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# ASSESSMENT OF UNPROFITABILITY OF COMPULSORY EMPLOYEE ACCIDENT INSURANCE TARIFFS IN KAZAKHSTAN

**Abstract:** Compulsory insurance of employees against industrial accidents is an important social protection tool in Kazakhstan, but the current rates are insufficiently stable and do not cover the actual risks, which leads to financial imbalances among insurers and reduces the level of compensation for employees. The purpose of this study is to identify the reasons for the unprofitability of existing rates and to develop proposals for their modernization based on modern risk assessment methods. The study used actuarial calculations, including analysis of loss ratios, payments, and total expenses, as well as the construction of linear trends to forecast future losses. In addition, statistical modeling methods were used, including probability distributions and Markov chains, which made it possible to justify the introduction of a differentiated tariff system and a bonus-malus mechanism for enterprises depending on the level of industrial injuries. The results of the analysis showed an increase in the loss ratio from 11.87 percent in 2020 to 35.33 percent in the second quarter of 2024 and an increase in the aggregate loss ratio from 65.6 to 73.1 percent. The calculations determined a new base rate


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of 0.6842 percent compared to the current level of 0.59 percent, reflecting the need to revise insurance rates to ensure the financial stability of the system. A two-tier tariff model has been proposed, taking into account industry and occupational risks, as well as a bonus-malus mechanism that creates economic incentives for employers to invest in improving occupational safety and reducing the number of accidents. The practical significance of the study lies in the possibility of applying the results obtained by insurers, government agencies, and employers in forming a balanced and sustainable compulsory insurance system capable of simultaneously strengthening the financial stability of the insurance market and increasing the social protection of workers.

**Keywords:** compulsory accident insurance (CAI), actuarial calculations, loss ratio, base rate, bonus-malus, occupational risk, insurance rates, social protection.

## Introduction

The purpose of the study is to assess the unprofitability of the current system of compulsory insurance of employees against industrial accidents in Kazakhstan and to develop a scientifically sound model for its reform. Research objectives:

To analyze the structure of current tariffs and their impact on the financial stability of insurance companies and the level of social protection of employees.

To assess the dynamics of loss ratios and payments using actuarial methods and statistical modeling.

Develop a concept for a new tariff model, including a two-tier system that takes into account industry risks.

Justify the introduction of a bonus-malus mechanism as a tool to encourage employers to reduce occupational injuries.

Formulate practical recommendations for improving the compulsory insurance system.

The research hypothesis is that the introduction of a risk-oriented two-tier tariff model with a bonus-malus mechanism will significantly reduce the unprofitability of compulsory insurance and at the same time increase its social effectiveness, ensuring a balance of interests between the state, insurers, and employers.

## Literature review

Modern research in the field of compulsory accident insurance (CAI) emphasizes its key role in reducing occupational risks and ensuring social protection of workers. Various models and approaches have been developed globally to address the complexities of CAI, each with distinct characteristics, strengths, and weaknesses. A fundamental distinction lies between the Bismarckian (contribution-based) and Beveridgean (tax-financed) models of social security systems [1].

Bismarckian Model: Originating in Germany in the 1880s, this model is primarily funded by contributions from employers and employees, typically proportional to wages. Benefits are usually linked to past contributions, and the system often operates through autonomous, self-governing insurance institutions. Its strengths include a strong link between contributions and benefits, fostering a sense of ownership and responsibility among stakeholders. However, recent analysis shows that Bismarckian welfare states have undergone fundamental reforms over the last years, shifting from labor shedding strategies to more employment-friendly approaches. While the model traditionally faced challenges with higher labor costs, modern reforms have helped overcome the low employment situation that characterized these systems in earlier decades [2].

Beveridgean Model: Prevalent in countries like the UK and Scandinavian nations, this model is financed through general taxation, and benefits are provided universally based on need,

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rather than contributions. Strengths include broader coverage and a focus on social solidarity. However, it can be susceptible to political influence on funding levels and may not always provide strong incentives for individual risk reduction [3].

Beyond these broad classifications, specific mechanisms within CAI systems vary significantly. For instance, integrated workers' compensation programs that combine prevention, medical management, and adjudication have shown substantial success, with lost-time claims decreasing from 22.15 to 4.32 per 1000 employees over a 32-year period [4]. This demonstrates the importance of combining compensation instruments with proactive management of occupational risks, as also emphasized by Moore [5].

Regarding regulatory aspects, recent sustainable insurance strategies emphasize that state participation is crucial for financial sustainability, requiring a comprehensive approach to tackle evolving market challenges while balancing consumer protection with the financial sustainability of insurance providers. These strategies incorporate measures to ensure fair distribution of coverage through regulatory modernization and transparency requirements [6].

In the context of Kazakhstan, domestic studies and ILO reports [7] indicate significant shortcomings in the existing CAI system, such as limited coverage, underdeveloped preventive programs, and a lack of coordination between insurance and occupational health measures. Historical analyses of workplace accident insurance systems, such as Andersson and Eriksson's [8] study of early twentieth-century Swedish mutual health insurance societies, reveal that addressing differences in occupational accident risk and ensuring adequate coverage remain persistent challenges across various insurance frameworks. These issues resonate with global trends identified by Hassink et al. [9], who underscore the need for integrated participation from employers, regulatory authorities, and workers for effective CAI system functioning.

To provide a clearer comparative overview, Table 1 summarizes the key features, strengths, and weaknesses of different occupational accident insurance models and approaches identified in the literature.

Table 1. Comparative Analysis of Occupational Accident Insurance Models

| Feature/Model | Bismarckian (e.g., Germany) | Beveridgean (e.g., UK) | Risk-Oriented (Proposed) |
|---|---|---|---|
| Funding Source | Employer/Employee Contributions | General Taxation | Employer Contributions (Risk-adjusted) |
| Benefit Basis | Linked to Contributions | Universal, Based on Need | Risk-adjusted, Incentivizing Safety |
| Administration | Autonomous Institutions | State-run Systems | Hybrid (State Oversight, Private Implementation) |
| Key Strength | Strong link between contributions and benefits, stakeholder ownership | Broad coverage, social solidarity | Incentivizes risk reduction, accurate risk reflection |
| Key Weakness | Higher labor costs, potential exclusion | Political influence on funding, weaker individual incentives | Requires robust risk assessment and data infrastructure |
| Focus | Compensation, prevention through self-governance | Social protection, universal access | Prevention, compensation, economic incentives for safety |
| Incentives for Safety | Indirect (through self-governance) | General (public health initiatives) | Direct (bonus-malus system, tariff adjustments) |
| Flexibility | Moderate | Low | High (adaptable to industry-specific risks) |
| Data Dependency | Moderate | Low | High (for accurate risk assessment and tariff adjustment) |

