Production Risk Economic Assessment Based on the Fuzzy Logic Approaches

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***Abstract*—Has elaborated economically-mathematical model of assessing the production risk associated with occupational injuries, based on the Mamdani's fuzzy inference method. The model includes assessment of risk associated with workers' safety and the risk assessment of the production profitability reducing due to occupational injuries. The practical application of the model can improve the effectiveness of decisions taken to manage risk.**

Keywords—risk assessment; production risk; industrial injury; prime cost; profitability; economically-mathematical model; fuzzy logic; Mamdani's method

I. INTRODUCTION

The competitiveness of an enterprise is largely determined by the quality and quantity of labor, invested in the manufacture of products. Sustainable development is based on increasing labor productivity, reducing costs and effectivization of the enterprise. Economic damage of workers' loss of labor capacity as a result of exposure to hazardous production factors (HPF)in Russia is growing. Industrialized countries experience demonstrates that harmful work-related exposure and high occurrence rate of industrial injuries cannot be satellites of prosperous business, as they cause eye-watering enterprise losses.

In foreign scientific works the influence of workplace environment on the enterprise economic conditions is given considerable attention. They consider the impact of HPF and workplace ergonomics on workforce productivity; methods for estimating the costs, connected with occupational injuries; models for optimizing workmen's safety costs[1], [5], [6], [8–12], [14–17], [19]. An advanced technique for assessing production risks today is fuzzy-multiple modeling [1], [16], [20], [21].

Various approaches to assess the industrial injury risk [2], [4] and to calculate the subsequent enterprise costs [3], [13], [18] are described in Russian scientific papers, but an integrated approach is needed. The scientific literature has failed to provide Occupational Health and Safety stakeholders with a cost-calculation tool that is both sufficiently accurate and does not require a data-collection stage ill-suited to the time constraints of workplace decision-makers [5]. This is due to the complexity of production risk mathematical assessment, because most of its constituent characteristics are traditionally given in non-numerical form. This obstacle can be overcome by methods of fuzzy logic [7].

In this paper, an approach, based on Mamdani's fuzzy inference method, that makes it possible to give an economic assessment of the risks associated with industrial injuries, is considered.

II. BACKGROUND OF FORMING THE RISK ASSESSMENT MODEL

The model consists of two consecutive systems of fuzzy inference (SFI): SFI1 (production risk component) and SFI2 (economic component). The following designations are used in the simulation.

SFI1: i $(i=\overline{1,n})$ – hazardous production factors (HPF), initiating injuries and property damage. Input variables: T_i - accident probability; S_i – accident severing, D_i – HPF exposure duration. Outcomevariable – R_i – accident risk. R_i, T_i, S_i, D_i are presented in linguistic form with terms: Y_{1j}, X_{1j}, X_{2j}, X_{3j}.

SFI2: P – production profitability; I – target profit, rub.; C – target prime cost, rub..; G – operating revenue, rub.; C_{0_i} – total cost of risk implementation R_i, rub.; $Q_i = C_{0_i}/C$. – R_{Ei} – comprehensive assessment of the production risk of the impact of HPF with subsequent costs; R_i и Q_i – input variables of a linguistic form with terms Y_{2j} and X_{4j}.

Expression of the form: $A=\{x/\mu_A(x)\}$ – is a set of ordered pairs of fuzzy subset A, where $\mu(x)$ – is a membership function of the value of the base variable to a subset; W_m – fuzzy predicate rules ($m=\overline{1,g}$).

III. ASSESSMENT OF THE PRODUCTION RISK COMPONENT

Forming the SFI1, method [1] is taken as a basis for assessing the industrial injury risk.The membership functions of the values of term-sets for T_i, S_i, D_i:

$$T_i^{X_{1j}} = \{x_T/\mu_T^{X_{1j}}(x_T)\}, \mu_T^{X_{1j}}(x_T) \to [0;1], x_T \in [0;1];$$

$$S_i^{X_{2j}} = \left\{ x_s / \mu_s^{X_{2j}}(x_s) \right\}, \mu_s^{X_{2j}}(x_s) \to [0;1], x_s \in [0;12775];$$

$$D_i^{X_{3j}} = \left\{ x_D / \mu_D^{X_{3j}}(x_D) \right\}, \mu_D^{X_{3j}}(x_D) \to [0;1], x_D \in [0;100].$$

When determining the numerical value S_i, it is assumed that the fatal injury is 35 years of disability (or 12775 days). For the numerical value D_i, HPF exposure duration on the employee in percentage of the number of working hours is assumed.

