




**Article**  
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**Mathematical methods as a basis and scientific justification for the development of an information-analytical database for the accounting and analysis of OSH expenditures<sup>1</sup>**

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**Abstract.** In contemporary conditions, there is a growing interest in the study of economic losses resulting from occupational injuries and diseases across various sectors of the economy. Mathematical methods serve as the primary research tools, and they are applied in calculations, structural and dynamic analyses, and related areas. The economic impact of such losses, along with their inverse relationship to investments in occupational safety (i.e., preventive expenditures), plays a crucial role in preserving workers' health, enhancing labor productivity, and fostering overall economic growth. This substantiates the need for continuous improvement in occupational safety and health (OSH) through various instruments, one of which is the comparative analysis of enterprise OSH expenditures, particularly those aimed at improving working conditions over a given period.

The article substantiates the development of an information-analytical database for the accounting and analysis of OSH expenditures based on the application of mathematical methods, including comparison, classification, and systematization, through the juxtaposition of primary data on key OSH expenditure items. The categories of expenditures analyzed are defined in accordance with the labor legislation of the Republic of Kazakhstan. The purpose of the study is to apply mathematical methods in the development of a software solution for OSH cost accounting and analysis.

**Keywords:** mathematical methods, information-analytical database, occupational safety and health cost accounting and analysis, baseline indicators, software solution.

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## 1. Introduction

In Kazakhstan, a national occupational safety and health (OSH) policy and program have been established in accordance with the provisions of ILO Convention No. 187 entitled «Promotional Framework for Occupational Safety and Health». This commitment is reflected in the Concept for Safe Labor until 2030, approved by the Resolution of the Government of the Republic of Kazakhstan dated December 28, 2023, No. 1182 [1, 2]. The Concept outlines the main directions of action to be taken at various levels of governance. A key distinguishing feature of the newly adopted national

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OSH program is that, for the first time at the national level, it emphasizes the need to introduce new financial and economic measures aimed at increasing the employer's contribution to improving working conditions. According to paragraph 9 of the Action Plan for the implementation of the Concept for Safe Labor in Kazakhstan for 2024–2030, it is envisaged to introduce approaches to economic planning of occupational safety and health expenditures.

It is important to note at the outset that a scholarly review of international approaches to the accounting and analysis of OSH expenditures has revealed that the terms «costs» and «expenses» carry distinct economic meanings [3]. The term «costs» refer to the value of various types of resources (material, financial, informational, labor, and others) utilized for production or the maintenance of operations. In contrast, expenses are those costs that have been paid and can be both documented and economically justified by the enterprise. In the context of OSH, this article will henceforth use these distinctions as a basis for further discussion.

The provisions of the Labour Code of the Republic of Kazakhstan dated November 23, 2015, No. 414-V ZRK [4], specifically Article 182, impose a number of obligations on employers. These include conducting an assessment of occupational risks and implementing measures to minimize or eliminate them through prevention, replacement of production equipment and technological processes with safer alternatives, providing training, briefings, and knowledge testing for workers on OSH, and ensuring the availability of documentation for safe conduct of production processes and operations.

Employers are also required to organize OSH training and knowledge assessments for managers and personnel responsible for OSH, at least once every three years; to provide workers with adequate sanitary and hygienic conditions, supply and repair of personal protective clothing and footwear, prophylactic treatments, cleansing and disinfecting agents, medical first-aid kits, milk or equivalent nutritional products, and/or specialized dietary (therapeutic and preventive) foods, as well as personal and collective protective equipment in accordance with standards established by the authorized state labor body.

Furthermore, employers must record, monitor, and analyze occupational accidents and diseases (OAD); conduct, with the participation of workers' representatives, periodic certification of workplaces with regard to working conditions at least once every five years, following regulations approved by the authorized labor authority; insure employees against occupational accidents and report the conclusion of such mandatory insurance contracts to the authorized labor authority under established procedures.

Additional responsibilities include the development, approval, and revision of OSH instructions in accordance with procedures set by the authorized labor authority; financing and conducting mandatory and periodic (throughout the course of employment) medical examinations, as well as pre-shift health screenings where required by agreements, collective contracts, or national legislation, or when transferring to work under different conditions or upon the emergence of signs of occupational illness; and implementing and monitoring the functioning of an OSH management system.

The source of funding for this broad range of employer obligations related to ensuring safe working conditions is the employer's own financial resources. Given the extensive scope of these OSH-related obligations, which require adequate funding, there is a pressing need for regular economic assessments and comparative analyses.

In this context, the article explores various applied mathematical methods for the accounting and analysis of the aforementioned OSH expenditures. It also provides a scientific rationale for the development of an information-analytical database for tracking OSH expenditures, the modification of reporting practices related to OSH expenditure accounting and analysis, and the development of a mathematical algorithm for accounting for costs associated with occupational accidents and for processing data within the information-analytical system.

## 2. Methods

Given the diversity of approaches to classifying OSH expenditures, it is recommended that cost accounting be based on the direct attribution of expenditures to OSH activities and the specifics of budgeting for both mandatory and special-purpose measures (the latter being applicable only

in the presence of hazardous or harmful working conditions as identified through occupational risk assessment). These expenditures may be grouped into three categories:

1. General OSH expenditures;
2. Special OSH expenditures;
3. Economic losses related to OSH.

General OSH expenditures are mandatory for all enterprises.

Special OSH expenditures are compulsory when hazardous and/or harmful working conditions are present in the enterprise.

Economic losses in the OSH domain include costs associated with penalties for non-compliance with OSH legislation and compensation payments to workers affected by occupational accidents.

