Methods of the Environmental Risk Analysis and Assessment, the Modified Method of the Risk Index

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Abstract. **Workplace safety is defined as statutory provisions and corresponding social, economic, organizational, technical, hygienic and prophylactic system of procedures in place, which guarantees the safety of the workplace, prevents accidents and health hazards of employees within a workplace, also it keeps the employability of workers throughout the labor process. The hazard identification and analysis is a comprehensive procedure, which is necessary to effectively address health and safety problems.**

The aim of this research is to study the risk assessment methods and techniques. The study analyzes the scientific literature, identifies the most common risk assessment methods and techniques, which are used for risk assessment. For this study, risk assessment methods are divided into three categories: qualitative, quantitative and semi-quantitative or hybrid methods. The authors of this research have developed a combined method for risk assessment, which combines a number of frequently used risk assessment methods and techniques.

Keywords: **Risk assessment methods, risk index**

I. INTRODUCTION

Human health in the work environment is adversely affected by noise, vibration, non-ionizing (visible light, electromagnetic fields) and ionizing (gamma, X-ray and partially ultraviolet part of the light) radiation, chemical and biological hazards, dust, micro-climate, inflexible work environment, the forced posture at workplace, various other factors and the combination of these factors. Today, working conditions and quality of working place are essential in life expectancy and health of employees.

The impact on health of the work environment depends on the strength of exposure and amount of the harmful factor. [2] It means that the human body can accumulate some environmental factors, reaching a critical level over time. In turn, allergens, ionizing radiation and chemical carcinogens cause an additional risk at all levels of hazard influences. People's individual characteristics are also taken into account while identifying, analyzing and assessing environmental factors, because both physical and psychological responses to these stimuli can be different.

The diversity and specifics of occupational risk factors, which impact human body in a wide range of variants, reveal an unusual clinical structure of occupational hazard factors. Hazards and their interaction give significant deviations of the functions of the human body. Inadequate working conditions can be the cause of occupational accidents and occupational diseases. The work-related accident rate has steadily declined in the workplaces in Latvia since 2008 – the total number of accidents has decreased by 1.3% in 2010, compared with 2009 (there were 1187 accidents in 2010 compared with 1203 in 2009 and 1781 in 2008), the number of serious accidents has declined by 6.3% (164 in 2010 compared with 175 in 2009 and 265 in 2008), but the number of lethal accidents has declined by 28% (23 in 2010 compared with 32 in 2009 and 44 in 2008). [11] However, the number of occupational diseases has rapidly increased from 2007 to 2009. [12] There has been stabilization in the number of newly registered occupationally disabled people only in 2010 – their number has decreased by 17% compared to the year 2009 (there were 1150 newly registered occupationally disabled people in 2010 compared with 1385 in 2009). [12] The expected residual life expectancy after the age of 65 in Latvian population is among the lowest in the European Union (EU), according to the "Eurostat" calculations, which used data from the year 2010. [8]

The identification, assessment and reduction of risks are some of the most important issues of safety in the workplace, to effectively address health and safety problems. Currently, there are a variety of methods used to assess risks in the workplace: quantitative and qualitative or their combination, but there are no single and efficient model for the risk assessment and management.

II. PRINCIPLES AND METHODS OF RISK ASSESSMENT

The risk is a complex concept, which covers the accident probability and the estimate of possible side effects of this accident. There are several types of risk: risk in the work environment, identified risk, unwinding (unexpected) risk and risk of environmental pollution. By its nature, the risk can be controlled, if there is a legal basis for risk assessment, methodological support and assessment procedure, as well as certain special requirements for risk reduction.

Probability, which determines whether the adverse event will occur;

Unintended consequences of the accident;

The expected consequences or mathematical probability of consequences;

Deviation from the acceptable level of risk (adverse effects), which investors are willing to tolerate or endure.

In the risk management methodology, risk is defined as the degree of adverse effects arising from a hazard, taking into account the probability of damage and side effects:

Risk = Probability x Consequences, or R=Q x p [3]

Q – probability (probability of an accident)

p – consequences (amount of the loss).

This formula is the basis for a number of quantitative risk analysis methods and can be applied to each adverse event. Thus, summarizing the risks in all cases, it is possible to assess the overall risk of the operation. By contrast, the probability is characterized by relative frequency – for example, the incidence of certain accidents in a certain amount of time divided by the total number of cases throughout the whole period of time.

Consequences, which are caused by the impact of adverse events, must be assessable; the concept of the particular situation must be formulated in commonly used terms:

- health effects (for example, fatalities, injury, disease), effects on the environment (such as loss of resources, endangered species),
- costs (for example, asset loss, loss of productivity, unproductive use of people's life years, the program deadline delay).

From the mathematical point of view, the risk in the risk management methodology is the mathematical probability of the consequences, and its unit of measurement is equal to the recovery unit.