Despite the accumulated achievements in theoretical and empirical understanding of this topic, a number of problems remain unresolved. In particular, many studies focus mainly on the compensatory aspect of insurance, while the integration of rehabilitation and preventive components remains insufficiently studied. Furthermore, existing models often lack the granularity to accurately reflect real-world sectoral risks, leading to financial imbalances for insurers and inadequate coverage for workers. There is a notable absence of comprehensive frameworks that effectively combine risk assessment with a dynamic tariff adjustment mechanism, especially within the specific socio-economic context of Kazakhstan. Previous research, while highlighting the importance of preventive measures, often fails to provide concrete, implementable models for incentivizing employers to improve working conditions through tariff adjustments. Additionally, the quantitative validation of proposed tariff models against actual loss data is frequently overlooked, limiting their practical applicability and scientific rigor. This study aims to overcome these gaps by developing a comprehensive conceptual model of reforming the CAI system in Kazakhstan, based on a synthesis of global approaches and taking into account local specificities, and by proposing a novel two-tier tariff system with a 'bonus-malus' mechanism that directly addresses the identified shortcomings.

**Methods and Materials**

This section presents the results of the revision of the parameters of the CAI system by substantiating the risk-oriented insurance model. To calculate the basic insurance tariff, which is the main parameter of the CAI system, an assessment of the combined loss-making capacity of the CAI portfolio was carried out, consisting of three main coefficients, i.e. the loss coefficient, the cost coefficient and the combined coefficient.

To calculate the loss Ratio, data was collected on insurance payments for all insured events of the life insurance company for 2020 – 2024 (II quarter) on the basis of an official request from the Agency of the Republic of Kazakhstan for Regulation and Development of the Financial Market, which is a state body in the field of state regulation, control and supervision of the financial market and financial organizations. The loss ratio is determined by the ratio of net Losses to Earned Premiums. At the same time, net losses include payments for declared losses, reserves for unresolved losses (RUL), reserves deferred to cover losses that have already occurred but have not yet been declared (PDCL) and reserves for declared but not settled losses (RDNSL), which, together with other reserves, form the statistical basis for assessing the combined loss ratio of the CAI [10] (see Appendix A).

The analysis showed that the loss ratio calculated taking into account reinsurance and excluding reinsurance has a tendency to grow, the loss rate of the CAI class increased from the level of 11.87% in 2020 to 35.33% in the second quarter of 2024, respectively. This fact indicates that reinsurance operations do not have a significant effect on reducing unprofitability, the coefficient of losses after reinsurance does not decrease (Figure 1).

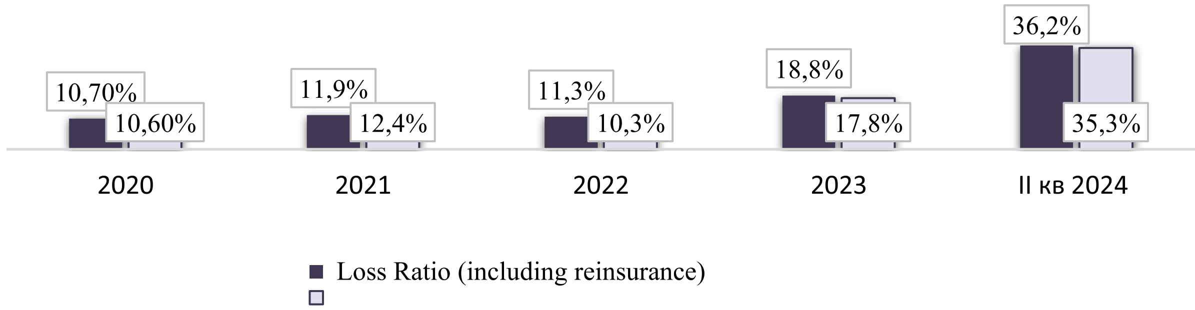


Figure 1. Loss Ratio of CAI

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During this study, combined losses were calculated in two stages. In the first stage, the share of CAI premiums in total premiums for all classes of life insurance was determined. Then, the total amount of administrative and acquisition expenses for all classes of life insurance was multiplied by the share of CAI premiums to determine the expenses related to this class of insurance. As a result, the amount of expenses obtained was used in the calculation of the CAI cost ratio.

The total amount of premiums for life insurance companies (LIC) in the insurance market of the Republic of Kazakhstan for 2023 amounted to 505,263,185 thousand tenge, of which 87,057,855 thousand tenge was accounted for by CAI , which is 17.23% of the total premiums for all classes LIC. For the first half of 2024, the total amount of premiums for all LIC companies amounted to 378,374,216 thousand tenge, and the amount of premiums for CAI was 68,479,758 thousand tenge, which is 18.03%. Thus, for further calculations, the average value for 2023 and 2024 was used, equal to 17.36%, which reflects the share of administrative, acquisition and other expenses related to the CAI insurance class.

Next, the CAI insurance payout ratio was evaluated in detailed breakdown by region and occupational risk classes, depending on the types of economic activity. Figure 2 shows the results of the assessment of the CAI insurance payout ratio in the regional aspect according to the average values for 2020 – 2024 (II quarter). Analysis of the data presented on the payout ratio revealed significant regional variability of this indicator.