Thus, based on the review, two main approaches have been identified:

Preventive expenditures («investment in OSH»), referring to costs aimed at ensuring safe working conditions and implementing OSH-related activities. These typically include expenses such as training, insurance, personal and collective protective equipment, occupational risk assessments, periodic medical examinations, and pre-shift health screenings, as well as the provision of milk or equivalent food products and/or specialized dietary (therapeutic and preventive) nutrition. These are expenditures intended to prevent the occurrence of a occupational accident.

Compensatory expenditures («economic losses»), referring to costs incurred as a result of an actual occupational accident. These generally include compensation payments, penalties, and related expenses. Concerning the accident, these are post-factum costs that carry a negative economic character.

The methodological foundation of this study is based on the cost analysis framework for OSH in industries with a high risk of occupational injuries [5]. The analysis is conducted using comparative methods, with baseline indicators for the reporting period (a minimum of two years, with a recommended three-year dynamic analysis) serving as the basis for calculations and assessments.

OSH cost analysis may be carried out using either a horizontal or vertical (structural) format, and may also involve the use of ratio analysis.

In horizontal analysis, both absolute and relative deviations across cost items are examined. This approach allows for the comparison of planned versus actual expenditures, previous periods versus the current reporting period, or all of these combined, thereby enabling a comprehensive evaluation of cost dynamics.

In vertical (structural) analysis, the obtained data are compared across individual cost items, allowing for cross-comparison between various categories from all types of reports. This type of analysis helps identify the factors contributing to increases or decreases in expenditures.

During ratio analysis, specific indicators are calculated, the values of which can be compared over different periods. These ratios can also be benchmarked against national or sector-specific averages.

The following formulas (1)–(3) may be applied for performing the necessary calculations:

$$Pb = \frac{Zf}{Zb} * 100\%, \quad (1)$$

where

$Pb$  – percentage relative to the baseline value,

$Zf$  – actual value,

$Zb$  – baseline value.

According to the formula, the percentage relative to the baseline value is calculated as the ratio of each item to the selected baseline value.

The implementation of horizontal analysis involves comparing indicators in both absolute and relative terms.

At the initial stage of the analysis, absolute deviations of financial reporting items are calculated relative to the baseline period.

$$\Delta abs = Zf - Zb, \quad (2)$$

where

$\Delta \text{ abs}$  – absolute change.

At the second stage, relative changes in the analyzed indicators are calculated in comparison with the baseline period.

$$\Delta \text{ rel} = \frac{\Delta \text{ abs}}{Zb} * 100\% \quad (3)$$

In this case, the absolute deviations are normalized relative to the baseline period value.

This approach is particularly useful when comparing multiple companies that differ in size and scale of operations. The total amount of OSH expenditures  $Z_i (i = 1, \dots)$  for the  $i$ -th enterprise is determined using formula (4).

$$Z_i = \sum_{k=1}^n S_k + \sum_{j=1}^m K_j, \quad (4)$$

where

$S_k$  ( $k=1, \dots, n$ ) – preventive expenditures,  $n$  – number of expenditure types;

$K_j$  ( $j=1, \dots, m$ ) – compensatory expenditures,  $m$  – number of expenditure types.

### 3. Results and Discussion

The modern enterprise accounting system comprises three primary types: financial accounting, managerial accounting, and tax accounting. It is from this perspective that a methodological overview of approaches to OSH cost accounting is presented.

Financial accounting is employed to prepare information on the enterprise's financial and economic activities for both internal and external use. It is mandatory and strictly regulated by the state [6], as reporting is submitted in accordance with officially established formats.

Tax accounting is essential for the accurate determination of the tax base and the calculation of mandatory tax payments. This type of accounting is also mandatory and governed by legislation, specifically the Tax Code of the Republic of Kazakhstan [7]. The rules for maintaining records and submitting reports are defined at the state level because tax accounting ensures accurate taxation of each organization and enables control over tax remittances. Thus, the primary objective of tax accounting is to accurately reflect cash flows to determine the amount of taxes owed and report this information to the state in a prescribed format.

Managerial accounting refers to the collection and use of information required by a company's management to support strategic decision-making processes.

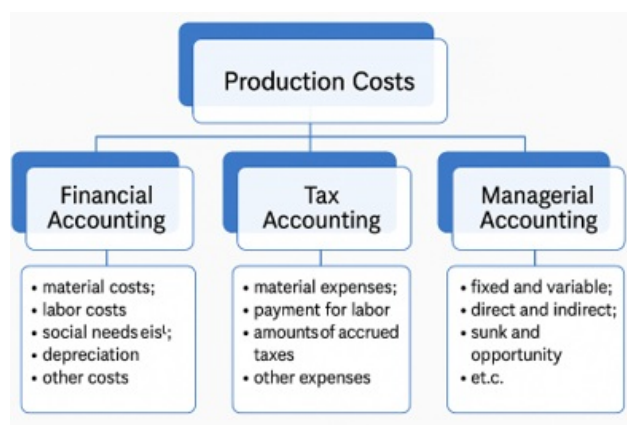


FIGURE 1 – Types of Cost Accounting

Taking into account the key distinctions among the three types of accounting within organizations—financial, tax, and managerial accounting—each is defined by its specific objectives. Financial accounting is maintained to record all financial transactions of the company to produce

accurate and reliable financial statements. The purpose of tax accounting is to optimize the company's tax liabilities and ensure compliance with tax legislation. Managerial accounting is organized to provide information for managerial decision-making and internal control.

In this context, modern organizations are increasingly implementing the integration of financial, tax, and managerial accounting systems, enabling a comprehensive approach to enterprise management.

Firstly, a unified data platform allows all three types of accounting to operate within a common information system, providing real-time access to relevant data.

Secondly, cross-functional reporting enables the use of data from different accounting systems to generate integrated reports. This facilitates more informed decision-making by management, taking into account financial, tax, and managerial perspectives.

