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МЕТОДИКА ОЦІНЮВАННЯ ЕКОНОМІЧНОЇ ЕФЕКТИВНОСТІ ЗАХОДІВ З ПРОФІЛАКТИКИ ВИРОБНИЧОГО ТРАВМАТИЗМУ З УРАХУВАННЯМ РИЗИКО-ОРІЄНТОВАНОГО ПІДХОДУ
EVALUATION PROCEDURE FOR ECONOMIC EFFICIENCY OFOCCUPATIONAL INJURIES PREVENTIVE MEASURES WITH RISK-BASED APPROACH

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Анотація. Запропонована методика визначення економічної ефективності заходів з профілактики виробничого травматизму, що базується на класичному підході до економічних розрахунків та на показниках "ціни ризику".

Ключові слова: виробничий травматизм,ризик, економічна ефективність.

Abstract. Proposed methodology on the classic approach to economic calculations and "risk price" indicators, a procedure for determining the economic effectiveness of occupational injuries preventive measures was designed.

Key words: occupational injuries, risk, economic calculations.

Introduction

By its nature the quantitative assessment of injury levels in the form of risk indicators, frequency coefficients, severity and fatality does not permit to get a generalized quantitative assessment of occupational injuries. Moreover, these indicators do not allow linking them to cost indicators thus constraining the use of economic studies of preventive measures, so the aim of the unit is to develop an algorithm of quantitative assessment of occupational injury risks considering cost indicators and to obtain generalized assessments, suitable for economically justified decisions on prevention of occupational injuries.

For most companies in today's manufacturing the funding of occupational injuries prevention is done by the allocation of a certain amount of funds for these purposes ("not less than 0.5 percent of the amount of sales", the Law of Ukraine "On Labor Protection"). Another way to finance the prevention of occupational injuries is the allocation of such an amount that would ultimately ensure all the prevention needs. In both cases, it is preferably to distribute the amount of funds allocated to prevention among preventive measures so as to obtain the maximum result (effect). Financing health and safety at an enterprise should mainly result in reduced levels of occupational injuries or minimized risks of accidents. Therefore, with limited amounts of funding of occupational injuries prevention it is necessary to achieve maximum risk reduction.

It is known that in regulations of Ukraine [1], risk in the labor safety is defined

as a probability of causing damage considering its severity [5, 6, 7, 8, 9] or as a combination of probability and consequences (effects) of a specific hazardous event.

To establish conditions under which the maximum impact can be achieved, while assessing risk and identifying options for its preventive measures, one should apply procedure of economic justification of such measures [10]. This procedure is based on the calculations of economic efficiency or, as is a norm in industrialized countries, on the "expenses/income" ratio.

The purpose of the work is to develop an evaluation procedure of economic efficiency of operational injuries preventive measures.

Materials and Methods

Methods of system analysis (for the formulation of theoretical and application-oriented generalizations about the nature of occupational injuries, for interpretation of the results of studies performed by other methods), correlation, component and regression analysis and probability theory methods were used during the research.

The validity and reliability of the obtained scientific statements, conclusions and recommendations were reached using scientifically based methods proven in similar studies in other areas of human activity, comparing research results with data of investigations of industrial accidents and the results of known researches by domestic and foreign scholars and experts.

Discussion Results

In scientific publications [2, 3, 4, 11], risk is often defined as a combination of two components: the probability of an unwanted event (an accident, an injury or an occupational disease) and the extent of its consequences. Therefore, the risk of occupational injury in general can be defined by the following Formula:

$$R = A(I) \times S(L) \quad (1),$$

Where: $A(I)$ is a probability of employee's occupational injury,

and $S(L)$ is injury's severity or extent of losses.

Definition of the first component of risk $A(I)$ is based on statistical data or on usage of theoretical and computational methods. It should be borne in mind that the statistical information on injuries in Ukraine is formed for its two varieties: for fatal injuries and for the total number of accidents, including fatal injuries. Accordingly, the first component of Formula (1), a probability of an occupational injury, can have two meanings – for fatal injuries and for injuries in general or for injuries without fatalities. It is extremely difficult to combine these two values into a single one.

Evaluation of a fatal accident using the number of the lost man-days (defined with the help of various assumptions and subjective, ill-grounded conclusions) also does not permit to compare the received estimates with the indicators of the accidents without fatalities. We believe, that for such a combination Formula (1) should consider the indicators of the probability for the two kinds of accidents consequences: for fatal accidents $A(I_f)$and for accidents without fatalities $A(I_{wf})$, in which case Formula (1) takes the following form:

$$R_{total} = A(I_f) \times S(L_f) + A(I_{wf}) \times S(L_{wf}) \quad (2),$$

Where: R_{total} is the total risk of injury, and $S(L_f)$ and $S(L_{wf})$ are severity or extent of losses due to fatal accidents and accidents without fatalities respectively.