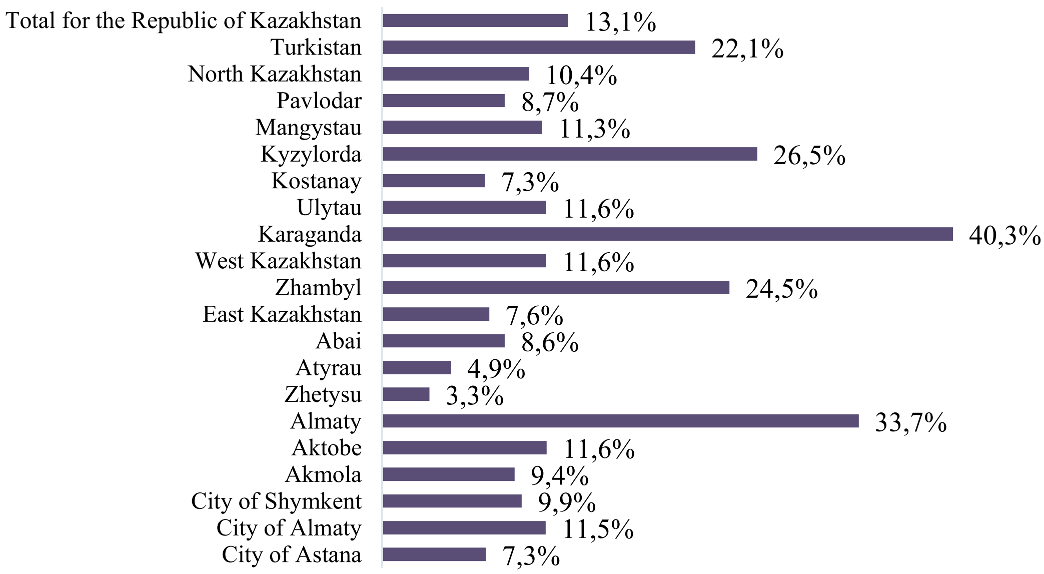


Figure 2. The payout ratio in the regional context

The highest levels were recorded in Karaganda (40.3%), Almaty (33.7%), and Kyzylorda (26.5%) regions, indicating significant insurance payouts compared to insurance premiums and pointing to a concentration of high-risk CAI portfolios. At the same time, the lowest payout ratios were observed in the Zhetysu (3.3%) and Atyrau (4.9%) regions, which is due to the low frequency of insurance claims and insufficient accounting for losses. Overall, the payout ratio for the country was 13.1%, but in global practice, the optimal level for this indicator ranges from 60% to 80%, indicating a balanced CAI system [11].

Also important for calculating the basic CAI tariff is the assessment of the CAI payout ratio in the context of professional risk class (ORC) by type of economic activity, which revealed significant variability in this indicator, the results of which are shown in Figure 3. The highest value is observed in 17 ORCS, where the payout ratio reached 59.5% (this ORC includes such activities as open-pit coal mining, production of cast iron, steel and ferroalloys, cement production, etc.)

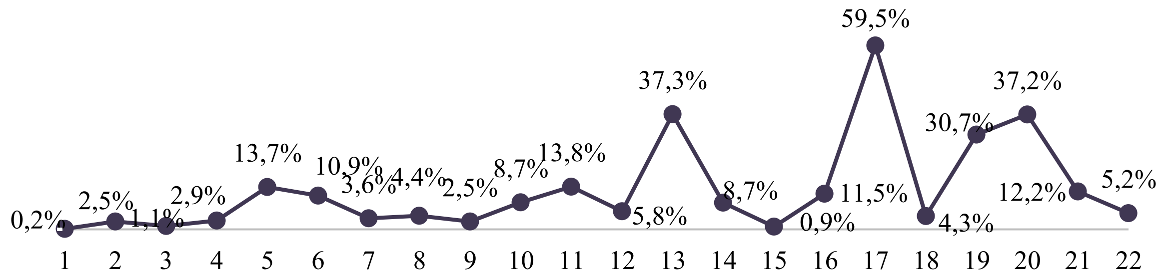


Figure 3. The coefficient of payments of CAI in the context of ORC by type of economic activity by average values for 2020 – 2024 (II quarter).

In the course of scientific work, it was revealed that most of the costs of LIC are acquisition costs (commissions of insurance agents and brokers) – about 37% of insurance revenue (Figure 4).

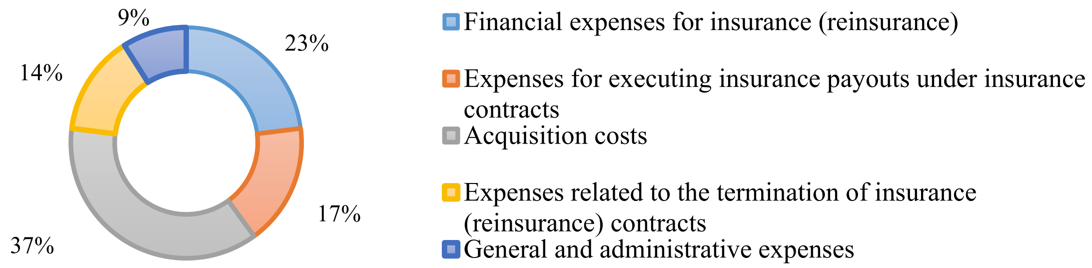


Figure 4. Structure of LIC expenditures in the average for 2020-2024 (II quarter)

The study showed an increase in the combined loss of CAI LIC from 65.6% in 2020 to 73.1% by the end of the second quarter of 2024, with a stable decrease in the cost ratio of CAI 1.5 times from 54.9% to 36.9% (Figure 5). This fact indicates a simultaneous increase in insurance payments and the cost of organizing and running a business, which negatively affects the financial stability of the CAI system.

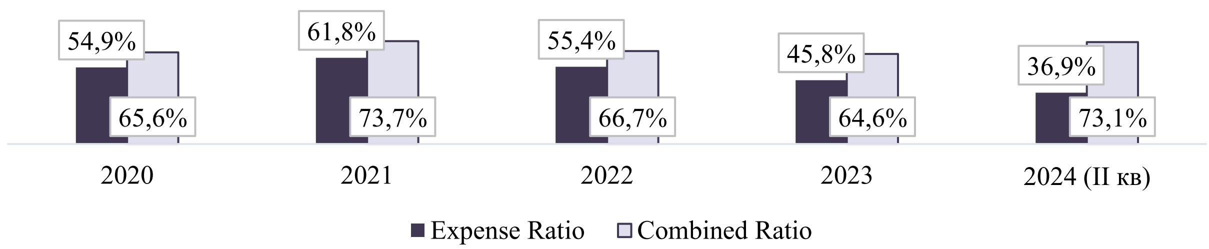


Figure 5. Cost ratio and combined loss ratio of CAI za 2020-2024 (II quarter).

During the implementation of the Program, the task was completed to revise the current CAI insurance tariff based on actuarial calculations of the new tariff rate, the methodological basis of which is the calculation of its basic components, shown in Figure 6 [12].

