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ASSESSMENT OF THE IMPACT OF WORKING RISKS IN THE EXPLOITATION OF RAW MATERIALS

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Abstract:
The presented article deals with the use and evaluation of individual risks of work in the environment of Slovak mining company. The mining company is also a manufacturing company. The company mines the raw material and the final product (clinker). The main goal of the article is to monitor the incidence of accidents over the last 10 years, to analyse the group of risks that have a significant impact on accidents in mining companies and to evaluate them. The Risk Matrix, shows the relationship between estimated consequences and probability of risks formation. The next step is to use the workplace Risk Assessment Method to define acceptable risks and minimize the impact on workers. Another method we used is the Fault Tree Analysis (FTA) model. The output of the FTA model is the creation of a faulty tree, which resulted in the individual traumatized accidents that resulted in the definition of the resulting risk - namely a load injury.

Key words: *occupational safety; risk management; occupational injury; FTA model; mining company; risks; risk matrix*

INTRODUCTION

Management activity is more effective the more its essential properties correspond to the essential properties of technology: operational efficiency, profitability, modernity, integrability, integrity, self-sufficiency of management methods, transformative nature and guarantee of achievement and reproducibility of results. Many scientists, experts and other official bodies such as the World Health Organization (WHO), the European Economic Community (EEC) consider noise and vibration to be a major health risk [1, 2]. The issue of noise in the scientific literature is focused on the studied health effects that have an impact on environmental noise (e.g. noise in the environment, in road transport, rail transport, air transport, or specific industries such as mining, construction, industrial noise). These effects can cause several negative consequences for employees, such as progressive hearing loss, psychological disorders, irritation and fatigue not only at work, but also at home. This leads to dysfunctions in everyday life [3, 4, 5].

Health and safety at work should be considered one of the pillars of our society. Therefore, the quality of the job of performance management is crucial for each enterprise. When assessing individual risks, they provide measures establishing a worker-friendly environment in which individual risks are eliminated to an acceptable level, and thus, many work-related injuries are prevented. All employees are required to make themselves familiar with the safety standards applied at their workplace [6]. They should also know the possible risks as well as the procedures to prevent their occurrence, their elimination, respectively.

So far, we have encountered no consistent risk monitoring in both, the mining or other medium-sized enterprises; these enterprises often have even no department or unit within own organizational structure earmarked to deal with effective risk monitoring. Often, they do so only after various industrial accidents, natural disasters, accidents at the workplace, or the production and technological failures occur. Therefore, it is important to pay attention to the risks before they occurred, or eliminate them to the extent possible. Gradually, this creates the need to replace a classical approach with the new dynamic methods with considerable software support. New approaches in the methods examined try to respect current trends in the risk management process, while adapting them to the specific conditions of each enterprise. In the context of the risk analysis, it is, therefore, necessary to take stock of all values in the enterprise that may be subject to loss or

destruction and also determine, which risk factors may compromise the running of the enterprise and assess the extent of the threat [7]. The issue of health and safety is currently under review and implementation by larger organizations than in the past. This is mainly because the situation is unsatisfactory in the company. In the current 21st century, the various risks associated with techniques remain by improving and exploiting other workers at risk. It is therefore necessary to address this issue in organizations in order to prevent or be able to eliminate risks [8].

At present, there is an increasing emphasis on safety and health, but there are still many accidents at work. Many of these accidents occur in the mining industry. Mining is the most endangered sector not only in Slovakia but throughout Europe. The most fatal accidents occur during the extraction and processing of raw materials and mineral resources. The second most common cause of injury or death is falling objects. The sector presents an increased likelihood of illness as a result of working in adverse weather conditions in exposed areas and when handling heavy loads. The most common problems are the consequences of joint inflammation, back problems and airway damage due to work in dusty environments. For these reasons, it is necessary to ensure that the general principles of prevention or precautions taken are respected.