The second component of risk – severity or extent of losses due to accidents –

can be defined in monetary terms. In this case, both products of Formula (2) will have the same dimension and content, providing accountability of the severity of injury consequences in the indicator R_{total} of the cumulative injury risk. Two questions arise when choosing an indicator to characterize $S(L)$:firstly, it is necessary to decide what parameters should measure this indicator exactly – enterprise's losses for a certain period of time, losses due to an accident or losses attributable to a probability of an accident, as proposed in [12].

Since the probability of an accident (the first component of risk) is a relative dimensionless parameter characterizing the frequency of adverse event of injury, it is logical to assume that the second component of risk is the severity, measured in monetary units with a focus on probability or frequency. Only in this case Formula (2) can combine frequency and cost characteristics of fatal injuries and injuries without fatalities.

To obtain the cost value of accident's probability or frequency we shall use an assertion set forth in [17] that with the relatively small values of risk, which are characteristic for occupational injuries, a relationship between the losses due to injury $S(L)$and the probability of injury $A(I)$ can be considered linear:

$$S(L) = \alpha \times A(I) \quad (3),$$

Where: α is a coefficient of proportionality, known as the risk price.

To determine the risk price it is necessary to know the magnitude of all the losses from occupational injuries$\sum_{i=1}^{n} S(L)$or a part thereof, which is of interest for a researcher, as well as values of the parameter or parameters of the probability of injury $A(I)$.

Based on Formula (3), the risk price α can be calculated by the following formula:

$$\alpha = \sum_{i=1}^{n} S(L)/A(I) \quad (4)$$

Considering Formula (4), Formula (1) takes the following form:

$$R_{total} = \alpha_f \times A(I_f) + \alpha_{wf} \times A(I_{wf}) \quad (5)$$

To simplify Formula (5) let's use frequency coefficients, the usual indicators in traditional injury analysis procedure:

$k_{fr} = K_{total}/N \times 1000$ – overall coefficient of injuries frequency;

$k_f = K_f/N \times 1000$ – coefficient of fatal injuries frequency;

$k_{wf} = k_{fr} - k_f$ – coefficient of frequency of injuries without fatalities; where

K_{total} is the total number of occupationally injured; K_f is the number of fatally injured; and N is the number of employees in the enterprise.

Subsequently Formula (5) takes the following form:

$$R_{total} = 0.001 \times [\alpha_f \times S(L_f) + \alpha_{wf} \times S(L_{wf})] \quad (6)$$

Thus, the algorithm can be used to determine the total individual risk of occupational injury considering its severity, measured in cost indicators. The advantages of this approach of injury risk evaluation are the following: for the first time frequency indicators of fatal injuries and injuries without fatalities are brought to the same dimension, allowing obtaining a single composite risk indicator. The use of the indicator in the practice of occupational injury risk assessment to justify preventive measures for its reduction or neutralization will permit to make more targeted and efficient decisions. Further research aimed at detailing the components

of the proposed algorithm by singling out and considering accidents leading to disabilities as well as specific manufacturing processes used in an enterprise is promising.

Using Formula (5) and Formula (6), it is necessary to consider the following: a sufficiently well-established national system for recording and summarizing statistical information on occupational injuries is in place to determine the actual or forecasted values of frequency or probability of (the risk of) fatal accidents and accidents without fatalities. However, currently no information is available on the magnitude of losses from occupational injuries either with statistical sources, the government or companies. There is information about some components of the losses (insurance payments to victims, some of the most tangible and obvious losses of companies, etc.), but as of now there is no information to provide the full picture of all the losses to determine $\sum_{i=1}^{n} S(L)_i$.

Accepted that the amount of losses from occupational injuries (fatal and without fatalities) consists of two major groups: insurance claims to the victims and losses of an enterprise that are not subject to compulsory insurance (other losses caused by occupational injuries are not included). It is a characteristic feature of insurance claims to the victims that they are made within the legislation limits (cost indicators of compensation for damage to the victims are stipulated by law) by virtue of companies' premiums, set depending on the class of professional risk established for an enterprise.

Since insurance against occupational accidents in Ukraine is provided by a private non-profit organization, it is advisable to consider all the expenses of the organization, including expenses on its maintenance and payments to victims in the past, when defining insurance claims to the victims. Therefore, when determining the risk price of insurance claims to the victims it is necessary to consider all the expenses of the insurance system. Information about these expenses is contained in the annual performance reports of the Social Insurance Fund from Occupational Accidents and Diseases of Ukraine [14]. Allocations per each victim for the period from 2012 to 2014 and the occupational injury risk price are defined according to these reports (table 1).