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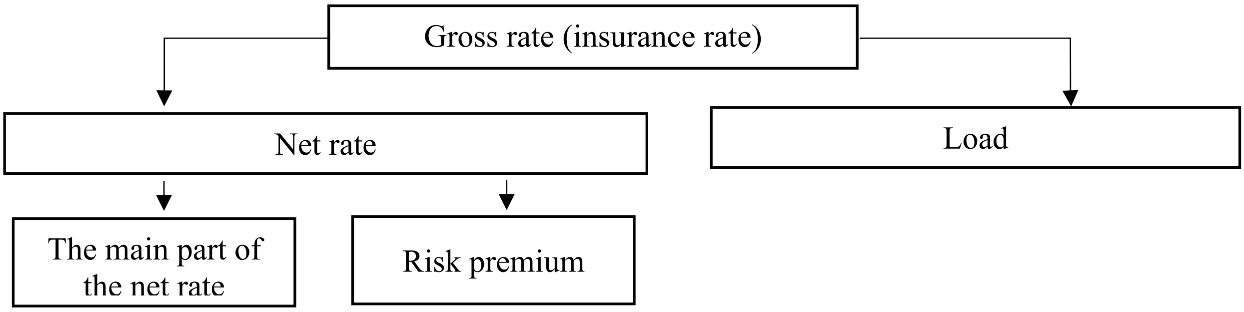


Figure 6. Components of the insurance tariff

Next, an assessment of the net rate and the risk premium was carried out, considering the condition under which the presence of a pronounced tendency to increase (decrease) the loss rate. The definition of the main part of the net rate as an average five-year loss leads to the establishment of a deliberately unprofitable (excessively profitable) tariff [13]. Therefore, the calculation is based on the construction of a linear trend (extrapolation) according to the following formula:

$$\overline{y} = a_0 + a_1 * t, \quad (1)$$

where,

$\bar{y}$ – loss-making of the insured amount (a function of $t$); $t$ – time in years (argument).

Next, linear trends from the system of equations $a_0$, $a_1$ are determined by the substitution method according to formula 2:

$$\sum_{i=1}^{5} y_i = n * a_0 + a_1 * \sum_{i=1}^{5} t_i$$
$$\sum_{i=1}^{5} (t_i * y_i) = a_0 * \sum_{i=1}^{5} t_i + a_1 * \sum_{i=1}^{5} t_i^2 \quad (2)$$

where,

$n$ – the number of years in the time series of loss indicators;

$y_i$ – the value of unprofitability in the first year;

$t_i$ – the number of the year to which the loss indicator corresponds $y_i$;

$a_0$, $a_1$ – linear trend parameters;

$i = 1...n$ – the numbers of the years of the time series of loss values.

Thus, a linear trend is obtained) $\bar{y}$ from a variable t Substituting the values sequentially into the found linear trend equation $t = 1, .., 5$, the theoretical (smoothed) values of loss-making as a percentage of the insured amount are determined according to formula 3.

$$y_1 = a_0 + a_1 * 1;$$
$$y_2 = a_0 + a_1 * 2;$$
$$y_3 = a_0 + a_1 * 3; \quad (3)$$
$$y_4 = a_0 + a_1 * 4;$$
$$y_5 = a_0 + a_1 * 5;$$

In this study, a linear trend extrapolation was applied as the baseline forecasting tool for estimating the future loss ratios and calculating the net tariff component. This approach provides a simple and transparent estimation method; however, it has clear limitations in capturing structural breaks, economic shocks, and non-linear dynamics in the insurance market. To address these challenges, future research will incorporate more advanced forecasting methods, including **time-series econometric models (ARIMA, GARCH) and machine learning approaches** (e.g., random forests, gradient boosting), which are widely used in actuarial science for modeling volatility and predicting claim frequencies. The integration of these methods will allow for **more accurate risk assessment**, **robust stress-testing under crisis scenarios**, and **improved actuarial pricing of CAI tariffs** in Kazakhstan.

According to the found linear trend, the unprofitability for the next year is extrapolated, $y_6 = a_0 + a_1 * 6$; The resulting loss for $t = 6$ is taken as the main part of the net rate.

At the next step, the risk premium is calculated, taking into account the deviation of the actual loss values in certain years from the theoretical (smoothed) values obtained for the calculation years for the calculation of the main part of the net rate according to the formula 14:

$$\delta = \alpha * y_\delta * V_\gamma \quad (4)$$

The risk premium $\delta$ is calculated as follows when there is a clear trend toward an increase (decrease) in losses:

The deviations of the actual loss-making values in individual years from the theoretical (smoothed) values obtained for the calculation of the main part of the net rate for these years are determined according to the formula 5:

$$(y_i - \bar{y}_i) \quad (5)$$

where,
$y_i$ – the actual loss rate for the I-th year;
$\bar{y}_i$ – the theoretical loss rate for the I-th year.
Then each of the obtained deviations is squared using formula 6:

$$(y_i - \bar{y}_i)^2 \quad (6)$$

where, $i = 1 \dots n$;

Table 2 shows the parameters for calculating the risk premium based on data on losses and insurance premiums of the CAI za 2020 – 2024 (II quarter).

Table 2. Parameters for calculating the risk premium

| Year | CAI losses | The insurance amount of the CAI | $y_i$ | $(\bar{y} - y_i)$ | $(\bar{y} - y_i)^2$ |
|---|---|---|---|---|---|
| 2020 | 7 988 466 | 6 254 852 650 | 0,1277% | 0,0487% | 0,000023731% |
| 2021 | 9 456 206 | 6 720 910 636 | 0,1407% | 0,0357% | 0,000012768% |
| 2022 | 10 410 466 | 8 584 515 983 | 0,1213% | 0,0552% | 0,000030426% |
| 2023 | 20 138 293 | 10 666 836 913 | 0,1888% | -0,0124% | 0,000001528% |
| 2024 (II кв) | 24 407 780 | 6 904 154 855 | 0,3535% | -0,1771% | 0,000313618% |

The calculation of the average loss ratio was performed using Formula 7, resulting in the following value:

$$\bar{y} = \frac{\sum_{i=1}^{5} y_i}{n} = 0,1764\% \quad (7)$$

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Next, the calculation of the quadratic deviation of the insured amount was performed using Formula 8, and its value is presented below:

$$\sigma_y = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{y}_i)^2}{n-1}} = 0{,}0816\% \quad (8)$$

In the course of actuarial calculations, the value of the risk premium was obtained equal to:

$$\delta = 2{,}33*0{,}0816\% = 0{,}1901\%$$

next, the value of the core component of the net rate was calculated using Formula 9:

$$T_n = \delta + \bar{y} = 0{,}1901\% + 0{,}1764\% = 0{,}3665\% \quad (9)$$

To reflect the amount of increase in future payments and risks, and risk premium of 30% of the net rate was introduced, then the final value of the net rate was calculated according to formula 10:

$$\text{The net rate is final} = \frac{T_n}{(1-\text{additional risk premium})} \quad (10)$$

Thus, the value of the final net bid is obtained $\frac{0{,}3665\%}{(100\%-30\%)} = 0{,}5236\%$.