Risk can also be described by the equation:

R =E x A x S. The equation includes:

E – probability that there are certain risks,

A – probability of avoiding risks,

S – category, which determines the severity of risk. [3]

- assessment of the situation in the workplace (access, safety of work equipment, microclimate, noise, lighting, etc.);
- tasks in the workplace (the one must make sure that all risks are included in the risk assessment);
- work monitoring (to see if worker's actions are consistent with the identified and defined principles, as well as whether there will be other risks);
- the nature of the work (to evaluate potential hazards);
- influence of external factors in the workplace (for instance, the weather during the outdoor work);
- an overview of the physical, psychosocial factors, which contribute to the stress, factor interactions and other labor organizational and environmental factors.

Risk can be assessed quantitatively and qualitatively, both types of estimates reflect the measurement and calculation results. Using quantitative risk assessment, the effects of injury level and the risk of effects are determined in the appropriate unit of measurement (the likelihood of the accident is probability). Quantitative estimates of risk are based on mathematical calculations, but a qualitative risk assessment describes the origin of potential hazards. Qualitative risk assessment does not in fact determine a dangerous probability of the event and the amount of loss or consequences. For example, an estimate based on a 5-point system can be considered a qualitative analysis.

Quantitative assessment has many advantages:

1. Numerical risk assessment allows judging the degree of hazard objectively.
2. Numerical risk assessment makes it possible to develop a package of measures and the risk management system.
3. Quantified risks can be cross-checked.

III. The Risk Assessment Methods in Latvia and Worldwide

Workplace risks are present in all sectors of the economy, and all employees are exposed to them. A person encounters risk factors at work and in everyday life; some of the life-threatening situations are outbreaks of epidemic diseases, environmental pollution. As a result, people's health is seriously affected by these factors, because cumulated and mutually reinforcing factors in the environment are always present, real and inevitable part of existence. Important nuance in different situations is also made by a combination of factors, namely, it can not only lead to a relatively similar effect on the health of a number of varieties, but also significantly increase the cumulative adverse health effects. For example, if the damage to the human health by each individual factor is relatively small, then in case of the effect of the complex of these factors, the damage is significant or even critical. Along with the environmental upgrading in the human life, several new risk factors appear, to which not only the worker is exposed, but many times even all fellow human beings.

Increased amount and intensity of work has resulted in the increased number of health problems of the employees. The number of occupational diseases has increased during past few years. To provide physical, mental and social well-being for every employee, employer has to take care of working conditions, because the working conditions dictate employee's relationship with the workplace.

Risk assessment in the workplace is one of the most important conditions to reduce the harmful influences. A variety of hazard sources identification and assessment procedures and methods are used in the risk analysis. Risk can be assessed qualitatively or quantitatively, or by using semi-quantitative methods, which are typically added to the qualitative risk analysis. In practice, qualitative methods are commonly used. These methods are simple and easy to use and do not require specific knowledge. One of the most popular risk assessment methods in Latvia is a Finnish five-point matrix, which is developed in Finland, Tampere University of Technology. [4]

According to the results of the study "Work Conditions and Risks in Latvia" [13], the situation to meet the requirements in terms of protection in companies has improved, but progress is slow. The environmental risk assessment has been carried out fully only in 31% of companies in 2010, so it can be concluded that there are only about 2% per year increase in the number of companies, which have a qualitative assessment of the risk in workplaces.

The authors of a comparative study "Risk Analysis and Assessment Methods in the Workplace" [6] point out that the main risk analysis and risk assessment methods are quantitative (65.63%) and qualitative (27.68%), while hybrid semi-quantitative methods are not widely used (6.7%). Mixed methods are difficult and often require specific knowledge, which hamper their widespread application. The analysis of

scientific literature for the period from 2000 to 2009 has been conducted, and Figure 1 gives an overview of risk analysis and assessment methods and techniques.

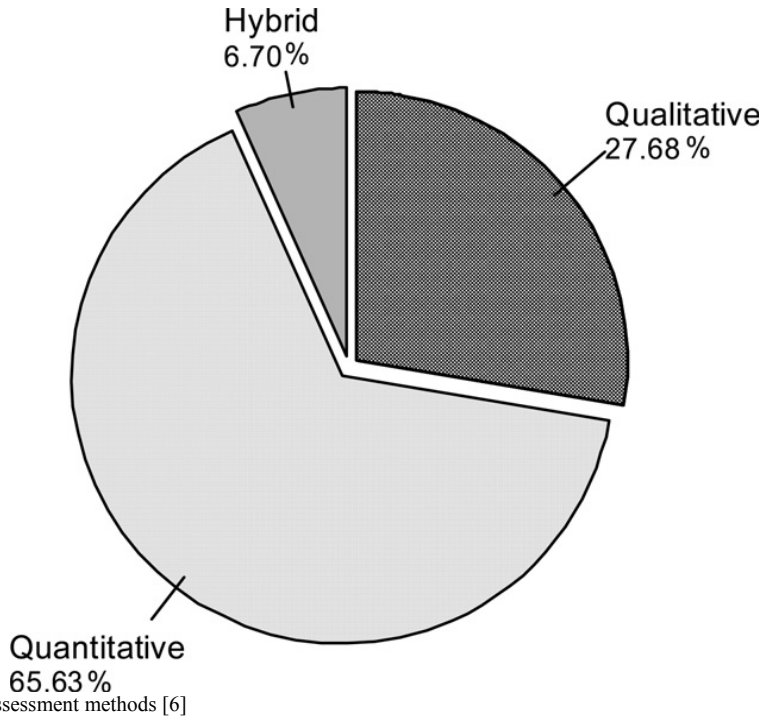

Fig. 1. The application of the risk assessment methods [6]

IV. The Security Index of The Work Protection System

According to the authors, one of the options to ensure risk assessment and mitigation measures, monitoring and surveillance is usage of the business risk indexing method. The quantified Finnish five-point system matrix is a base for this method.