The presented article deals with the use and evaluation of individual risks of work in the environment of Slovak mining company. The main goal of the article is to monitor the incidence of accidents over the last 10 years, to analyse the group of risks that have a significant impact on accidents in mining companies and to evaluate them.

LITERATURE REVIEW

The main objective of risk management is to ensure the prevention of adverse events that could negatively affect the health of employees. Risk management should be more proactive than reactive concerning the way they act, and this process should be carried out at least once a year. Thus, whenever assessing the safety of operations, it is also necessary to determine the relationship between a man, machine, and an environment by analysing the various links between work organization, a technique used by employees as well as their working conditions [9].

Focusing on the problems of using integrated risk management mechanisms, as a way to increase guarantees to achieve the goals of implementing quality of risk management in industrial enterprises, has actualized the key problem associated with the involvement of personnel in risk-taking decisions [10].

There is a tremendous need for change, both in terms of organizational and legal issues but also in terms of employers' awareness regarding the need to create safe and accident-free jobs. Management of occupational safety in small-sized enterprises is not only essential but possible, although it definitely poses a great challenge to employers and employees themselves [11]. Management of each company in the field of health and safety is expected to contribute to establishment of the so-called "safe enterprise." Such an enterprise should meet safety and accident prevention attributes. At the same time, it has to ensure the gradual elimination of individual risks by applying safety innovations. The safe enterprise should also make sure that economic aspects come always only second. The health of workers, as well as the protection of environment account for important factors in the decision-making process. Another objective of a safe enterprise should be the right motivation of employees to maintain the highest possible level of safety in the workplace, especially by using personal protective equipment [12, 13]. The systematic application of risk management techniques has contributed to a substantial decline in injury frequency rates in developed nations. Further improvement, however, is required to reach rates tolerable to the broader community [14].

The main safety requirements and rules are established in Act 124/2006 Coll. on occupational health and safety and on amendments and supplements to certain acts which came to effect on the 1 July 2006, which was followed by the Decree of the Ministry of Labour and Social Affairs of the Slovak Republic No. 500/2006 Coll. that provides a template for filing a record of a registered occupational accident. As established in 2013, the only injury classified is a recorded severe personal injury, death as a result of an accident, respectively. Severe personal injury is further assessed according to the categories defined in §3 (a). l), Act No. 124/2006 Coll [15]:

- Mutilation;
- Loss or substantial impairment of work capacity;
- Paralysis of a body part;
- Loss or substantial impairment of sensory system function;
- Damage to an important body organ;
- One´s disfigurement;
- Induction of miscarriage or causing of death of the fetus;
- Agonizing hardships.

When managing OHS opportunities and risks or enhancing the performance of the workplace health and safety to protect workers at all organizational levels, the individual companies should refer to ISO 45001:2018 (issued March 12, 2018). Having been aligned with other management system standards – ISO 9001:2015 and ISO 14001:2015, ISO 45001:2018 replaces the original OHSAS 18001:2007. Companies that are currently certified by OHSAS 18001:2007 are granted three years for the transition and implementation of the new requirements set out in ISO 45001:2018 [16, 17]. Researchers in Slovakia also carried out research in this area with the aim of exploring the use of selected methods in terms of their effective use in business practice. However, many of these methods cannot be used in mining.

The aim of paper is to identify important causes of injury to workers during working hours. Fault Tree Analysis (FTA) is used for analysis, which can be described as a graphical model of a combination of faults that result in the occurrence of a predefined adverse event (the highest event)

[18]. Fault-tree analysis is a versatile tool that has rapidly won favour with those involved in reliability and safety calculations. But fault-tree models do have disadvantages. Probably the most outstanding one is the cost of development in first-time application to a system. Some inductive analysis technique, like Failure-Mode-and-Effects Analysis (FMEA), is a much simpler and more cost effective technique to apply in analysing small systems when a single-point failure analysis is adequate. However, as systems become more complex and the consequences of accidents become catastrophic, a technique such as fault-tree analysis should be applied. Fault-tree analysis can efficiently direct the efforts of an analyst in considering only those basic events that can contribute to system failure and represent the relationship of human error and environmental conditions in causing system failure. With the fast progress of automated fault-tree analysis, this technique can be a more effective and sophisticated analytic reliability tool [19].