Two methodological approaches were used for actuarial calculations of the gross rate, i.e., taking into account an increase in the amount of the load and by estimating the average gross tariff [14].

According to Formula 11, the gross rate value obtained using the first approach is:

$$T_б = \frac{T_n}{1-f} = \frac{0{,}5236\%}{100\%-50\%} = 1{,}0473\% \quad (11)$$

where $f$ – this is the total amount of the tariff load, this amount includes different types of expenses and the profit margin. The amount of the load is set at 50%.

As a result of calculating the gross rate for the first approach, its structure is obtained, which is shown in Figure 6.

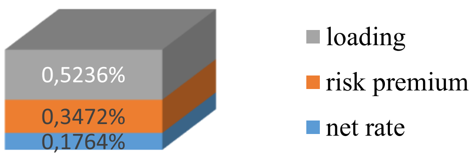


Figure 6. Gross rate structure for the first approach

Next, the average tariff was calculated using the formula 12 and its value was obtained:

$$T_б = \frac{T_н}{100\%-f} = \frac{0.1606\%}{100\%-50\%} = 0.3211\% \quad (12)$$

Based on the results of the calculations, the gross rate structure for the second approach is determined, which is illustrated in Figure 7.


Figure 7. Gross rate structure for the second approach

The study determined that as an estimate of the average basic tariff, it is necessary to take the average value of the results obtained for two approaches, which was 0.6842%, It is important to note that in the current CAI system, the average value of the insurance tariff is 0.59%. The calculation established the percentage of CAI insurance payments in the structure of the basic tariff, shown in Figure 8.

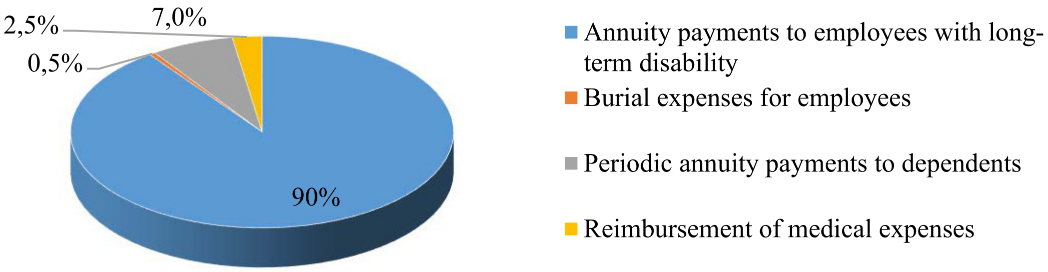


Figure 8. The structure of the basic tariff for insurance payments

To revise the main parameter of the CAI– the insurance tariff for ORC depending on the types of economic activity using the average base tariff obtained as a result of the calculation, the following conditions for adjusting payments were recommended:

I. Payments to victims will be lifelong (with indefinite Loss of Professional Work Capacity (LPTD));
II. Payments to victims with a LPTD of 5-29%;
III. In the event of an insured event, an insurance payment shall be made to the insured party to cover the costs of preventive measures in an amount not exceeding 6% of the insurance premium, calculated on the date of expiry of the CAI contract, and for the implementation of rehabilitation measures in an amount not exceeding 6% of the insurance premium in accordance with the approved Rules for reimbursement of costs for preventive measures and/or rehabilitation measures [15], calculated on the date of expiry of the insurance contract;
IV. Reimbursement of sanatorium treatment in an amount not exceeding 100 Monthly Calculation Index (MCI) (369,200 tenge with an MCI of 3692 tenge in 2024), also in the absence of insurance cases during the last 3 years (previously it was 5 years) preceding the date of conclusion of the CAI agreement, a discount of no more than 10% is allowed (previously, the discount reached up to 70% in the absence of insurance claims from the organization).

At the same time, several parameters are given to apply the above conditions:

- life expectancy as of 2024 for women is 79.06 years, for men – 70.99 years;
- the average increase in the term of annuity payments is 11% for men and 29% for women in case of transition to lifetime payments;
- losses for employees injured with LPTD 5-29% account for about 25% of the total value of CAI losses.

During the implementation of the research task, the need to adjust tariffs that will cover current losses and the proposed terms of insurance payments was identified, while the expected level of increase in losses will be about 40-50%. Consequently, future insurance rates will be increased by 20%, while the remaining part of the losses will be covered by canceling the commission fee for this class of insurance.

The calculation is based on a system of basic insurance rates set according to professional risk classes depending on the types of economic activity of the insured parties. These values form the first component of the insurance rate and are presented in Table 3.

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Table 3. Basic insurance rates by professional risk class depending on the type of economic activity

| Classification of occupational risks | Insurance tariffs | Classification of occupational risks | Insurance tariffs |
|---|---|---|---|
| 1 | 0,15% | 12 | 0,95% |
| 2 | 0,36% | 13 | 1,61% |
| 3 | 0,60% | 14 | 1,94% |
| 4 | 0,61% | 15 | 1,41% |
| 5 | 0,65% | 16 | 1,46% |
| 6 | 0,66% | 17 | 1,51% |
| 7 | 0,68% | 18 | 3,04% |
| 8 | 0,81% | 19 | 2,19% |
| 9 | 0,70% | 20 | 2,56% |
| 10 | 1,10% | 21 | 3,18% |
| 11 | 0,94% | 22 | 3,70% |

The tariff values between risk classes do not change according to a strictly ascending function with an algorithm that provides for an increase in the tariff as the professional risk class increases.

The tariff value in each professional risk class depends not only on the risk class value, but also on several other factors, such as historical losses in a given professional risk class.

The procedure for assigning types of economic activity to professional risk classes is determined by the authorized body. If the insured carries out several types of economic activity, they are assigned to the professional risk class corresponding to their main type of activity.

If the insured carries out activities under a contract for the provision of personnel services as the sending party, they shall be classified under the type of economic activity that has a professional risk class not lower than the professional risk class of the receiving party or the highest professional risk class of the receiving party, in accordance with the contracts for the provision of personnel services concluded by them.

If the insured carries out several types of economic activities that are evenly distributed in the total volume of production, they shall be classified under the type of economic activity that corresponds to the higher professional risk class. If the insured has a branch (branches) that carries out activities different from those of the insured, it shall be classified according to the type of economic activity that corresponds to its professional risk class.

