SOFTWARE PRODUCTS FOR RISK ASSESSMENT AND MANAGEMENT OF OCCUPATIONAL ACCIDENTS AND DISEASES IN INDUSTRY

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ABSTRACT. The mining industry is considered to be among the most hazardous in the world – cave-ins, blasts, toxic air, and extreme temperatures are perils faced by the employees in this sector on a daily basis. Risk management is a core component involving a cyclic process of identifying high injury risk activities, updating operating procedures to reduce risks, implementing these changes, and evaluating their effectiveness. Infrastructure development, work process automation, integrating the equipment with centralised software systems all allow for entirely new approaches in risk management and assessment. A number of products are being developed and implemented in production, like RISKGATE, AnyLogic, Nexsys, etc. MGU ENGINEERING Ltd. has developed the *Mine Accident Risk v.2003* risk assessment software system which provides tools for recording and analysing the risk of occupational accidents and diseases in the mining industry. This article offers a critical analysis of the technical capacities of the software product, along with of how to improve and extend its scope by means of contemporary software products and technologies.

Key words: risk assessment, risk management, mining industry, software systems.

СОФТУЕРНИ ПРОДУКТИ ЗА ОЦЕНКА И УПРАВЛЕНИЕ НА РИСКА ОТ ТРУДОВИ ЗЛОПОЛУКИ И ПРОФЕСИОНАЛНИ ЗАБОЛЯВАНИЯ В ИНДУСТРИЯТА

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РЕЗЮМЕ. Минната индустрия се счита за една от най-рисковите в света – срутвания, експлозии, токсичен въздух и екстремни температури са сред опасностите, пред които ежедневно са изправени работещите в този сектор. Управлението на риска е централен компонент, включващ непрекъснат процес на идентифициране на дейности с висок риск от наранявания, актуализиране на оперативните процедури с цел намаляването на рисковете, прилагане на тези промени и оценка на тяхната ефективност. Развитието на техническата инфраструктура, автоматизирането на работните процеси, свързването на оборудването с централизирани софтуерни системи, дава възможност за изцяло нови подходи в управлението и оценката на рисковете. Редица продукти в тази насока биват разработвани и внедрявани в производството – RISKGATE, AnyLogic, Nexsys. Компютърната система за оценка на рисковете “Mine Accident Risk v.2003” е разработена от „МГУ ИНЖЕНЕРИНГ ООД“. Тя предоставя инструменти за отчитане и анализ на риска от трудови злополуки и професионални заболявания в минната индустрия. В настоящата статия предлага критичен анализ на техническите възможности на софтуерния продукт. Освен това представя идеи за неговото подобрение и разширение, с помощта на съвременни софтуерни продукти и технологии.

Ключови думи: оценка на риска, управление на риска, минна индустрия, компютърни системи.

Introduction

Mining industry has always been known as one of the most hazardous. Prompt risk assessment is necessary in order to maintain safety working environment.

On the other hand, the dynamics of technological evolution gives rise to a serious need for modern approaches to risk assessment and analysis in the mining industry. The use of optimal technology could prevent, reduce, or even eliminate unexpected events that can lead to environmental accidents, accidents at work, or production losses.

The development of an appropriate risk management plan is carried out after a careful assessment of possible events that may occur ~~in~~ under certain circumstances.

What is characteristic of the mining activity is the presence of natural risks which require both compliance with technology and change in human behavior in order to avoid the human and material consequences of these specific risks.

Risk assessment

Risk management includes systemic implementation of policies, procedures, and risk identification practices, assessment of risk consequences, assessment of risk and its levels against the related criteria and goals, as well as decisions for minimising risks identified (Vladkova, 2015).

Risk assessment is an approach taken in many industries. It forms the basis on which risk hazards are identified and measured (Kostadinova, 2020). It is characterised by four main steps:

- risk identification - identification of hazards and situations that may arise and cause damage or loss (also called "undesirable situations");
- risk analysis - careful analysis and critical assessment of the risk of "adverse situations";
- risk control - a set of appropriate risk mitigation and control measures that is considered unacceptable;

- implementation and maintenance of control measures - implementation of risk control measures, as well as monitoring the effectiveness of these measures.

Mine Accident Risk’03

Mine Accident Risk’03 (or shorter: *MAR'03*) is a system for recording/reporting and analysis of the risk of accidents at work and occupational diseases, including the preparation of a basic analysis of the risk of accidents at work and occupational diseases, which is the foundation of the software for continuous assessment of the dangers and safety in the mining companies (Mihaylov, Petrov, 2003).

The system was developed in 2003 by a team from MGU "St. Ivan Rilski” under the supervision of Prof. Mihaylov from the Department of Mine Ventilation.

Among the main functionalities of *MAR'03* are:

- data entry for accidents at work;
- automatic form loading;
- preparation of reports and risk assessment.

The effectiveness of MAR’03 is related to the preparation of three types of analysis of the risks in mines - basic, detailed, and continuous. Risk management software creates an environment for complex decision-making as an ongoing analysis of any decision and activity that has the potential to cause damage, analyzes risks, and implements strategies to reduce those risks.