FTA is a logical and diagrammatic method for evaluating failure probability of an accident. An unexpected event (failure of system) is considered as a top event of a fault tree. Logical signs, such as 'AND' and 'OR' gates, are used to represent relationships among various events. Recently, this has been widely applied to evaluate safety of mining. It is very important to evaluate safety and reliability of complex and large scaled system. Fault-tree analysis (FTA) has been widely used to calculate reliability of the complex system. It is a logical and diagrammatic approach for evaluating the possibility of an accident resulting from sequences and combinations of failure events. The fault tree describes an accident model and explains relationship among malfunction of components and observed system and the probability of a top event (an undesired event) is a function of the failure probability of the system [20]. The evaluation of a fault tree can be qualitative, quantitative, or both, depending upon the scope of the analysis. Qualitative fault-tree analysis consists of determining the minimal cut sets and minimal path sets and the common cause failures. Two major approaches used for determining minimal cut sets for fault trees are Monte Carlo simulation and deterministic methods [21].

METHODOLOGY

The paper deals consist of a description of the system analysed, behaviour and risk analysis, and therefore this strategy is aimed at minimizing the risk of individual jobs. The method is evaluated in terms of its advantages and disadvantages. The outcome of these assessments is the FTA model [22, 23].

The aim of this analysis and risk assessment is to explain in a simple and accessible way the principles and procedures for calculating the comprehensive Workplace Risk Assessment Method and applying the FTA methodology, as well as the partial results of the analysis on the example of a mining company. The investigated mining company is engaged in the extraction of raw materials and operates in Slovakia, where the mining and processing activities of the company are distributed in several regions. In addition to product quality, it also takes into account the environmental aspects of mining, the production and processing of raw materials, as well as the friendly approach to nature and the environment in all places [24].

The Risk matrix (matrix of consequences and probabilities) shows the relationship between the estimated consequences and probability, while its objective is to express the level of risk or to determine its classification. This matrix consists of a multidimensional table that combines different probability and consequence levels [25].

As stated in the Table 1, in a 5x5 matrix, we distinguish among five different probability groups and five consequence groups. The final risk rates in this table are further broken down into three groups. While the first group is the low risk group, the second group includes the medium risks and high to extreme risks are put in the third group. The assessment of individual groups of risks in terms of accident rate management is recorded in the table below.

Table 1

An example of a probability versus impact matrix

	Impact				
Probability	Negligible	Marginal	Moderate	Critical	Catastrophic
Al most certain	5	10	15	20	25
Likely	4	8	12	16	20
Possible	3	6	9	12	15
Unlikely	2	4	6	8	10
Rare	1	2	3	4	5

Source: [19].

Workplace Risk Assessment Method – method was developed by the International Social Security Association (ISSA). Its application requires identification of elements that need to be paid particular attention and those that, on the contrary, is possible to neglect, its principle being to accurately assign a point value for individual elements of the system and to define the acceptable risks [26, 27]. Given its subjectivity, the human factor assessment is rather critical to evaluate. To minimize this impact, the elaboration of the method should be condemned by one person or by the same team of experts [28]. As shown Table 2, the workplace risk assessment consists of assessment of individual risk groups in terms of point's distribution.

The first step is to determine the effect of the risk caused by the device (*M*). In this step, you need to assign values to the following:

- Identification of possible damages (*S*);
- The danger exposure (*Ex*);
- Probability of occurrence of dangerous situations (*Wa*);
- Possibility to prevent or minimize damage (*Ve*).