In this case, the branch (branches) must have confirmation of the type of economic activity it (they) carries out.

Insurance rates depending on the degree of IAOR (second component) are proposed to be set in accordance with Table 4.

Table 4. Insurance rates depending on the degree of occupational risk (second component)

| ORC | 1 degree | 2nd degree | 2nd degree | 4th degree | 5th degree |
|---|---|---|---|---|---|
| for grades 1-22 | $k_1$ | basic insurance rate | $k_2$ | $k_3$ | $k_4$ |

where:

$k_1$ – reduction coefficient to the insurance tariff, which is applied to the policyholder in the case of IAOR of the 1st degree.

$k_{2\text{-}4}$ – loading coefficient to the insurance tariff, which is applied to the policyholder in the case of IAOR of the 3rd-5th degree.

The insurance rate for an insured person who, based on the results of an integrated assessment of occupational risk, has been assigned a 1st degree of IAOR (acceptable risk, allowing for safe working conditions and the absence of occupational injuries and diseases) is determined by multiplying the insurance rate for the corresponding OR class (1-22) by the correction coefficient $k_1$. In this case, a OR level of 1 is established. The insurance rate for an insured person who, based on the results of the IAOR, has been assigned a level of 2 is determined on the basis of the established insurance rates. The insurance rate for an insured person who has been assigned a OR level of 3 to 5 based on the results of the occupational risk assessment is determined by multiplying the insurance rate for the corresponding OR class (1–22) by the corresponding coefficients $k_{2-4}$.

Based on the experience of other countries in determining risk adjustment factors and underwriting recommendations for adjusting rates based on risk factors, which were outlined in the previous sections, it is proposed that the $k_1$-$k_4$ factors be set as follows:

$k_1$ is proposed to be equal to 10%, $k_2$=25%, $k_3$=50%, $k_4$=100%.

Next, we obtain a table with tariff values broken down by professional risk classes. Table 5 presents a matrix model for setting a two-component insurance tariff.

Table 5. Matrix model for establishing a two-component insurance tariff

| **Classification of occupational risks by type of economic activity – first component** | **Degree of integral professional risk (based on the professional risk assessment procedure) – component 2** | | | | |
|---|---|---|---|---|---|
| | 1 degree $k_{1\ (10\%)}$ | 2nd degree basic insurance rate | 2nd degree $k_{2(25\%)}$ | 4th degree $k_{3(50\%)}$ | 5th degree $k_{4(100\%)}$ |
| 1 | 0,14% | 0,15% | 0,19% | 0,23% | 0,30% |
| 2 | 0,33% | 0,36% | 0,45% | 0,54% | 0,73% |
| 3 | 0,54% | 0,60% | 0,75% | 0,90% | 1,20% |
| 4 | 0,55% | 0,61% | 0,77% | 0,92% | 1,23% |
| 5 | 0,59% | 0,65% | 0,81% | 0,98% | 1,30% |
| 6 | 0,60% | 0,66% | 0,83% | 0,99% | 1,33% |
| 7 | 0,61% | 0,68% | 0,84% | 1,01% | 1,35% |
| 8 | 0,73% | 0,81% | 1,02% | 1,22% | 1,63% |
| 9 | 0,63% | 0,70% | 0,88% | 1,05% | 1,40% |
| 10 | 0,99% | 1,10% | 1,38% | 1,65% | 2,20% |
| 11 | 0,84% | 0,94% | 1,17% | 1,41% | 1,88% |
| 12 | 0,86% | 0,95% | 1,19% | 1,43% | 1,90% |
| 13 | 1,45% | 1,61% | 2,02% | 2,42% | 3,23% |
| 14 | 1,74% | 1,94% | 2,42% | 2,91% | 3,88% |
| 15 | 1,27% | 1,41% | 1,77% | 2,12% | 2,83% |
| 16 | 1,32% | 1,46% | 1,83% | 2,19% | 2,93% |
| 17 | 1,36% | 1,51% | 1,89% | 2,27% | 3,03% |
| 18 | 2,73% | 3,04% | 3,80% | 4,56% | 6,08% |
| 19 | 1,97% | 2,19% | 2,73% | 3,28% | 4,38% |
| 20 | 2,31% | 2,56% | 3,20% | 3,84% | 5,13% |
| 21 | 2,86% | 3,18% | 3,97% | 4,76% | 6,35% |
| 22 | 3,33% | 3,70% | 4,63% | 5,55% | 7,40% |

This approach is fully consistent with international standards for underwriting and actuarial practices, which use risk adjustment factors to adjust base rates for different categories of policyholder risk.

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In order to provide economic incentives for improving working conditions and occupational safety through the transformation of the CAI system, it is advisable to apply a risk-oriented insurance model, i.e., a two-tier insurance rate that takes into account the type of economic activity, the degree and class of occupational risk. The main idea of this model is to incentivize entities with low insurance losses by offering discounts on insurance rates (bonuses), as well as to economically penalize entities with high losses by increasing insurance premiums (maluses). This differentiation makes it possible to simultaneously stimulate employers' investment in occupational safety measures and increase the responsibility of enterprises with elevated risk indicators. This section describes in detail the proposed Methodology for establishing discounts on insurance rates, which takes into account the frequency of accidents at work and allows employers to allocate the savings to improving occupational safety. The empirical basis for the study is data from the National Statistics Bureau of the Agency for Strategic Planning and Reforms (NSB). The sample includes data for 2023 on enterprises where industrial accidents were recorded. The initial data set included only enterprises with at least 10 employees, resulting in a final sample of 210,138 enterprises, of which 33,122 had at least one recorded accident. It is important to note that the absolute number of accidents correlates directly with the scale of the business, so the frequency indicator is used for analysis rather than the absolute number of incidents. To formalize this approach, enterprises are grouped according to the frequency value (k), which is calculated using the following formula:

$$\text{Frequency of accidents} \frac{\text{Number of accidents}}{\text{Number of insurers}} \times 100 \tag{13}$$

Enterprises are then classified into enterprise classes. The coding of enterprise groups is illustrated in Table 6.

Table 6. Coding of enterprise classes

| Group | Interval |
|---|---|
| 0 | Нет |
| 1 | 0 > A ⩽ 10 |
| 2 | 10 < FA ⩽ 20 |
| 3 | 20 < FA ⩽ 30 |
| 4 | 30 < FA ⩽ 40 |
| 5 | 40 < FA ⩽ 50 |
| 6 | 50 < FA |

To calculate the new premium rates, it is necessary to know the distribution of enterprise groups. The distribution of enterprises by group according to statistical data for 2023 is shown in Table 7.