Thirdly, process synergy arises when the optimization of one type of accounting (e.g., tax accounting) positively impacts another (e.g., managerial accounting), as cost and revenue information can be used both to reduce tax liabilities and to improve operational efficiency.

Fourthly, integration enhances analytical and forecasting capabilities, allowing for a more holistic assessment of a company's financial activities.

P. Richardsson [8] emphasizes that effective OSH cost accounting requires a comprehensive approach and that investments in OSH lead to a reduction in workplace accidents, decreased downtime, and increased productivity, ultimately generating substantial long-term economic benefits.

Cameron A. Mustard and B. Yanar [9] apply a transparent methodology to assess the financial benefits of OSH expenditures, highlighting that even moderate investments in OSH can yield significant economic advantages for employers.

Raini D. Wirahadikusumah and Felix Adhiwirya [10] examine OSH-related costs associated with the implementation of safety management systems in construction projects. The authors note that mandatory OSH management system costs can range from 2.01% to 3.70% of the contract value, with the most significant components being expenditures on OSH personnel, insurance, and licensing, as well as training and the promotion of OSH programs.

Particular interest is drawn to the work of V.L. Pavlova [11], which demonstrates the correlation between OSH expenditure levels and the degree of occupational risk. To determine the required volume of financial resources, the author proposes a formula for calculating costs by classification group, based on the existing and projected levels of occupational risk. The level of occupational risk is treated as a variable necessary to link OSH expenditures to the actual performance outcomes of the enterprise in the field of OSH.

The article further presents an analysis of costs associated with OAD, which entail severe losses, including direct physical harm to the injured individual, emotional distress for their family and community, and damage to societal values such as justice and solidarity. While attempts are made to assign monetary value to these losses (a necessity, especially in legal proceedings aimed at determining damages), in the end, no financial figure can truly capture the irreparable harm that cannot be restored through compensation [12].

To assess the magnitude of economic losses and analyze their impact on the enterprise and related organizations, various methods and models are applied in global practice. These tools provide insight into losses resulting from worker absenteeism, occupational accidents, staff turnover, loss of work capacity, changes in working conditions, and other factors. The same methods and models can also be employed to analyze the costs of OSH improvement measures and to determine the economic efficiency of such interventions.

A substantial body of scientific literature is devoted to methodologies for estimating the cost of OAD. The estimation of these costs was the focus of research by H. Heinrich [13], who demonstrated that the costs associated with workplace accidents in American companies were significant, and that many of these expenses remained hidden from management.

Numerous similar studies have been conducted following H. Heinrich's work in various countries—for example, by Grimaldi and Simonds [14], Larsson and Betts [15], and N. Monnerie [16]. These studies document that substantial costs may be associated with OAD.

A frequently cited rationale for measuring OSH-related expenditures is that making such costs explicit encourages managers to consider OSH issues in their decision-making processes. In other words, OSH and workplace safety concerns become more closely aligned with core business operations and exert a greater influence on managerial decisions.

Overall, in the literature on this topic, OSH-related costs are generally divided into two broad categories:

Costs associated with the functioning of the OSH management system and initiatives aimed at promoting and sustaining a culture of workplace safety within the company. These costs are typically relatively stable, as they are not directly affected by the occurrence of adverse events such as OAD.

Costs resulting from OAD. These may take the form of direct expenditures, increased operational costs, potential revenue losses, or opportunity costs. Such costs vary depending on the type and number of adverse outcomes.

This categorization is reflected in a range of studies dedicated to the assessment of OSH-related expenditures.

D. Andreoni [17], along with V. Khrimak and H. Perezgonzalez [18], employ the terms «prevention costs» and «accident costs», where prevention costs are not contingent on the occurrence of individual accidents. This terminology is, to some extent, comparable to the cost-of-quality framework used by B. Dale and J. Plunkett [19].

However, it should be noted that certain expenditures may fall into both categories. For instance, some insurance-related costs include fixed annual premiums as well as variable components that increase with the frequency or severity of claims.

According to the International Financial Reporting Standards (IFRS), an entity shall present an analysis of expenses recognized in profit or loss using a classification based either on their nature or their function within the entity, depending on which method provides information that is reliable and more relevant.

An entity must present an analysis of expenses recognized in profit or loss using a classification based either on the nature of the expenses or on their function, depending on which approach ensures more reliable and relevant information.

The nature of the expense method involves grouping expenses recognized in profit or loss according to their nature (e.g., procurement of personal protective equipment (PPE), social security costs) without allocating them to the functional areas of the entity.

This method may be simpler to apply, as it does not require the reallocation of expenses based on their purpose or function within the organization.

The function of the expense method classifies expenses according to their purpose. An entity that classifies expenses by function is required to disclose additional information on the nature of the expenses, including those related to the acquisition or use of PPE.

These methods provide insights into costs that may vary, either directly or indirectly, with changes in the enterprise's sales or production volume. Since each presentation method has its own advantages depending on the type of entity, the standard requires management to choose the presentation format that is both reliable and most relevant.

Expense analysis is carried out based on an analytical model consisting of 17 cost elements, aligned with the labor legislation of the Republic of Kazakhstan regarding the provision and financing of OSH measures.

The analysis covers a range of expenses, including:

1. costs associated with the assessment of occupational risks;
2. certification of production facilities with respect to working conditions;
3. training, instruction, and knowledge testing on OSH issues for workers, managers, and personnel responsible for OSH;
4. mandatory insurance of employees against accidents occurring in the course of performing their professional (official) duties (MAI);
5. provision of personal protective equipment (PPE);
6. provision of collective protective equipment;
7. provision of sanitary and welfare facilities and installations;

8. distribution of milk or equivalent food products and/or specialized dietary (therapeutic and preventive) products to employees;
9. granting of reduced working hours, additional paid annual leave, and increased wage rates;
10. periodic medical examinations and pre-shift health screenings;
11. payment of mandatory professional pension contributions.