Table 2

Example of a consequences table for probability and impact

Score	Probability	Example	Score	Impact	Consequence
1	Rare	Seen every 10 and more years	1	Negligible	Without the intervention of supervisory authorities
2	Unlikely	Seen every 5-10 years	2	Marginal	Required accident notification
3	Possible	Seen every 5 years	3	Moderate	Interested in additional information
4	Likely	Seen to occur more than once a year	4	Critical	Reach and in-depth investigated event
5	Almost certain	Seen several times a year	5	Catastrophic	Rapid intervention, priority situation

Source: Authors' results by internal company material.

Applying the above-mention values, we can calculate the final assessment of the risk factor caused by the installation. The calculation is based on the following formula:

$$M = S \cdot Ex \cdot Wa \cdot Ve \quad (1)$$

The next step is to assess the environmental impact. In this section, it is necessary to analyse the following three areas that we have examined:

- Organization of the workplace and intervention zones (*Ua*);
- Working environment (*Ub*);
- Other complicated areas (*Uc*).

The resulting environmental impact assessment is calculated as follows:

$$U = Ua + Ub + Uc \quad (2)$$

The third part of the assessment process is to assess the person's ability to deal with the risk. This section consists of three areas, as follows:

- Qualification of person (*Q*);
- Physical and mental factors (*φ*);
- Organizing work activities (*O*).

The final assessment of a level of one´s competency to handle the risks is calculated as follows:

$$P = Q + \varphi + O \quad (3)$$

The final step is to determine the resulting risk value, which is calculated based on the following relationship:

$$R = M \cdot U - P \cdot (M \div 30) \quad (4)$$

Another method we have applied to business conditions is FTA - a tool for identifying and analysing factors that help determine the so-called top event. Before carrying out the analysis itself, the following actions need to be completed:

- To accurately identify the peak event;
- To describe the tracked events;
- To identify phenomena that have a very low probability of occurrence and will not be assessed;
- To identify physical boundaries;
- To describe the status of the system;
- To define the level of analysis.

The composing of the error tree itself is time-consuming and requires the collaboration of experts with sufficient experience in the field. The error tree is represented by a logical graph that shows the paths of the different types and sequences of events. FTA method – analysis of the error tree, the output of the method is the process of creation of the error tree, which resulted in the individual traumatized accidents that resulted in the definition of the resulting risk – namely a load injury [29, 30].

RESULTS AND DISCUSSION

In identifying and assessing the occurrence of risk groups, in the reporting period 2008 to 2018, we paid attention to accidents individually and assigned them individual characteristics. Individual operations were divided into three divisions: mining (underground) division, surface division and maintenance division. These divisions were subsequently assigned values according to the number of accidents that occurred in the division during the reporting period.

- As part of our research, we observed the following characteristics in 2008-2018:
- Development of the frequency of injuries;
- Number of injuries in each division;
- Number of injuries by working shift;
- Number of injuries per day;
- Injuries rate with respect to the number of years worked;
- Injuries rate according to its sources (mining injuries, surface injuries, maintenance division injuries);
- Injuries rate according to its causes.

Figure 1-7 graphically depicts the direct relationship of two variables via the XY.

Figure 1 present development of the frequency of injuries.

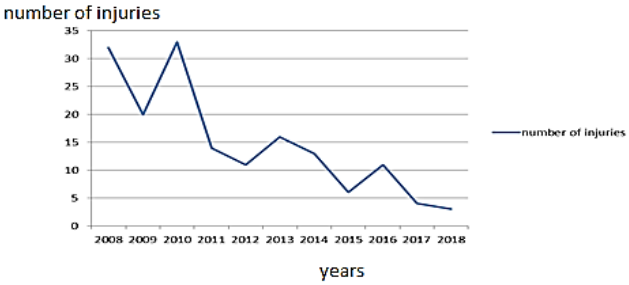

Fig. 1 Development of the frequency of injuries

Figure 2 represent number of injuries in each division in mining company.

