Using of automated risk assessment systems to ensure the safety of personnel at construction sites

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Abstract. The development of automated risk assessment systems is a promising area for scientific research in the field of OSH management. The paper analyses the main problems of the functioning of the OSH management system and identifies the need for its improvement in order to reduce occupational injuries. As a way to improve it, we propose the development and implementation of an automated system for forecasting and managing professional risks (AS FMPR), which implements an algorithm for multivariate analysis of the causes of occupational injuries. The stages of risk assessment are considered. The aim of this work is to assess the applicability of automated risk assessment systems to ensure the safety of personnel at construction sites. The results of the distribution of the probability of injury to workers depending on the factors studied are presented. This system will bring the procedure for assessing occupational risks in construction to a whole new level.

1. Introduction

At present, in Russia, as in many other developing countries, the construction industry is one of the most traumatic industries. According to the International Labor Organization, annually the number of victims of accidents in the construction industry is more than 450,000 people a year [1]. The types of incidents that result in personal injury to workers include the following [2-7, 24]:
- fall of victims from a height;
- falling objects on the victims;
- electric shock;
- the impact of rotating, moving parts of machines and mechanisms;
- jamming between a moving and a stationary object;
- transport accidents;
- collapse of the soil during earthwork, etc.

| Year | The average number of employees (thousand people) | The number of victims of industrial accidents with loss of ability to work for 1 working day or more and fatal accidents at work | The number of victims of fatal accidents at work |
|------|-----------------------------------------------|------------------------------------------------|-----------------------------------------------|
|      | The number of victims | per 1000 employees | The number of victims | per 1000 employees | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| 2017 | 1192.2 | 2146 | 1930 | 1.8 | 1.7 | 214 | 190 | 0.179 | 0.165 |
| 2018 | 1150.3 |               |               |               |               |     |     |         |      |

Table 1. The dynamics of industrial injuries by type of economic activity "Construction" in the Russian Federation for 2017-2018.
According to the data of table 1, in Russia there is a tendency to reduce the level of injuries in construction, but so far this industry remains the leader in the number of injured. The main type of incident is the fall of the victim from a height [8-9].

The data of the international labor organization and Eurostat on the level of injuries in the EU countries indicate that the share of accidents pertaining to various types of work on construction sites is 61.7% (for cases without fatal outcome) and 52.9% (cases with fatal outcome) [1, 10, 11] (Table 2).

| NACE (Section) | Non-fatal accidents at work | Fatal accidents at work |
|----------------|-----------------------------|-------------------------|
|                | Total | Industrial site | Tertiary (office, entertainment, miscellaneous) | Public area | Construction site, opencast, quarry or mine | Health establishment | Farming, fishing, forest zone | In the home | Other or no information |
| NUMBER         |       |                 |                             |             |                                     |                        |                        |             |                           |
| Total (all activities) | 3344.5 | 995.5 | 615.1 | 333.0 | 307.5 | 227.3 | 106.5 | 80.6 | 678.9 |
| Construction (F) | 376.4 | 51.4 | 6.9 | 22.9 | 232.4 | 0.9 | 1.7 | 8.3 | 51.9 |
| SHARE          |       |                 |                             |             |                                     |                        |                        |             |                           |
| Total (all activities) | 100.0 | 29.8 | 18.4 | 10.0 | 9.2 | 6.8 | 3.2 | 2.4 | 20.3 |
| Construction (F) | 100.0 | 13.7 | 1.8 | 6.1 | 61.7 | 0.2 | 0.5 | 2.2 | 13.8 |
| NUMBER         |       |                 |                             |             |                                     |                        |                        |             |                           |
| Total (all activities) | 3 552 | 637 | 174 | 1017 | 518 | 29 | 287 | 58 | 832 |
| Construction (F) | 733 | 61 | 8 | 135 | 388 | 2 | 10 | 10 | 119 |
| SHARE          |       |                 |                             |             |                                     |                        |                        |             |                           |
| Total (all activities) | 100.0 | 17.9 | 4.9 | 28.6 | 14.6 | 0.8 | 8.1 | 1.6 | 23.4 |
| Construction (F) | 100.0 | 8.3 | 1.1 | 18.4 | 52.9 | 0.3 | 1.4 | 1.4 | 16.2 |

The main reasons for injuring people at construction sites are non-compliance with safety rules, non-use of personal protective equipment and others. But the main reason is the erroneous actions of workers.