This section briefly presents the practical results of testing the proposed methodology. A total of 240 distinct OSH-related data points were processed; dynamic trends over three years were analyzed across 119 indicators; and econometric indicators were calculated based on 167 data entries. All numerical characteristics were further subjected to graphical analysis. As a result, an information-analytical database for the accounting and analysis of OSH expenditures was developed (Table 1).

Based on the information-analytical database for the accounting and analysis of OSH expenditures, a cost analysis was conducted in accordance with the established methodology.

The OSH expenditures analysis for **Enterprise A**—a large-scale enterprise employing a total of 4,826 workers, of whom 4,714 (or 97%) are engaged in hazardous working conditions—revealed that, during the analyzed period, expenditures were allocated across 14 out of 17 identified cost categories. On average over the three years, the dominant OSH expenditure items were: provision of PPE - KZT 276.32 million (29%), MPPC - KZT 252.93 million (26%), and provision of additional paid leave -KZT 252.90 million (26%).

The nature of OSH expenditures reflects the working conditions at the enterprise, which are classified as hazardous and/or harmful.

Total expenditures on benefits and compensation for employees working under hazardous conditions at the enterprise account for 61% of overall OSH spending, which is attributable, in part, to the increase in the number of employees identified as working in hazardous environments based on the results of workplace certification, from 4,299 to 4,686 individuals.

A significant rise was observed in the costs of advanced training for managers and OSH-responsible personnel, due to an increase in the number of trainees from 277 to 357 persons.

Expenditures on MAI have been increasing annually by approximately 20%, reaching a total of KZT 85.1 million in 2019. These insurance costs are calculated as 0.76% of the total wage fund, based on the classification of the enterprise's economic activity under Risk Class 12, which determines the premium under the insurance contract. Positive growth trends were also recorded for expenditures on: PPE, cleansing and neutralizing agents (24%), sanitary and welfare services (25%), and periodic medical examinations (12%).

The OSH expenditure analysis for **Enterprise B**, which employs a total of 242 workers—41 of whom (16%) are engaged in hazardous working conditions—shows that, during the analyzed period, funds were allocated to 11 out of 17 categories of OSH expenditures (see Table 1).

Over the three years, the dominant OSH expenditure items at Enterprise B were: provision of PPE – KZT 8.75 million (43%), pre-shift medical screenings – KZT 2.59 million (13%), payment of MPPC – KZT 2.45 million (12%). The expenditures on PPE were related to the procurement of 368 types of special clothing, protective footwear, and other PPE. A comparative analysis of OSH expenditure dynamics reveals a baseline growth rate of 26.2%. The increase is primarily driven by rising costs in the following areas: MAI – up by 129.6% (under the mandatory insurance contract, the insurance premium rate is 0.65%, with the enterprise classified under Professional Risk Class 8); granting of additional paid leave for employees working in hazardous and/or dangerous conditions – 69.6% increase; MPPC – 31.1% increase.

These trends are linked to the expansion of the workforce, following the commissioning of an additional production unit, and the increase in the total wage fund due to higher wages. This growth in wages has directly impacted the volume of expenditures on MPPC, MAI, additional leave entitlements, and increased wage payments.

A violation of labor legislation was noted with regard to internal OSH oversight. Specifically, at this industrial enterprise employing more than 50 people, an OSH service has not been established, and OSH responsibilities are being carried out by an employee assigned on a part-time basis.

TABLE 1 – Information-analytical database for the accounting and analysis of OSH expenditures at six enterprises (A–G) over a five-year period

Names of Cost Items	Enterprises											
	A		B		C		D		E		F	
	Exp., KZT*	Share, %**	Exp., KZT*	Share, %**	Exp., KZT*	Share, %**	Exp., KZT*	Share, %**	Exp., KZT*	Share, %**	Exp., KZT*	Share, %**
Provision of PPE, cleansing, and neutralizing agents	276 323 539	29	8 751 667	43	1 074 333	4	1 063 804 495	16	22 468 819	8	1732600	42
Provision of sanitary and welfare services	1 948 948	0	268 333	1	335 333	1	425 672 333	6	247 168	0	820000	20
Certification of production facilities based on working conditions	5 624 788	1	1 824 095	9	179 667	1	6 672 000	0	1 408 693	0	0	0
Occupational risk assessment				0		0		0		0	0	0
Periodic medical examinations	5 052 013	1	870 332	4	802 000	3	98 692 333	1	4 723 619	2	75000	2
Pre- and post-shift medical screenings	2 900 000	0	2 593 000	13	65 667	0	41 177 000	1		0	0	0
Mandatory accident insurance	74 323 971	8	1 674 733	8	3 212 333	13	154 554 333	2	38 064 688	13	864792	21
Advanced OSH training	1 413 667	0	324 000	2	312 667	1	6 368 000	0	500 000	0	90000	2
Training, instruction, and knowledge testing				0		0	15 352 333	0	10 081 667	3	59000	1
Equipping OSH and safety training rooms	1 056 631	0		0	145 667	1	6 784 000	0		0	351000	9
Distribution of milk or equivalent food products	62 475 467	7	638 333	3	2 131 667	8	3 065 333	0	11 641 663	4	130000	3
Provision of therapeutic and preventive nutrition (TPN) and vitamin supplements	2 408 000	0		0		0	544 776 333	8		0	0	0
Granting of additional paid leave	252 901 600	26	1 029 333	5	15 863 400	62	345 792 333	5	59 627 513	20		0
Increased wage rates				0		0	3 102 026 333	46	106 075 217	36		0
Reduced working hours	15 559 576	2				0	517 374 000	8		0		0
Payment of mandatory professional pension contributions (MPPC)	252 931 802	26	2 446 000	12	1 556 333	6	354 338 667	5	37 421 474	13		0
Consulting services	7 280 361	1				0		0		0		0
<b>Total</b>	959 773 575	100	20 419 826	100	25 679 807	100	6 086 449 829	100	292 260 520	100	4 122 392	100