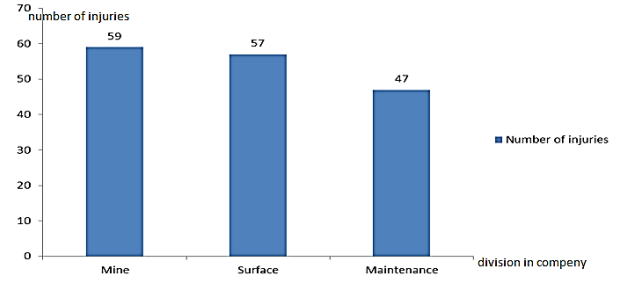

Fig. 2 Number of injuries in each division

On Figure 3 is number of injuries by working shifts.

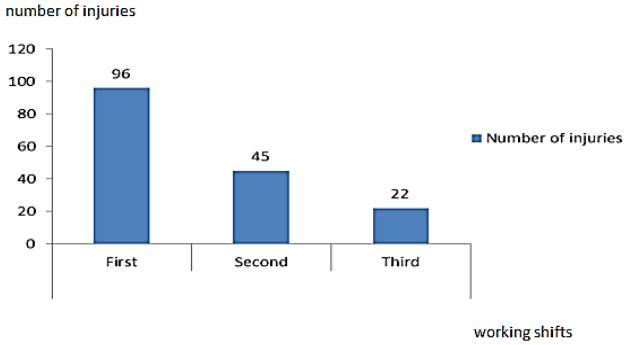

Fig. 3 Number of injuries by working shifts

Figure 4 present number injuries per day.

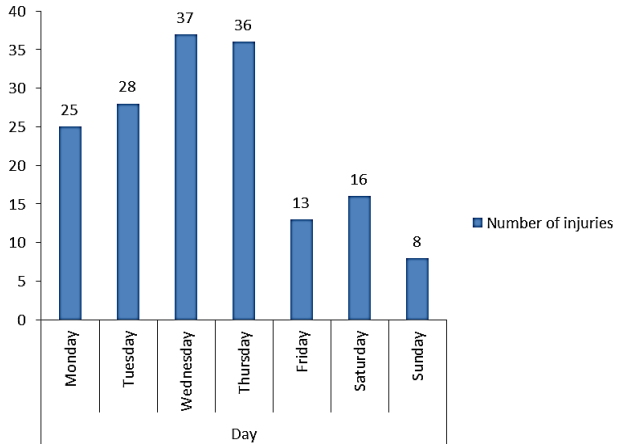

Fig. 4 Number of injuries per day

Number of years worked injuries rate you see on Figure 5.

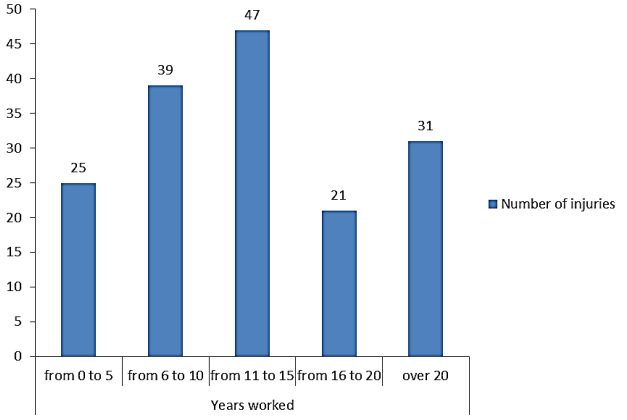

Fig. 5 Injuries rate with respect to the number of years worked

Figure 6 draw injuries rate according to its sources.