The system is built with the following software tools:

- Fox Pro – database management system;
- Visual Basic – an object-oriented programming language that allows rapid application development (also known as-RAD) with a graphical user interface (GUI).

Types of statistical analyses in *MAR’03*

Statistics is the collection and analysis of data using mathematical techniques. It also includes the interpretation of data and the presentation of findings. Another use of statistics is to discover patterns or relationships between variables and to evaluate these patterns to see how often they occur.

Pearson's Chi-square Test

Chi-square (χ^2) test is a non-parametric statistical analysing method often used in experimental work where the data consist in frequencies or ‘counts’ (Zibran, 2007).

The significance of Chi-square value is determined by using the suitable degree of freedom and degree of significance and consulting a Chi-square table (Moore, 1994).

The two special purposes of Chi-square test are to test the hypothesis that there is no correlation among two or more groups, populations or criteria, and to test to what extent the observed data distribution fits to the expected distribution. (Turhan, 2020).

What is characteristic for this test is the formulation of the null hypothesis, i.e. we assume that all individual characteristics of an indicator have the same probability (Ho).

It is necessary to determine N - the number of characteristics of the information indicator, from which we can determine the degrees of freedom according to the equation:

$$Df = N - 1 \tag{1}$$

The difference in the numerical values in the characteristics of the information indicator can be huge. In this case, they are normalised by calculating in percentage according to the equation:

$$\overline{F_\iota} = \frac{F_i}{\sum_{i=1}^{N} Fi} * 100[\%], \tag{2}$$

where F_i – – is the actual distribution of accidents according to the characteristics of the information indicator.

The criterion χ^2 is calculated according to the formula:

$$\chi^2 = \sum_{i=1}^{N} \frac{(\overline{F_\iota} - \overline{E_\iota})^2}{\overline{E_\iota}} \tag{3}$$

where $\overline{E_\iota}$ is the hypothetical distribution of the accidents according to characteristics of the indicator and is calculated by the following equation:

$$\overline{\mathrm{E}_\iota} = \frac{100}{N} \tag{4}$$

The obtained result is compared to the critical value $\chi^2_{\text{кр.}}$, taken tabularly, according to the chosen level of significance and the degrees of freedom. The null hypothesis is confirmed when:

$$\chi^2 < \chi^2_{\text{кр.}} \tag{5}$$

Otherwise, it is assumed that the individual characteristics have significant differences in their distribution according to the information indicator.

Paired Student’s t-Test

The paired samples t test, sometimes called the dependent samples t-test, is used to determine whether the change in means between two paired observations is statistically significant. (Mishra et al. 2019). Two hypotheses are formulated:

- the null hypothesis (H0), which states that the difference between the average values, by characteristics of one information indicator for two periods of time, are equal to zero, i.e. there is no difference]
- the alternative hypothesis (H1) – the difference between the average values, by characteristics of one information indicator for two periods of time, are not equal to zero, i.e. there are significant differences.

The number of characteristics are determined according to the selected indicator N, as well as the degrees of freedom according to formula (1), then the standard deviation of the differences S_d is calculated according to the following formula:

$$S_d = \sqrt{\frac{N \sum D_f{}^2 - (\sum D_f)^2}{N(N-1)}} \tag{6}$$

The mean of the population μ is determined, as well as the mean of sample $\overline{\mathrm{X}}$. The value of the criterion t is determined by the following formula:

$$t = \frac{\bar{X} - \mu}{S_d/\sqrt{N}} \tag{7}$$

The calculated criterion t is compared with the taken tabular critical value $t_{кр}$ for the selected level of significance and degrees of freedom. If the condition (8) is met

$$t < t_{кр.} \quad (8)$$

the null hypothesis is accepted - there are insignificant differences between the two compared observations. If the condition is not met, the alternative hypothesis H_1 is accepted.

Parametric Student test

In this test, it is necessary to determine two time periods (f1(i) and f2(i)), the absolute frequencies for which are known. The periods are chosen so that the second f2 is part of the first f1. It can be used to check the differences in the individual characteristics of an indicator.

The null hypothesis is formulated - the difference between the average relative values for each characteristic is random.

The next step is to calculate the relative frequencies as well as the average relative frequency for the whole indicator:

$$\bar{f}(i) = \frac{f_2(i)}{f_1(i)}; \quad \bar{p} = \frac{\sum_i \bar{f}(i)}{N} \quad (9)$$

The criterion of Student is calculated for each individual characteristic of the informational indicator:

$$t_i = \frac{\bar{p}-\bar{f}_i}{S_{dp}(i)}, where\ S_{dp}(i) = \sqrt{\frac{\bar{p}(1-\bar{p})}{f_1(i)}} \quad (10)$$

The calculated criterion t_i is compared with a tabular critical value $t_{кр}(i)$ for a selected level of significance and degrees of freedom. If the condition of formula (8) is fulfilled, the null hypothesis is accepted. If the condition is not met, it is rejected, i.e., there are significant differences.