Table 1

Expenses of the Fund per Victim of an Occupational Accident for Years 2012-2014

Year	Expenses of the Fund per Victim, 1 UAH/1 Victim		Injury Risk (Frequency), Victim/Number of Employees		Risk Price, Cost per Occupational Injury Risk	
	Fatal	Without fatalities	Fatal	Without fatalities	Fatal	Without fatalities
2012	74 088	28 685	0.000099778	0.00216154	7.39	62.39
2013	97 545	36 686	0.000094553	0.00205465	9.22	84.60
2014	143 546	49 164	0.000089342	0.00185777	12.82	104.16

Analysis of the results of research of indirect (uninsured) losses of an enterprise

(a company) from occupational injuries, published in various sources [15], approximate estimates of these losses at some enterprises of Ukraine and the results of expert assessments show that the real value of the losses in terms of Ukraine is in average not less than the direct (insured) losses of an enterprise. This means that the real "risk price" of occupational injuries is in average double the value of insurance payments to the victims (including all expenses of the insurance company).

For a more precise definition of indirect (uninsured) losses at each enterprise it is possible to determine the amount of possible indirect losses, using the list presented in Table 1 and the manufacturing specifics and adopted practice of enterprise's participation in the social protection of its staff.

Therefore, using the above approach to risk assessment in terms of cost, it is possible to estimate the losses from occupational injuries, which can be prevented by certain preventive measures.

Assessments of possible reduction of occupational injuries losses, obtained using the proposed method, can be used for either a direct evaluation of the economic effect of preventive measures or in the calculation of economic efficiency of prevention of occupational injuries.

Economic effect or efficiency is generally determined by comparing the economic result to the expenses incurred. Economic effect is the difference between the economic results of activities and expenses incurred. Economic efficiency is the ratio of economic results to expenses, and "expenses/income" is the reciprocal value of the economic efficiency indicator.

To evaluate performance of measures on prevention or reduction of occupational injuries an economic efficiency indicator is often used, which is calculated by the following formula for a single preventive measure:

$$E_i = PL_i/EL_i \quad (7),$$

Where: E_i is the economic efficiency of a preventive measure i;

PL_i are the previous losses from occupation injury by implementing preventive measure i;

EL_i are the expenses for the preventive measure i.

To use Formula (7) in economic justification of preventive measures it is necessary to determine its components PL_i and EL_i. Considering the results of the research presented in [10], we accept that indicator PL_i shows the overall risk of injury $R_{total,i}$, prevented by implementing preventive measure i. Then, considering Formula (7), we obtain the following:

$$PL_i = R_{total,i} = \alpha_f \times A(I_f)_i + \alpha_{wf} \times A(I_{wf})_i \quad (8),$$

Where: $A(I_f)_i$ is a probability of a fatal injury prevented by preventive measures i;

$A(I_{wf})_i$ is a probability of an injury without fatality prevented by preventive measures i.

Since the thesis proposes to use a variety of risks as binary groups "cause of injury – kind of injury event" $\alpha_f \times_{wp} C_i K_j^f$ (for fatal injuries) and $\alpha_{wf} \times_{wp} C_i K_j^{wf}$ (for injuries without fatalities) in identification and assessment of injury risks, Formula (8) takes the following form:

$$PL_i = \alpha_f \times_{wp} C_i K_j^f + \alpha_{wf} \times_{wp} C_i K_j^{wf} \quad (9)$$

Since the expenses for preventive measure i, aimed at preventing a kind of operational risk ${}_{wp}C_iK_j$ are determined by an ordinary calculation, Formula (7) is transformed into the following formula:

$$E_i = (\alpha_f \times {}_{wp}C_iK_j^f + \alpha_{wf} \times {}_{wp}C_iK_j^{wf})/EL_i \quad (10)$$

Thus, using Formula (10), it is possible to determine the economic efficiency of a preventive measures i to prevent a specific kind of occupational risk, detected and evaluated using proposed in the thesis methods.

To evaluate a set of preventive measures in order to neutralize or reduce all the risks identified at a workplace, a workstation, in a work shop or in an enterprise in general, Formula (10) takes the following form:

$$\sum_{i=1}^{n} E_i = (\alpha_f \times \sum_{i=1}^{n} wpC_iK_j^f + \alpha_{wf} \times \sum_{i=1}^{n} wpC_iK_j^{wf})/\sum_{i=1}^{n} EL_i \quad (11),$$

Where: n is the number of identified kinds of risk (binary groups “cause of injury – kind of injury event”).

Conclusions

Based on the classic approach to economic calculations and “risk price” indicators, a procedure for determining the economic effectiveness of occupational injuries preventive measures was designed. Calculations performed with its help provide a rational allocation of a fixed amount of money with the maximum reduction of occupational risks for such an amount.

The proposed methodology combines probabilistic occupational injury risk indicators and the value of direct and indirect losses from fatal occupational injuries and occupational injuries without fatalities. The estimations of possible reduction of occupational injuries losses due to preventive measures can be used for evaluation of the economic efficiency of occupational injuries preventive measures.

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