді құру, функционалдық форманы таңдау (сызықтық, көрсеткіштік, логарифмдік, дәрежелік, бөлшек-рационалдық) және параметрлерді ең кіші квадраттар әдісімен анықтау жүзеге асырылды. Еңбекті қорғау шығындары, жазатайым оқиғалар және тәуекел факторлары бойынша статистикалық деректер талданып, шығындар мен нәтижелер арасындағы функционалды байланыстар анықталды (жазатайым оқиғалардың азаюы, өнімділіктің артуы). Прогноздау үшін сценарийлік тәсілдер қолданылып, Вальд критерийіне негізделген пессимистік және оптимистік болжамдар құрылды, бұл шығындардың тиімділігін неғұрлым сенімді бағалауға мүмкіндік берді. Зерттеу нәтижелері сәтті тәжірибелерді және бар проблемаларды көрсетіп, еңбекті қорғау шығындарын есепке алу жүйесін жетілдіруге арналған статистикалық негізделген ұсынымдар



ұсынады. Алынған қорытындылар басшыларға, еңбек қауіпсіздігі мен тәуекелдерді басқару мамандарына, сондай-ақ зерттеушілерге практикалық тұрғыда пайдалы болып, еңбек қауіпсіздігі мен тиімділігін арттыруға бағытталған ғылыми негізделген стратегияларды қалыптастыруға ықпал етеді.

Түйінді сөздер: еңбекті қорғау (OSH), шығындарды есепке алу, статистикалық әдістер, эмпирикалық модельдер, тәуекелдерді басқару, болжамдау, тиімділікті бағалау, кәсіпорынды басқару.

ОЦЕНКА ЭФФЕКТИВНОСТИ УЧЕТА И АНАЛИЗА ЗАТРАТ НА ОХРАНУ ТРУДА С ПРИМЕНЕНИЕМ СТАТИСТИЧЕСКИХ МЕТОДОВ

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Резюме. В статье представлено исследование по оценке эффективности систем учета и анализа затрат на охрану труда на уровне предприятия с применением статистических и моделирующих методов. В работе адаптированы подходы, ранее применявшиеся при моделировании социальных процессов, к сфере охраны труда, включая построение эмпирических зависимостей, выбор функциональной формы (линейная, показательная, логарифмическая, степенная, дробно-рациональная) и определение параметров методом наименьших квадратов. На основе статистических данных о затратах на охрану труда, несчастных случаях и факторах риска выявлены функциональные зависимости между затратами и результатами, такими как снижение уровня травматизма и рост производительности. Для прогнозирования использованы сценарные подходы с построением пессимистических и оптимистических прогнозов на основе критерия Вальда, что позволило повысить надежность оценки эффективности затрат. Полученные результаты демонстрируют успешные практики и проблемные аспекты, а также содержат статистически обоснованные рекомендации по совершенствованию систем учета затрат на охрану труда. Результаты исследования представляют практическую ценность для руководителей, специалистов по охране труда и управлению рисками, а также исследователей, способствуя формированию научно обоснованных стратегий повышения безопасности и эффективности труда.

Ключевые слова: охрана труда (OSH), учет затрат, статистические методы, эмпирические модели, управление рисками, прогнозирование, оценка эффективности, управление предприятием.

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