Table 7. Distribution of enterprises by class k

| k | Number of enterprises |
|---|---|
| 0 | 177.016 |
| 1 | 30.867 |
| 2 | 1.868 |
| 3 | 279 |
| 4 | 83 |
| 5 | 17 |
| 6 | 8 |

The null hypothesis that “the data are taken from a Poisson distribution” for the data in Table 2 is tested using the Kolmogorov–Smirnov test. The test shows that the groups are calculated based on a Poisson distribution with $\lambda = 0.1709$ ($p>0.05$). The mean and variance of the data in Table 2 are $X = 0.1709$ and 2 $S = 0.1749$, respectively. Thus, $\tau\hat{}$ and $A\hat{}$ are calculated as:

$$\tau = \frac{0.1709}{0.1749-0.1709} = 43.725 \quad \text{and} \quad a = \frac{(0.1709)^2}{0.1749-0.1709} = 7.473 \tag{14}$$

To calculate the premium coefficients, it is necessary to determine the premium coefficient for the initial group. All enterprises pay insurance premiums at the base rate depending on the occupational risk class (from 1 to 22) in accordance with the existing system. Accordingly, the base insurance rate for each occupational risk class will range from 0.12% to 2.96%.

Discounts and surcharges on insurance rates at enterprises start at a certain initial class, and their classes vary depending on the number of accidents in a given year. In discounts and surcharges on insurance rates, as the number of accidents increases, the premium coefficients increase; otherwise, they decrease.

The next step after determining the number of discount/surcharge classes for the insurance rate is to decide how the transitions between classes should be. The rule for transitions between classes is defined in this study as follows:

1. If the accident rate of a given enterprise is 0, its class is reduced by one level.
2. If the accident rate of a given enterprise increases, its class increases accordingly.

For example, if the accident rate of a class 6 enterprise is 2, its new class is 8 (6+2). On the other hand, if the accident rate of a class 6 enterprise is 0, then its new class is 5 (6-1). However, since there are only 22 classes in total, the highest class is 22. Table 3 shows the rule for transitions between classes.

Table 8. Transition matrix between classes

| **Classification of occupational risks** | **Accident rates** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 4 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 5 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 6 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 7 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 8 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 9 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 10 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 11 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 12 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 13 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 14 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 15 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 16 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 17 | 17 | 18 | 19 | 20 | 21 | 22 | 22 |
| 18 | 18 | 19 | 20 | 21 | 22 | 22 | 22 |
| 19 | 19 | 20 | 21 | 22 | 22 | 22 | 22 |
| 20 | 20 | 21 | 22 | 22 | 22 | 22 | 22 |
| 21 | 21 | 22 | 22 | 22 | 22 | 22 | 22 |
| 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |

* The figures in Table 8 show which class the business will fall into next year.

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If the distribution of accident rates is Poissonian, then the transition matrix is calculated as shown in Figure 9.

$$P = \begin{pmatrix}
0.84291 & 0.14405 & 0.01231 & 0.00070 & 0.00003 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.84291 & 0 & 0.14405 & 0.01231 & 0.00070 & 0.00003 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.84291 & 0 & 0.14405 & 0.01231 & 0.00070 & 0.00003 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0.84291 & 0 & 0.14405 & 0.01231 & 0.0007 & 0.00003 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.84291 & 0 & 0.14405 & 0.01231 & 0.00070 & 0.00003 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.84291 & 0 & 0.14405 & 0.01231 & 0.00070 & 0.00003 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0.84291 & 0 & 0.14405 & 0.01231 & 0.00070 & 0.00003 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.84291 & 0 & 0.14405 & 0.01231 & 0.00070 & 0.00003 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.84291 & 0 & 0.14405 & 0.01231 & 0.00073 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.84291 & 0 & 0.14405 & 0.01304 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.84291 & 0 & 0.15709 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.84291 & 0.15709
\end{pmatrix}$$

Figure 9. Transition matrix

Here, let time t = 0 be equal to 2023. The value 0.84291 at the intersection of row 1 and column 1 represents the probability of remaining in the same class for a given business during the transition from 2024 to 2030, and it is calculated as follows:

$$P\{Y_1 = 1 | Y_0 = 1\} = f\ (0|\lambda) = P(X = 0|\lambda) = \frac{e^{-\lambda}\lambda^0}{0!} = 0.84291 \quad (15)$$

Similarly, the value 0.14405 at the intersection of row 1 and column 2 represents the probability of transition from class 1 to class 2 for a given business during the transition from 2023 to 2024. The matrix is used to calculate the probabilities of transitions between classes by year, which can be used to estimate the amount of insurance premiums until the system reaches a steady state.

Discounts/surcharges on insurance rates are a system that determines premium rates, taking into account the number of accidents at enterprises. Fatal accidents at work that have occurred in recent months in mines due to inadequate safety measures have paved the way for the need to introduce a system based on discounts/surcharges to the insurance rate to improve occupational safety measures.

**Results and Discussion**

To encourage improvements in working conditions and occupational safety within the modernization of the CAI system, it is proposed to adopt a risk-based insurance model. This approach relies on a differentiated tariff structure that takes into account the nature of the enterprise's activity, as well as the level and category of occupational risk.

The core idea is to provide incentives for organizations with low insurance loss rates by granting them reduced premiums, while applying higher rates to enterprises with significant losses as a financial deterrent. In addition, the methodology for determining the final tariff may include adjustment factors (discounts or surcharges) that reflect the actual risk level at a specific workplace: premiums are increased when risks are high and lowered when risks are minimal.

In this regard, work was carried out on the scientific justification of the introduction of a two-tier insurance tariff according to the principles of the bonus-malus model [16]. As a result, a tariff formation system is proposed, consisting of the first level of the insurance tariff, i.e. the basic insurance tariff and the second level - lowering/increasing coefficients from the degree of occupational risk according to the results of the integrated assessment of occupational risk (IAOR) (Table 4).

Table 4. Two-tier insurance rate

| ORC | 1 degree | 2nd degree | 2nd degree | 4th degree | 5th degree |
|---|---|---|---|---|---|
| for grades 1-22 | $k_1$ | basic insurance rate | k2 | $k_3$ | $k_4$ |

where:

$k_1$ – reduction coefficient to the insurance tariff, which is applied to the policyholder in the case of IAOR of the 1st degree.

$k_{2-4}$ – loading coefficient to the insurance tariff, which is applied to the policyholder in the case of IAOR of the 3rd-5th degree.