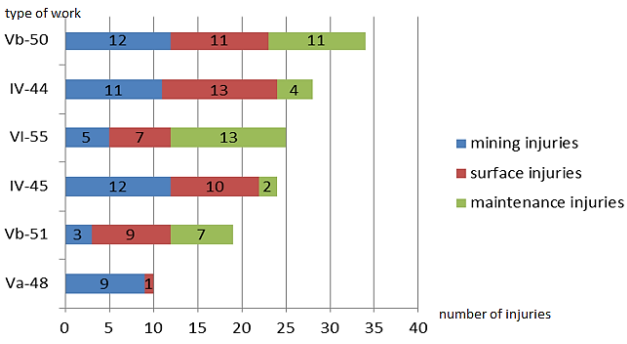

Fig. 6 Injuries rate according to its sources

How to look for figures, the most common representation of suspects has a Vb-50 source of injury, which means load injuries (Fig. 7) [31, 32, 33].

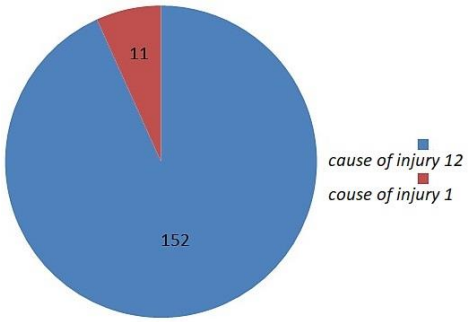

Fig. 7 Injuries rate according to its causes

When assessing individual risks, we preceded from Table 1, mentioned in the methodology, where we assigned to the respective sources of accidents corresponding probabilistic and impact values, resp. result. As shown in the Table 3, sources IV-44, IV-45 and Va-48 represent the highest level of risk.

Table 3

Risk matrix of selected injuries

	Impact				
Probability	Negligible	Marginal	Moderate	Critical	Catastrophic
Almost certain		Vb-50	IV-44		
Likely		VI-55	IV-45		
Possible			Vb-51	Va-48	
Unlikely			I-02		
Rare					

We have paid the greatest attention to these risks in this section, as these risks require an assessment of measures to reduce the risk of their occurrence as quickly as possible.

Use of the Workplace Risk Assessment Method

In this position, the employee works at different heights up to the chimney mouth, which can reach up to approximately ninety meters (Fig. 8, Table 4).

Fig. 8 Employee - excavation of vertical works

Source: Author's results by internal company material.

The excavator, which punches vertical works, works with vibrating tools (VK-22) and works with a high weight of other loads. VK-22 represent a high type of risks works. The working environment is extremely damp, weak, resp. not ventilated; the workplace is illuminated only by lamps [34].

Table 4

Assessment of occupational risk – excavation of vertical works

Risks parameters	Value	Interval of Values
identification of possible damages (*S*)	9	1-10
the danger exposure (*Ex*)	1.9	1-2
probability of occurrence of dangerous situations (*Wa*)	1.3	0.5-1.5
possibility to prevent or minimize damage (*Ve*)	0.85	0.5-1
$M = S \cdot Ex \cdot Wa \cdot Ve$	**18.90**	**0.25-30**
organization of the workplace and intervention zones (*Ua*)	1	0.5-1
working environment (*Ub*)	0.6	0.3-0.6
other complicated areas (*Uc*)	0.4	0.2-0.4
$U = Ua + Ub + Uc$	**2**	**1-2**
qualification of person (*Q*)	9	0-10
physical and mental factors (ϕ)	2.8	0-3
organizing work activities (*O*)	4.5	0-5
$P = Q + \varphi + O$	**16.3**	**0-18**
Risk Value $\boldsymbol{R = M \cdot U - P \cdot (M \div 30)}$	**27.52**	**0-60**

In the case of this job position, it can be assumed that if an undesirable event occurs, the consequences of the accident may be critical. The likelihood of such an event occurring is considerably high as there are unfavourable working conditions. Against this background, it is essential that the person carrying out the work has a high level of expertise as well as physical and psychological prerequisites.

As a measure to minimize risk, the following have been assessed:

- Purchase of rubber suits against moisture;
- Purchase of higher quality rotary hammers (with lower weight and lower vibration coefficient);
- Use of anti-vibration gloves;
- Use of harnesses with a fall energy absorber (to minimize possible damage to the spine and other injuries when using conventional harnesses).