Outcome variable R_i is represented in linguistic form:

$$R_i^{Y_{1j}} = \left\{ x_R / \mu_R^{Y_{1j}}(x_R) \right\}, \mu_R^{Y_{j1}}(x_R) \to [0;1], x_R \in [0;1];$$

$$Y_{1j} = \left\{ \begin{matrix} "very\_low";"low";"medium"; \\ "high";"very\_high" \end{matrix} \right\}. \quad (1)$$

The bases of rules SFI1 in terms of a set of fuzzy predicate rules have the form: W_m :if T_i is X_{1j} and S_i is X_{2j} and D_i is X_{3j}, that means R_i is Y_{1j}, $m = \overline{1,125}$ [1]. Thus, enterprise production risks, caused by industrial injuries, are classified into five main groups (1).

IV. ECONOMIC RISK ASSESSMENT

Economic risk means a comprehensive production risk assessment of the HPF impact, taking into account the subsequent costs, listed in [2], [3], [6].

The amount of these expences increases the planned prime cost, and reduces the profitability of the enterprise, because:

$$I = C \cdot P; G = C + I = C + P \cdot C. \quad (2)$$

If C is increased by C_{0_i} with considering (2) and: $C_{0i}/C \to P$, $I \to 0$. I.e., if $Q_i \geq P$, $I \leq 0$, it is becoming a money-losing.

For example, for an enterprise with a profitability of 8.5%, $Q_i \geq 0,085$ is critical. “Negligible” can be considered a 5%-deviation: $Q_i \leq 0,00425$. Let's express Q_i in a linguistic form:

$$Q_i^{X_{4j}} = \left\{ x_Q / \mu_Q^{X_{4j}}(x_Q) \right\}, \mu_Q^{X_{4j}}(x_Q) \to [0;1], x_Q \in [0;1];$$

$$X_{4j} = \left\{ \begin{matrix} "negligible","small","significant", \\ "measureable","critical" \end{matrix} \right\}.$$

Intermediate values of the scale (“small”, “significant” and “measureable”) are set flexibly, depending on the acceptable level of profitability for the owner of the enterprise. Terms, distributed according to the trapezoidal membership function, provide the most complete description for Q_i changing.

ThebasesofrulesSFI2 for R_{Ei} with matching Q_i and R_i are presented in Table 1. The comprehensive assessment of the production risk of the impact of HPF with subsequent costs is represented in linguistic form too:

TABLE I. COMPREHENSIVE ASSESSMENT OF THE PRODUCTION RISK OF THE IMPACT OF HPF WITH SUBSEQUENT COSTS

C_0/C \ R_i	**Very low**	**Low**	**Medium**	**High**	**Very high**
Negligible	negligible	narrow	middle	middle	middle
Small	narrow	narrow	middle	middle	notable
Significant	narrow	middle	middle	notable	notable
Measureable	middle	middle	notable	notable	heavy
Critical	middle	notable	notable	heavy	heavy

V. CONCLUSION

The proposed model allows making a comprehensive assessment of the enterprise's risk associated with occupational injuries. Firstly, it can be used to assess the risk of an accident from exposure to HPF, based on the data on likelihood of occurrence, severity of consequences and duration of the impact of each specific HPF in the workplace. Secondly, the model makes it possible to conclude how the enterprise expenses associated with the occupational accident will affect the prime cost and the profitability of production.

Thus, enterprise production risks, caused by industrial injuries, are flexibly classified into five main groups. The application of this model rationalizes for the business-owner the task of making an economically justified and socially oriented decision of the production risk management, that meets the strategic goals and objectives of the enterprise.

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