\* averaged over a five-year period

\*\* share in total expenditures, averaged over a five-year period for each enterprise



The OSH expenditure analysis for **Enterprise C**, which employs a total of 236 workers – 87 of whom (36%) are engaged in hazardous working conditions – shows that over the three years, the dominant OSH expenditure items were: provision of additional paid leave for employees engaged in heavy work or work under hazardous and/or dangerous conditions – KZT 15.86 million (62%), MAI – KZT 3.21 million (13%), distribution of milk or equivalent food products – KZT 2.13 million (8%).

It should be noted that the nature of OSH expenditures is determined by the classification of working conditions as hazardous and/or harmful. Accordingly, the total volume of OSH expenditures—including the dominant categories listed above—is calculated based on the number of employees engaged in such conditions, as defined by the approved occupational risk lists.

Thus, expenditures for the provision of additional paid leave are calculated based on the number of actual working days performed under hazardous and/or harmful conditions, taking into account the employee's occupation in accordance with the approved list, with a minimum of six calendar days. MPPC expenditures are calculated as 5% of the wage fund for employees engaged in heavy work or work under hazardous conditions.

MAI expenditures are calculated as 1.55% of the total wage fund of the enterprise, based on the classification of its economic activity under Professional Risk Class 14, which determines the amount of the insurance premium under the insurance contract.

A comparative analysis of OSH expenditure dynamics reveals a baseline growth rate of 9.7%. The increase is primarily driven by rising costs in the following areas: periodic medical examinations – up by 229.1%, pre-shift medical screenings – up by 120.0%, and advanced training for managers and OSH-responsible personnel – up by 73.7%. These increases are attributed to the growth in the number of employees at the enterprise.

The OSH expenditure analysis for **Enterprise D**, which employs a total of 1,447 workers – 1,131 of whom (78%) are engaged in hazardous working conditions – shows that, during the analyzed period, funds were allocated to 10 out of 17 OSH expenditure categories. Over the three years, the dominant OSH expenditure items were: increased wage payments for employees engaged in heavy work or work under hazardous and/or dangerous conditions – KZT 106.07 million (36%), provision of additional paid leave for such employees – KZT 59.6 million (20%), MPPC – KZT 37.4 million (13%), MAI – KZT 38.01 million (13%). It should be noted that the structure of OSH expenditures reflects the classification of working conditions as hazardous and/or harmful.

MAI expenditures are calculated as 1.13% of the total wage fund of all employees, based on the classification of the enterprise's economic activity under Professional Risk Class 15, which determines the insurance premium under the contract.

A comparative analysis of OSH expenditure dynamics shows a baseline growth rate of 46.1%. The increase is primarily due to rising costs in the following areas: provision of additional paid leave for employees working under hazardous and/or dangerous conditions, up by 31.2%, periodic medical examinations, up by 66.1%, training, instruction, and knowledge testing of employees, up by 28.2%. Overall, this growth is associated with a 25% increase in the number of employees working under hazardous and/or harmful conditions. At the same time, there was a notable decrease in expenditures for: advanced training for managers and OSH-responsible personnel – down by 62.6%, which is explained by the training cycle for managers (every three years); sanitary and welfare services – down by 30.3%.

The OSH expenditure analysis for **Enterprise E**, which employs a total of 4,102 workers – 3,484 of whom (84%) work under hazardous conditions – shows that, during the analyzed period, funds were allocated to 15 out of 17 OSH expenditure categories. Over the three years, the dominant OSH expenditure items were: increased wage payments for employees – KZT 3,100 million (46%), provision of PPE – KZT 1,063.8 million (16%), distribution of therapeutic and preventive nutrition (TPN) and vitamin supplements – KZT 544 million (8%), reduced working hours – KZT 517 million (8%). The structure of OSH expenditures reflects the classification of working conditions as hazardous and/or harmful. Accordingly, the total volume of OSH expenditures—including the dominant categories listed above—is determined based on the number of employees engaged in hazardous and/or harmful conditions, by the approved lists. MAI expenditures are calculated as 1.55% of the total

wage fund of all employees, based on the classification of the enterprise's economic activity under Professional Risk Class 14, which determines the insurance premium under the insurance contract.

A comparative analysis of OSH expenditure dynamics shows a baseline growth rate of 37.6%. The increase is primarily driven by rising expenditures in the following areas: sanitary and welfare services – up by 149.8%, equipping OSH and safety training rooms – up by 303.9%, distribution of therapeutic and preventive nutrition and vitamin supplements – up by 137.1%, provision of PPE, cleansing and neutralizing agents – up by 79.9%. These increases are associated with a 17.9% growth in the number of employees.

The OSH expenditure analysis for **Enterprise F**, a small enterprise with a total workforce of 58 employees, indicates that no hazardous working conditions were identified based on the results of workplace certification. During the analyzed period, funds were allocated to 8 out of 17 OSH expenditure categories. The dominant OSH expenditure items were: provision of PPE – KZT 1.73 million (42%), MAI – KZT 0.86 million (21%), sanitary and welfare services – KZT 0.82 million (20%). It is worth noting that, during the inspection, non-compliance with the requirement to conduct pre-shift medical screenings was identified, which was attributed to insufficient OSH funding.