Within this method, we examined the most common source of injury – *Vb*-50, injuries caused by loads. For the purpose of our article, we used the FTA model for this type of injury (Fig. 9). FTA method – analysis of the error tree, the output of the method is the process of creation of the error tree, which resulted in the individual traumatized accidents that resulted in the definition of the resulting risk – namely a load injury.

The following risk reduction measures were proposed:

- Take care of the use of technical aids when carrying loads;
- The use and thorough inspection of hoe plates on platforms;
- Use and control of personal protective equipment;
- Proper organization and management of works;
- Avoiding overhead work;
- Thorough knowledge and assessment of risk during work;
- Regular training;
- Adherence to technical discipline and compliance check.

A company should seek to establish a safer working environment as well as to enhance safety at the workplace. Thus, whenever assessing the safety of operations, it is also necessary to determine the relationship between a man, machine, and an environment by analysing the various links between work organization, a technique used by employees as well as their working conditions.

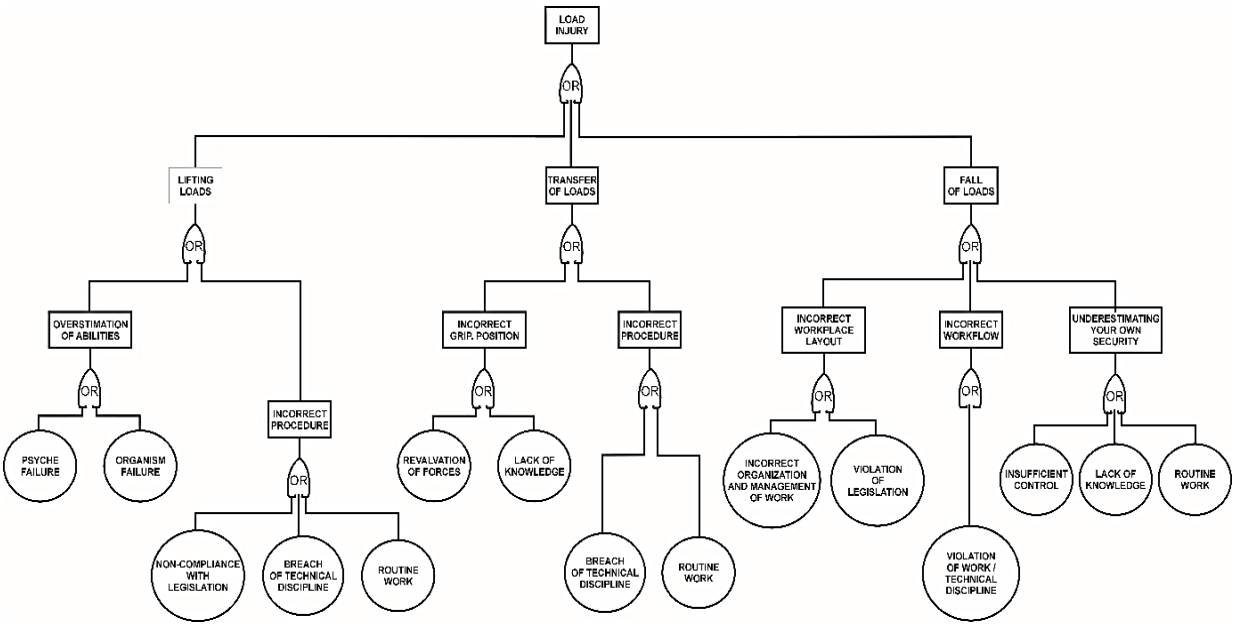

Fig. 9 FTA model for injury with loads

The prevention of the occurrence of risks ideally resulting in minimizing the number of accidents should be emphasized. When managing risks, the following should be taken care of:

- Elimination of danger by proactive safety measures;
- Application of protective measures if the risks could not be sufficiently minimized by proactive measures;
- Informing employee of the security risks and consequences that may occur during the performance of their tasks.