Based on the experience of other countries in determining corrective risk coefficients and underwriting recommendations for adjusting tariffs for risk factors, the coefficients k1–k4 are proposed to be set as follows:

$$k_1 = 10\%, k_2 = 25\% , k_3 = 50\%, k_4 = 100\%$$

In the system of discounts to the insurance tariff, the insurance premiums that policyholders must pay are reduced as an incentive if they reduce the number of accidents, thereby increasing the volume of investments in labor protection by reducing the amount of insurance premiums. On the one hand, if an enterprise reduces the number of accidents, then for it this system means a financial incentive tool. The fact that businesses are making efforts to reduce the number of accidents to take advantage of such incentives helps to reduce costs, which are funded by CAI insurance funds. Discounts should be reasonably dependent on the retrospective data on employers' accidents, considering their size, claims or claims from affected employees and their volume, etc.

In this regard, as part of the scientific research, a methodology for establishing discounts to the insurance tariff was developed, allowing employers to increase investments in occupational safety. This methodology describes the mechanism for granting discounts to the insurance tariff and the procedure for their calculation.

In calculating the discounts, statistical analysis methods were employed. The modeling approach involved analyzing the distribution of work-related accidents and estimating expected insurance premiums based on claim frequency patterns [17]. The Poisson distribution was applied to model the number of accidents, representing a fundamental approach in actuarial practice for assessing claim frequency in workers' compensation insurance. This probabilistic model assumes that accidents occur randomly and independently over time, with the probability of a specific number of accidents within a given period determined by the average accident rate. Furthermore, Markov chain models [18] were utilized to represent transitions between different ORC, enabling a dynamic assessment of how employers' safety improvements influence their risk classification over time.

In the course of this research, the legislative norm «accounting for employee guilt» was analyzed when determining the amount of monthly insurance payments, which was in effect until 2023, but because of improving the CAI system initiated by MLSPP RK as part of strengthening social protection for workers employed in harmful and dangerous working conditions, they were excluded. It should be noted that in accordance with the principle of no fault (theory of social compromise), employers and employees agree to a compromise in which employers are relieved of individual obligations to pay compensation and court cases for damages for indus-

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trial injuries or diseases, and employees waive the right to sue their employer in the event of accidents, but they are automatically entitled to benefits under the compensation system [19].

During scientific research, guilt-free liability within the framework of social insurance (EISS) has been defined as an effective tool in terms of time and money than the judicial system, which focuses on who is to blame for OI (theory of least social costs).

Thus, as a result of the revision of the parameters of the CAI system by justifying the risk-oriented insurance model of a two-tier insurance tariff, taking into account the class by type of economic activity and the degree of IORA, incentive measures will be created for the employer to improve working conditions and reduce occupational risks, it will be possible to reduce insurance costs and invest the released funds in improving working conditions and social programs protection of employees.

**Conclusion**

In the context of a profound transformation of the socio-economic institutions of the Republic of Kazakhstan, the modernization of the compulsory accident insurance system (CAI) acquires strategic significance. The implementation of a risk-based approach, the introduction of a two-tier tariff model, and the application of the bonus-malus mechanism reflect a commitment to more flexible and equitable regulation aimed at establishing a sustainable insurance environment that balances the interests of employees, employers, and insurers. However, amid the growing digitalization of the economy, there arises an objective need to integrate new technological solutions capable of fundamentally enhancing the efficiency and transparency of the CAI.

One of the most promising development directions for the system is the adoption of blockchain technologies, which possess a range of unique characteristics aligned with the principles of integrity, accountability, and sustainable growth. The decentralized architecture of blockchain enables the creation of an immutable register of insurance cases, thereby eliminating the possibility of data falsification, manipulation, or retrospective alterations. This ensures a high level of trust among system participants, reduces the risk of conflicts, and enhances the legitimacy of decision-making. At a time when public trust in social protection institutions is increasingly critical, such solutions contribute to the strengthening of the institutional environment as a whole.

Particular attention should be paid to the potential of smart contracts, which can automate key processes within the CAI – from recording the occurrence of an insured event to the execution of payments. For instance, with the integration of the system into external data sources such as medical facility databases or IoT devices monitoring working conditions, payments could be triggered automatically once predefined conditions are met. This minimizes bureaucratic barriers, reduces the administrative burden, and increases the speed of insurance support delivery to affected workers. Simultaneously, it lowers the likelihood of subjective decisions and corruption risks.

The implementation of blockchain solutions also opens new opportunities in the field of actuarial calculations and risk analysis. Modern platforms make it possible to aggregate and process data from various enterprises and sectors in real time, which ensures more accurate risk segmentation, timely tariff updates, and improved financial sustainability of the entire system. Thus, the digitalization of the insurance model using distributed ledgers and big data analytics provides a foundation for building a dynamic and adaptive tariff policy.

From a theoretical standpoint, the proposed CAI development model demonstrates a successful synthesis of economic, social, and technological components that collectively enhance the effectiveness of the insurance mechanism. The use of blockchain not only helps achieve internal system goals – such as cost reduction, fraud prevention, and improved risk management – but also integrates CAI into the broader context of sustainable development. In particular, this direction fully aligns with Sustainable Development Goal 8 (SDG 8), which advocates for the promotion of decent work and sustainable economic growth [20].

Nevertheless, the successful implementation of this model will require interdisciplinary and institutional cooperation. At the regulatory level, it is necessary to develop and adopt legal acts that legitimize the use of blockchain technologies in the field of compulsory insurance. From a technical perspective, the creation of a scalable digital infrastructure compatible with existing accounting and control systems will be essential. Furthermore, the training of qualified personnel and the development of a digital culture among public authorities, insurers, and business entities play a crucial role.

It is also important to take into account the challenges associated with personal data protection, cybersecurity, and the need to ensure interoperability between different digital platforms. These aspects require particular attention in the design and deployment of blockchain solutions, especially given the public nature of the CAI.

Taken together, the proposed measures lay the foundation for a new paradigm of social protection – one that is inclusive, transparent, automated, and financially sustainable. The integration of risk-based approaches with the technological potential of blockchain opens a pathway for Kazakhstan to build a "smart" compulsory insurance system aligned with leading international practices and focused on delivering long-term social and economic outcomes.

This approach not only responds to the challenges of the digital age but also reinforces Kazakhstan's position as a state capable of integrating innovation into key mechanisms of social security, thereby ensuring sustainability, fairness, and trust in the relationship between the state, business, and society.

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