The OSH expenditure analysis for **Enterprise G**, which employs a total of 247 workers—207 of whom (83.8%) are engaged in hazardous working conditions—shows that, during the analyzed period, funds were allocated to 9 out of 17 OSH expenditure categories. Over the three years, the dominant OSH expenditure items were: increased wage payments for employees – KZT 41 million (27%), provision of PPE, cleansing and neutralizing agents – KZT 31.86 million (20%), distribution of milk or equivalent food products – KZT 27.8 million (18%).

The structure of OSH expenditures reflects the classification of working conditions as hazardous and/or harmful. A comparative analysis of OSH expenditure dynamics reveals a baseline growth rate of 9.3%.

The analysis of OSH expenditures across the surveyed enterprises over three years demonstrates the stability of cost structures in terms of their dominant categories. This consistency confirms the alignment between the nature of the expenditures and each enterprise's OSH management strategy. The dominant OSH cost categories across the enterprises were: increased wage payments – 22%, additional paid leave – 21%, provision of PPE – 20%, MPPC – 12%.

These expenditures are justified by the significant proportion of employees engaged in hazardous working conditions.

Specialized software tools can be used for analyzing OSH expenditures. Below is a summary of the functionality of OSHA's «Safety Pays» program [20], developed by the Occupational Safety and Health Administration (U.S. Department of Labor). This tool provides information on the frequency and cost of occupational injuries and illnesses.

Based on data collected from thousands of workplaces, «Safety Pays» offers a unique opportunity to benchmark a company's workplace safety indicators against those of similar enterprises. The tool also helps evaluate compliance with OSH obligations.

Employers can utilize the «Safety Pays» tool in various ways, depending on the extent of available data on occupational injuries and diseases within their organization. The tool is particularly effective when used in conjunction with OSHA Form 300A, which employers are required to complete. In the absence of such data, the tool can still be used to estimate the potential financial burden associated with workplace injuries and illnesses.

The functionality of the «Safety Pays» program, in the absence of internal occupational injury and illness statistics, allows users to:

- estimate the probability of injury based on the industry and workforce size;
- assess the potential costs associated with a typical injury within the selected industry;
- identify current expenditures and evaluate their impact on business operations.

When OAD data are available, this tool can be used to:

- compare the company's insurance rate with those of similarly sized employers within the same industry;
- calculate the potential annual burden associated with these cases.

### Step 1. Enter Your Business Information ▲

Please enter your industry and select your industry; and size.

1. Enter Your NAICS code:

2. Or select an industry:

3. Enter your annual employee hours worked:

### Step 2. Enter the Number of Injury/Illness Cases and Lost Workday Cases ▲

Enter data at a level that corresponds with the heading of each column in the OSHA 300 or NAICS Table 1.

Select input type:

☐ Enter cases recorded annually per employee hours worked, as instructed on column H of the OSHA 300A. [?](#)

☒ Enter cumulative totals as recorded over the past year on the columns H and I of the OSHA 300A. [?](#)

1. Enter the number of total injury/illness cases recorded in columns H and I of the OSHA 300A:

2. Enter the number of injury/illness cases that involved days away from work recorded in column H of the OSHA 300A:

### Step 3. Adjust the Business Assumptions Used for Calculation Outputs ▼

FIGURE 2 – Functionality of the «Safety Pays» Program

The «Safety Pays» tool uses the following data sources in its calculations:

1. Occupational injury and illness rates by industry.

OSHA utilizes industry-specific injury quartile tables from the Bureau of Labor Statistics (BLS) to determine or calculate the Total Case Rate (TCR) and the DART rate (Days Away, Restricted, or Transferred) across industries and establishment size categories.

The «Safety Pays! tool applies two benchmark estimates:

- the average rate for the entire industry and establishment size category («all competitors»),
- the average rate among firms below the 25th percentile («top-performing competitors»).

2. Types of Injuries and Illnesses by Industry. The Bureau of Labor Statistics (BLS) provides data on injuries and illnesses by nature of injury or illness (e.g., fracture) for serious nonfatal cases (i.e., cases where the worker was away from work for at least one day beyond the day of injury or illness onset). OSHA uses this dataset to calculate the proportion of serious cases by injury or illness type for specific industry sectors.

3. Costs of Wage-Loss Compensation Claims by Type of Injury. The cost estimates for wage-loss compensation claims used in the «Safety Pays» tool are provided by the National Council on Compensation Insurance, Inc. (NCCI). These data reflect the average cost of wage-loss claims based on statistical reports from member jurisdictions submitted to NCCI.

It is important to note that in the United States, NCCI manages the nation's largest database of workers' compensation insurance information. NCCI analyzes industry trends, provides rate recommendations for workers' compensation insurance, evaluates the cost of proposed legislation, and offers various services and tools to support the effective operation of the workers' compensation system.

Significantly, the estimates of direct (i.e., workers' compensation) and indirect costs are provided in dollar terms across major industry sectors. Workers' compensation claims may include medical-only claims (covering medical expenses only) and lost-time claims (covering wage-loss payments due to time away from work).

3. For medical-only claims, the tool uses the average cost of an emergency department visit, based on data from the Centers for Disease Control and Prevention (CDC) Web-based Injury Statistics Query and Reporting System (WISQARS). This cost estimate applies to all nonfatal injuries that are treated and released (i.e., not resulting in hospitalization) for individuals aged 20 to 64. In addition

to lost-time claims, a company's workers' compensation costs may also include medical-only claims. For such claims, the tool utilizes the average cost of an emergency department visit, derived from the CDC's Web-based Injury Statistics Query and Reporting System (WISQARS). This cost estimate applies to all nonfatal injuries that are treated and released (i.e., not resulting in hospitalization) for individuals aged 20 to 64.