These points further imply the obligations of both producers and the users of machinery, machine systems, etc.

In regards to the above, each producer is bound to:

- Ensure the safety of the machinery construction;
- Ensure sufficient amount of technical protection measures;
- Provide the information on possible risks and instructions on how to proceed if they occur.

The user is bound to:

- Participate in education, training;
- Use of personal protective equipment;
- Act in compliance with organizational measures;
- Monitor, evaluate and inform on the state of residual risks.

In most cases, the risk cannot be fully eliminated; it is only possible to minimize its negative impact.

The aim of the research was to map the use of a comprehensive method of risk management in the environment of a Slovak mining company. These businesses often encounter OHS risks. We realize that our research has some boundaries and there is still room for improvement. Our research will continue to focus on the risk management of mining companies and the use of job risk assessment and FTA, as we consider these methods as a tool for measuring and managing a business free from accidents and other threats.

Risk management should be more proactive than reactive in businesses, and it should be carried out at least once a year in the following cases:

- After the final approval of the workplace in the event of the opening of a new department when legal or other requirements for risk assessment has been changed;
- In the event of a change of operating conditions, activities, products and services;
- If equipment, technologies, raw materials or materials used have been replaced by the new ones;
- When changes resulting from management survey results occur;
- In the case of deficiencies that have been identified through internal and external OHS audits;
- In the case of deficiencies arising from observation, inspection, employee initiative or the initiative of a health and safety representative;
- In the event of an accident, in circumstances close to the accident, respectively;
- Whenever required by state professional supervision bodies for OHS.

CONCLUSION

As can be seen from the above post, the most common source of accidents at work was the Vb-50 accident, an accident caused by loads. The most common cause was marked value 12 (Table 1), missing personality prerequisites for proper work performance (immediate psychophysiological conditions). These facts confirm that in the case of accidents at work, employees did not engage in work that could have prevented accidents at the time of their accidents [35]. Due to the fact that employees work in one position for a long time, there is no active internal mobility of employees, they are underestimated in risky situations - routine work. Every research carried out in this area has its limits. The main limit of our study is internal data from the surveyed company, from which we obtained data on the number of accidents at work Companies do not like to publish this data. For future research, we will focus on expanding the research sample (analysis of more companies) to obtain more accurate data on this issue. The assessment of the impact on occupational risks and the health and safety aspects of employees should be an integral part of the overall safety and health management system of any organization. The main benefit of this article is the use of risk assessment to assess the impact of risks on the safety of the working environment of employees in the production process and compliance with safety conditions in the workplace.

The article contains a generally used concept of risk assessment, which arises from management system standards (ISO 9001:2015, ISO 45001:2018) and fills the gaps in the use of risk assessment in occupational safety management. The use of the Risk Matrix, Workplace Risk Assessment Method and FTA model are advantageous in terms of analysis because they take into account the individual approach of the employee's working conditions when dealing with risk management processes. At the same time, a large sample of data is not required for evaluation. Further research should deepen the analysis of the problem of integrating Risk Assessment with the OSH management system towards the identification of risks and contributing factors and address the use of other methods that will contribute to the elimination of risks in the workplace. At the same time, these risk assessment methods could be an impetus and bring a new perspective on occupational risk management and increase the company's development potential by eliminating all or part of the risks.

The introduction of our proposed FTA model in manufacturing companies will strengthen the safe environment if the company has clearly defined rules and principles. Employees will be informed about changes and regulations that are implemented in individual workplaces. Such employees will be better able to adhere to work ethic, minimize problems and breaches of security principles in the company, and facilitate the resolution of adverse situations. By introducing the mentioned model, it is possible to eliminate the risks of selected processes in manufacturing companies.

This research study is sector specific (mining company) and the use of selected methods may vary in other industries or companies with higher/lower numbers of employees. We consider these facts as additional limits of the study that will be the subject of our further research.

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