Erroneous actions or omissions of an employee are associated with non-compliance with safety rules, including with getting used to dangerous conditions, with disruption of the normal flow of the technological process, with errors of the management, lack of application or lack of personal and collective protective equipment, etc. Therefore, the selection of modern tools and technologies is required to establish the conformity of the psychological characteristics of the person with the activities performed, assessment criteria his psycho-emotional state, their accounting and analysis, together with factors affecting the creation of a risky situation [8, 9, 14, 15].

2. Materials and methods
Modern OSH management systems (OSH) are based on the principle of hazard prevention. Risk category - is one of the hazard characteristics currently in use [9].

The most promising and effective approach to the implementation of "hazard prevention" in practice is the process of identification, assessment and management of professional risks. In foreign countries, this tool allows you to achieve exceptionally high results and the desired goal - jobs without injuries and occupational diseases [10]. According to the ILO, the most dangerous are the manufacturing and construction sectors, followed by transport, agriculture and mining.

At present, in Russia, the transition to a professional risk management system is only advisory in nature. At the same time, the definition of occupational risk management given in the Labor Code of the Russian Federation indicates that the introduction of this system entails the need to change the OSH management system as a whole.
Assessment of occupational risks, ensuring health and labor safety are an important part of the entire enterprise management, the development and implementation of which can be ensured on the basis of the international standard OHSAS 18001: 2007 “Occupational health and safety management systems” and a number of domestic laws, taking into account economic aspects related to the compensation of costs for improving the conditions and labor protection of employees [12, 13].

For effective risk management, a more adequate and comprehensive risk assessment is necessary, taking into account the professional and personal qualities of the personnel, their psychophysiological state, and factors of working conditions in real time. At the same time, the enterprise management should optimally assess the production risk for the safety and health of employees, taking into account the nature of their work in the enterprise and all types of impacts in the performance of their duties, and for this an ongoing risk management process should be introduced.

At the same time, it is necessary to take into account a significant degree of uncertainty of factors that determine the level of professional risk, and the limited capabilities of specialists of enterprises responsible for labor safety. In this regard, the use of modern information technologies and automation systems for assessing, forecasting and managing professional risks (AS FMPR) will significantly accelerate this process [12, 13].

Modern tools for predicting incidents and unsafe employee behaviour are algorithms created on the basis of various technologies that combine the capabilities of a computer and the Internet. At the same time, they use intelligent systems based on neural network models, Markov networks, Bayes networks, and other models.

The work of Russian scientists is mainly aimed at assessing and managing occupational health risks for workers, including the use of bio information technologies [12]. The theory of functional systems of P.K. Anokhin was chosen as the methodological basis for managing occupational risks to the health of a human operator. Based on intelligent neural systems, cognitive technologies have been developed to assess the impact of harmful production factors [13].

Abroad, there are attempts to create models of unsafe behaviour of workers based on the analysis of indicators of their behaviour and the working environment, such as the level of management control, working conditions, safety management system, level of employee participation, level of knowledge of safety requirements, attitude to safety, motivation, allocation of resources and work stress.

The foreign models of analysis of employee behaviour are based on Bayesian network theories [16–20, 24]. The following technologies are used at the heart of foreign expert systems:
- Fault Tree Analysis (FTA) analysis methods;
- Analysis of errors and their consequences (Failure Mode and Effects Analysis (FMEA));
- Analysis of processes based on fuzzy approaches (Fuzzy Analytic Network Process);
- Forecasting events based on Bayesian Networks;
- Analysis of events and processes using GERT networks (Graphical Evaluation and Review Technique);
- Forecasting events using the technology of neural networks (Neural Networks).