4. Indirect Costs. The estimates of indirect costs presented in this tool are drawn from the publication Improving Construction Safety Performance by the Business Roundtable and are based on a study conducted by the Department of Civil Engineering at Stanford University.

TABLE 2 – Indirect Costs

Direct Costs	Indirect Cost Ratio
\$0–2,999	4.5
\$3,000–4,999	1.6
\$5,000–9,999	1.2
\$10,000 or more	1.1

The magnitude of indirect costs is inversely proportional to the severity of the injury: the less severe the injury, the higher the ratio of indirect to direct costs. Although indirect costs may constitute a significant portion of the actual cost of an incident, they are typically uninsured and therefore not reimbursable.

The indirect cost multipliers used in the Safety Pays tool represent average estimates (across all injury types, based on data from the construction industry) and are derived from a limited study on this subject. The actual indirect cost multiplier may vary depending on the employer's specific circumstances.

Below are cost estimates by type of OAD, as well as by industry sector.

TABLE 3 – Cost estimates by type of OAD

Type of Injury	Cost*	Type of Injury	Cost*
Asphyxia	\$221 596	All other cumulative trauma disorders	\$46 179
Circulatory disorders	\$208 441	Respiratory disorders (gases, fumes, chemicals, etc.)	\$44 771
Cancer	\$178 367	Inflammation	\$42 707
Laceration	\$177 312	Heat stroke	\$41 109
Electric shock	\$172 716	AIDS	\$39 973
Silicosis	\$163 583	Vision-related disorders	\$39 576
Multiple injuries, including both physical and psychological	\$133 919	Mental stress	\$38 372
Enucleation (e.g., removal of a tumor, eye, etc.)	\$112 238	Dust disease, NOC (not otherwise classified pneumoconioses)	\$38 109
Amputation	\$104 800	Overexertion	\$34 957
Multiple physical injuries only	\$85 301	Infection	\$34 278
Loss of vision	\$82 838	Carpal tunnel syndrome	\$33 764
Dislocation	\$82 080	Sprain	\$33 281
Fracture	\$74 947	Fainting	\$33 229
Angina	\$73 775	Metal poisoning	\$32 056
Asbestosis	\$73 496	Puncture	\$30 352
Crushing injury	\$73 143	Contusion	\$30 162
Myocardial infarction (heart attack)	\$72 598	Chemical poisoning (excluding metals)	\$29 782
Mental disorder	\$64 863	Non-physical injury	\$28 233
Radiation	\$63 910	Frostbite	\$25 193
Pneumoconiosis	\$63 883	Hearing loss or impairment (injury-related only)	\$24 861
Fracture (repeated for clarity if needed)	\$59 882	Foreign body	\$23 971
Concussion	\$59 571	Avulsion	\$23 876
All other specific injuries	\$58 899	Hernia	\$22 859
All other occupational illnesses	\$51 583	Hearing loss	\$20 553
Burn	\$51 516	Infectious disease	\$11 777
Poisoning – general (not cumulative trauma)	\$50 703	Dermatitis	\$10 568

\*Average cost of a lost-time claim

Indirect cost estimates are calculated by applying a multiplier to the direct cost estimates <sup>2</sup>

<sup>2</sup>These multipliers are based on a 1982 study conducted by researchers at Stanford University.

TABLE 4 – Cost estimates related to OAD by industry sector

Code	Sector Name	Direct Lost-Time Costs	Indirect Lost-Time Costs	Direct Medical-Only Costs	Indirect Medical-Only Costs
00X	All Industries	\$43 920	\$48 311	\$3 130	\$14 083
ADW	Administrative, Support, and Waste Management Services	\$42 922	\$47 214	\$3 130	\$14 083
AER	Arts, Entertainment, and Recreation	\$43 666	\$48 033	\$3 130	\$14 083
AFH	Agriculture, Forestry, Fishing, and Hunting	\$45 514	\$50 065	\$3 130	\$14 083
AFS	Accommodation and Food Services	\$42 136	\$46 349	\$3 130	\$14 083
EDS	Educational Services	\$44 714	\$49 185	\$3 130	\$14 083
FIN	Finance and Insurance	\$49 626	\$54 589	\$3 130	\$14 083
HAS	Health Care and Social Assistance	\$42 749	\$47 024	\$3 130	\$14 083
MCE	Management of Companies and Enterprises	\$44 465	\$48 911	\$3 130	\$14 083
MIN	Mining, Quarrying, and Oil and Gas Extraction	\$43 889	\$48 278	\$3 130	\$14 083
PST	Professional, Scientific, and Technical Services	\$41 345	\$45 480	\$3 130	\$14 083
RET	Retail Trade	\$42 015	\$46 216	\$3 130	\$14 083
RRL	Real Estate and Rental and Leasing	\$49 046	\$53 950	\$3 130	\$14 083
TRW	Transportation and Warehousing	\$42 008	\$46 208	\$3 130	\$14 083
UTL	Utilities	\$46 407	\$51 048	\$3 130	\$14 083
WHT	Wholesale Trade	\$43 099	\$47 409	\$3 130	\$14 083
CON	Construction	\$45 671	\$50 238	\$3 130	\$14 083
MFG	Manufacturing	\$45 068	\$49 575	\$3 130	\$14 083
INF	Information	\$39 962	\$43 958	\$3 130	\$14 083
OTS	Other Services (except Public Administration)	\$43 181	\$47 499	\$3 130	\$14 083
SP1	Public Administration	\$42 961	\$47 257	\$3 130	\$14 083

Thus, the OSHA «Safety Pays» tool is an online calculator that utilizes injury and illness cost data collected by the National Council on Compensation Insurance (NCCI). It processes this data on your behalf to calculate the direct and indirect costs of an injury, as well as the additional revenue your business would need to generate in order to offset those costs.