Opportunities for improving the MAR 03 system

The main disadvantages of the MAR 03 software product are:

- The system does not offer multi-user access;
- The application does not provide an opportunity for on-line work, which makes it difficult to access;
- The database is not stored centrally, but locally. This is a prerequisite for problems in data processing, as well as for the creation of redundancy and conflicting data - it is possible to use several copies of the system to describe the same objects;
- Only a relational model is used to describe the data. It is not possible to work with popular data formats such as XML, JSON, CVS, etc., which limits the ability to use the same data from other applications;
- The software tools used to implement the system are obsolete - support for FoxPro was discontinued in 2007, and VisualBasic's ability to implement an interactive and dynamic user interface is limited.

These limitations point to the fact that despite the use of proven algorithms, the system is hardly used today.

All this creates preconditions for improvements of MAR 03 in several directions:

- Rewriting the user interface (GUI) using modern software. The use of software tools such as C #, JavaScript, etc. would enable the implementation of a dynamic and interactive web and mobile interface;
- Using a database server. This will allow data to be stored centrally. In addition, all modern database servers (including those distributed for free as MySQL) allow relational data to be shared with other formats, most often hierarchical or key-value based. This in turn would facilitate the transition to BigData (Dimitrov et al. 2021; Yanev 2019);
- A new approach to the analysis, using programming languages such as Python and R. This will allow the inclusion of new types of analysis - for accuracy and completeness of data, rapid implementation of statistical analysis, graphical visualization of selected data, etc.

All these changes will lead to the construction of new software with promising development, forecasting and prevention of accidents at work and a more adequate and rapid response to emergencies.

Software products for risk evaluation

AnyLogic (https://www.anylogic.com/)

This software system allows building an interactive simulation where any changes can be tested with high level of detail, to communicate ideas at dynamic animation, and to collect statistics. A simulation model is a risk-free environment. AnyLogic has built-in industry-specific toolkits which speed up simulation of any complexity and scale. The software's experiment framework allows running complex experiments, including those for training AI algorithms. AnyLogic Cloud takes these and other software abilities online, so that you can easily share your insight and collaborate on ideas.

RISKGATE (http://www.riskgate.org/)

RISKGATE is a software system which contains 17 high-consequence risk areas (called topics in the system). It is designed for coal open-pits and mines. These 17 topics are focused on the industry activities of mining, processing, transport, and storage.

RISKGATE is developed by the SMI-MISHC (Sustainable Minerals Industry (Minerals Industry Safety and Health Centre) at the University of Queensland, Australia.

From a broader industry perspective, RISKGATE provides an environment for knowledge acquisition and knowledge exchange to drive innovation and best practice in risk identification, assessment, and management in the coal industry. This digital platform offers utilities for assembly and delivery of risk management know-how across many sectors, including construction, transportation, utilities or heavy industry (Kirsch et al. 2012).

Nexsys (https://www.nexusrisk.com/)

The prominent features of the Nexsys™ system are: a novel risk profiling matrix based on industry standards that provides decision support to control room operators, the ability of Nexsys™ to analyse a large amount of disparate mine data in real time, a rule engine that triggers alarms and changes the risk profile matrix and the client-server architecture allowing clients to be located worldwide, including on any web-enabled device. A novel predictive data analysis function is currently under development. (Haustein et al. 2009).

Nexsys allows underground coal mines to interrogate vast amounts of digital information from a variety of sensors and systems throughout the mine, which normally do not communicate with each other.

The system analyses this integrated data to provide real-time risk management and decision support for control room operators, including automatic triggering of response plans if it discovers a hazardous condition (Juuso, Koistinen, 2015).

Goldsim (https://www.goldsim.com/)

GoldSim is a software platform that uses Monte Carlo simulation to help with decision making and risk analysis.

GoldSim allows you to create quantitative models for risk and vulnerability analysis through a combination of a graphical simulation framework and specialised features to support risk analysis.

The platform also has a package for modelling ecological systems, e.g. in mine water and waste management and human health risk assessment.

@Risk (https://www.palisade.com/risk/)

@Risk (pronounced “at risk”) is risk analysis software. It is an add-on to Microsoft Excel that allows risk analysis to be analysed using Monte Carlo simulation. With this method, the probabilities of an event, as well as the possible consequences, can be calculated.

@Risk is used to predict risk when planning a project and estimating costs. It has a tool that provides different risk management strategies for the optimal resource and asset allocation.

Conclusion

Using all available knowledge, information technology provides an opportunity for continuous change, improvement, and innovation in the mining sector. They provide an opportunity to monitor equipment, healthy working conditions, to help prevent risks, and to respond properly to emergencies.

Modern process simulation software can process huge amounts of data, which significantly increases their accuracy and makes them particularly suitable for environmental and occupational safety assessment.

Mining companies that have embraced digitisation and use simulation and risk assessment products can reach new levels of efficiency in terms of safety, sustainability, and productivity in all environmental, socio-economic and social terms.

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