An analysis of these works showed that they are based on predictive modelling of incidents based on known statistics for certain types of jobs and professions, but they do not take into account the constantly changing factors of the work environment, the labor process, and changes in the psychoemotional and physiological state of the employee. It should be noted that the results of well-known domestic and foreign studies have not been brought to practical implementation in the form of expert labor safety management systems implemented in real enterprises.

3. Results and discussions
The analysis of accidents made it possible to single out the following causes of work-related injuries: technical, sanitary-hygienic, and organizational (including ergonomic), geographical, social, psychophysiological, biographical, and economic.
The developed risk assessment system includes the maximum possible number of assessment criteria to reduce errors in the assessment. The effectiveness of the proposed risk assessment system depends on the choice of modelling method, forecasting and calculation of the probability of incidents with employees of the enterprises and the magnitude of professional risk. To determine the most effective incident modelling method, it is necessary to calculate the probability of an incident taking into account the influence of the factors studied. For this, it is proposed to use the following methods of modelling and forecasting events and incidents:
- logical and probabilistic modelling by the fault tree method;
- analysis of processes based on fuzzy approaches (Fuzzy Analytic Network Process);
- a method for constructing and calculating probability using Bayesian networks.

An example of event modelling (industrial accident) can be the construction of a fault tree (Fig. 1).

**Figure 1.** The scheme for calculating the probability of injury to an employee, taking into account time, social factors, the level of competence and the psychoemotional state of a worker.

**Figure 2.** The distribution of the probability of injury to workers by age factor.
Figure 3. The distribution of the probability of injury to workers by the factor of work experience by profession.

Taking into account the data on the probability of injury to workers for each factor studied, it is possible to determine the probability of an incident (injury or death of an employee), taking into account their joint influence on the final probability of the event. At the first stage of the process of incident probability determination, a retrospective analysis of the statistical indicators of injuries is carried out by means of a quantitative statistical assessment of the factors causing occupational injuries. At the second stage, a predictive analysis of the magnitude of the indicators of injuries and occupational risk is carried out on the basis of fuzzy logic methods. The third stage involves the quantification of traumatic factors based on an expert method. The fourth stage is the identification of problem jobs. The final stage is responsible for choosing a managerial decision to manage the level of professional risk (a database of decision options for managers and specialists of enterprises responsible for ensuring labor safety) [21-23, 25].

For example, for an employee aged 45 who has 5 years of work experience, the level of education is the average professional for the current date and time (June 18, 2020, 14:00 00), the probability of an incident will be 0.046. For comparison, for an employee aged 55 years, the work experience in the profession is 5 years, the level of education is secondary, and the probability of an incident will be 0.16.

This model can serve as a base for its further refinement and expansion, taking into accounts the influence of factors such as gender, elapsed time after checking the knowledge of an employee on labor protection, the class of working conditions, type of production, profession, qualification, the presence of harmful factors, etc.

4. Summary
Prediction and management of occupational risks will positively affect the overall safety and the level of occupational injuries of the enterprise, and will allow employers to significantly increase the effectiveness of the processes for assessing, forecasting and managing occupational risks in enterprises or specific workplaces.

To improve the safety of workers performing work at heights, it is proposed to apply new training technologies in the field of labor protection, in particular, pre-shift testing, as well as encouraging the use of safe working practices and observing safety rules; an assessment of the psychoemotional state of the employee to reduce the risk of injury is recommended to be introduced in real time, i.e. introduce an individual integrated diagnosis of the body, an assessment of the level of fatigue, stress, the influence of emotions; also in real time to keep records and analysis of parameters characterizing working conditions.
Automated risk assessment system, which has been developed at BSTU named after V.G. Shukhov allows us to reliably calculate the risk and select the best measures to reduce it.

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