According to OSHA, the «Safety Pays» program has been used in the United States to estimate the economic losses resulting from workplace fatalities, injuries, and illnesses. For example, in 2021, it was reported that employers paid over \$1 billion per week in direct workers' compensation costs for disabling, nonfatal workplace injuries that occurred in 2018. The National Safety Council estimated that work-related deaths and injuries cost the nation, employers, and individuals approximately \$171 billion in 2019. Employers who implement effective OSH programs can expect to significantly reduce the number of workplace injuries and illnesses, as well as the associated costs, including workers' compensation claims, medical expenses, and productivity losses. Moreover, employers often find that the process improvements and operational changes introduced to enhance OSH performance lead to substantial gains in productivity and profitability for their organizations.

#### 4. CONCLUSION

The findings presented in this article are interim results and will be further developed with the aim of designing a software tool that will enable the calculation of required funding (budgeting) for OSH measures, as well as the accounting and analysis of related expenditures.

Numerous studies have demonstrated that investments in OSH yield tangible benefits from a microeconomic perspective, with a return on prevention ratio of 2.2. In practical terms, this means that for every KZT 1 invested annually by companies in prevention, there is a potential economic return of KZT 2.20. In this regard, the authors of the article aim to produce scientifically grounded evidence, through the continuation of this research, in support of corporate investment in preventive OSH measures.

Against the backdrop of the widespread adoption of digital technologies and automation systems, there is a growing need for specialized software to monitor and analyze occupational risks, as well as the development of online platforms for training and informing workers about safety measures. It is also important to establish economic incentives for employers. This may include the design and implementation of financial benefits and tax preferences for enterprises that demonstrate a high level of workplace safety.

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#### *Authors' Contributions:*

Sh. Abikenova developed the methodological framework of the study, identified the scientific novelty, and substantiated the use of mathematical methods for analyzing occupational safety expenditures. She also provided the overall scientific editing of the article.

Sh. Aitimova conducted the empirical part of the research, including the collection, systematization, and comparative analysis of occupational safety expenditure data across industries with high rates of occupational injuries. She also contributed to the development of the analytical data bank.

A. Kocherbayeva participated in the interpretation of the relationship between economic losses and investments in preventive measures and contributed to the formulation of conclusions and practical recommendations.

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**Еңбек қорғау шығындарын есепке алу және талдау бойынша  
ақпараттық-талдамалық деректер базасын қалыптастырудың негізі мен ғылыми  
дәйегі ретіндегі математикалық әдістер**

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**Аннотация.** Қазіргі жағдайда өндірістік жарақаттар мен кәсіби аурулардан туындайтын экономикалық шығындарды түрлі экономикалық салалар аясында зерттеуге қызығушылық артып отыр. Бұл бағыттағы негізгі әдістердің бірі – құрылымдық, серпінді және салыстырмалы есептеулерде қолданылатын математикалық әдістер. Экономикалық шығындар мен еңбек қорғауға (превентивтік шығындарға) салынатын инвестициялар арасындағы кері пропорционалды өзара байланыс – қызметкер денсаулығын сақтау, еңбек өнімділігін арттыру және жалпы экономикалық тиімділікті қамтамасыз етуде маңызды фактор болып табылады. Осыған орай, еңбек жағдайларын жақсартуға бағытталған шығындарды салыстырмалы түрде бағалау – еңбек қорғау жүйесін жетілдірудің маңызды құралдарының бірі ретінде қарастырылады.

Мақалада еңбек қорғау саласындағы шығындарды есепке алу және талдау мақсатында ақпараттық-талдамалық деректер базасын қалыптастырудың ғылыми негіздері қарастырылады. Бұл үшін математикалық әдістердің ішінде салыстыру, топтастыру және жүйелеу тәсілдері қолданылып, бастапқы деректер еңбек қорғауға жұмсалатын негізгі шығын баптары бойынша салыстырылған. Талдауға жататын шығын түрлері Қазақстан Республикасының еңбек заңнамасына сәйкес айқындалған. Зерттеудің мақсаты – еңбек қорғау шығындарын есепке алу мен талдауға арналған бағдарламалық өнім әзірлеу барысында математикалық әдістерді қолдану.

**Түйін сөздер:** математикалық әдістер, ақпараттық-талдамалық деректер базасы, еңбек қорғау шығындарын есепке алу және талдау, базалық көрсеткіштер, бағдарламалық өнім.

**Математические методы как основа и научное обоснование к формированию  
информационно-аналитического банка данных по учету и анализу затрат на  
охрану труда**

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**Аннотация.** В современных условиях возрастает интерес к исследованию экономических потерь от производственного травматизма и профзаболеваний в различных отраслях экономики. Основными методами исследования являются математические методы, которые используются при расчетах, анализе структуры, динамики и т.д. Влияние экономических потерь и их обратно-пропорциональная связь с инвестициями в охрану труда (превентивными расходами) является важным в сохранении здоровья работника, повышения производительности труда и экономики в целом, что обосновывает необходимость в совершенствовании охраны труда, посредством разнообразных инструментов, одним из которых является сравнительный аспект затрат на охрану труда предприятия, в частности, направленных на улучшение условий труда в анализируемом периоде.

В статье дается обоснование информационно-аналитического банка данных по учету и анализу затрат на охрану труда на основе применения математических методов, среди которых отметим методы сравнения, группировки и систематизации посредством сопоставления первичных данных по основным статьям расходов на охрану труда. Виды анализируемых расходов определены согласно нормам трудового законодательства Республики Казахстан. Цель исследования состоит в применении математических методов при разработке программного продукта по учету и анализу затрат на охрану труда.

**Ключевые слова:** математические методы, информационно-аналитический банк данных, учет и анализ затрат на охрану труда, базовые значения, программный продукт.

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