Figure 2. [1] The risk index is calculated by the formula: $R_i = Q \times p$.

TABLE 1

THE LEVEL OF RISK AND ITS COMPLIANCE WITH THE RISK INDEX R_I [1]

No.	Risk Index	The Level of the Risk
1	Ri = 1..3	I – Insignificant risk
2	Ri = 4..6	II – Acceptable risk
3	Ri= 8..10	III – Tolerable risk
4	Ri = 11..15	IV – Significant risk
5	Ri = 16..20	V – Intolerable risk

Quantified Finland matrix is compatible with a number of different risk assessment modified matrices:

1. Noise
2. Lighting
3. Microclimate
4. GPI air pollution index method [1]
5. Physical workload, SGR-DS method [1]
6. Technological risks, matrix “K5-T” [10]
7. Finland method for chemical risk assessment [1]
8. Work ability index [5]
9. Biological risks, Australia matrix from Griffith University [11]

The goal was to create a complex system for assessing risks qualitatively or quantitatively, where the end result is expressed as an index of risk as seen in Table 1. The index is calculated for each occupational risk factor alone. Introducing a single risk index calculation system, using different methods of evaluation at each enterprise, levels of the risk are quantified and expressed as indexes. Risk factors, which have a fixed exposure level or threshold values, are given in terms of index.

Probability of the accident	Consequences of the accident			
	p1 Insignificant	**p2** Tolerable	**p3** Significant	**p4** Very dangerous
Q 1 Very little	**1**	**2**	**3**	**4**
Q 2 Unlikely	**2**	**4**	**6**	**8**
Q3 Rare	**3**	**6**	**9**	**12**
Q 4 Possible	**4**	**8**	**12**	**16**
Q 5 Frequent	**5**	**10**	**15**	**20**

Fig. 2. Matrix to determine the risk index [1]

TABLE 2

RISK ASSESSMENT INDEX FOR VARIOUS RISK FACTORS

No.	Risk Index	GPI% Air Pollution Index	Noise Exposure, Lex8h,dB	Enlightening	Physical Workload, SGR-DS (sum of points)	Technological Risks, Matrix "K5-T"; Sum of Points (RR risk rating)	Finland Method for Chemical Risk Assessment (level of risk)	Biological risks, Australia Matrix from Griffith University (risk value points)	Work bility Index
1	Ri = 1..3	<10	< 80	Normal	<10	0-10	I	2	I
2	Ri = 4..6	10-50	80- 85	+/- 10-25%	10 <25	10-30	II	2-4	II
3	Ri= 8..10	50-100	85-87	75-50 % from normal	25<50	30-50	III	5-6	III
4	Ri = 11..15	100-200	87-90	50-10% from normal	50<100	50-80	IV	7-8	IV
5	Ri = 16..20	>200	>90	10% from normal	>100	80-100	V	9-10	V

The combination of different risk assessment methods in Table 2, allows setting up a complex system for assessing risks, where the evaluation process is done qualitatively or quantitatively, the end result is expressed as an index of risk. The index is calculated for each occupational risk factor separately. Introducing a single risk index calculation system, using different methods of evaluation at each enterprise, in the end, levels of the risk are quantified and expressed as indexes. Risk factors, which have a fixed exposure level or threshold values, are given in terms of index.

Quantified Finland Matrix may provide a more accurate assessment of workplace risk quantify risk in the form of an index. According to the resulting assessment, one can accurately identify the risk factors, which increase the risk index average value, and distinguish them for the assessment and report results. The authors believe that such a method is easy enough and high-quality and the obtained results are easy to understand.

The authors propose to use the overall average risk index value $\overline{R_I}$ for the calculation of the company's total risk index, which is divided by the largest possible index value, in this case it is 20 points:

$$R_{i\ company} = \frac{\overline{R_i}}{20}, \qquad (1)$$

The formula (1) allows calculating the average risk factor index, which if necessary can also be expressed as a percentage, if multiplied by 100. Calculation resulted in a coefficient characterizing the environmental risk index for the company. One can create a risk assessment report on the company and show the company's overall risk index, using the calculations of the figures obtained. One can also evaluate the individual components that make up the company's total risk index, and determine the extent to which they contribute to the overall index value. Such evaluation procedure may be applied to all types of security systems in companies and in different other objects, and the magnitude of the risk is expressed by the same score.

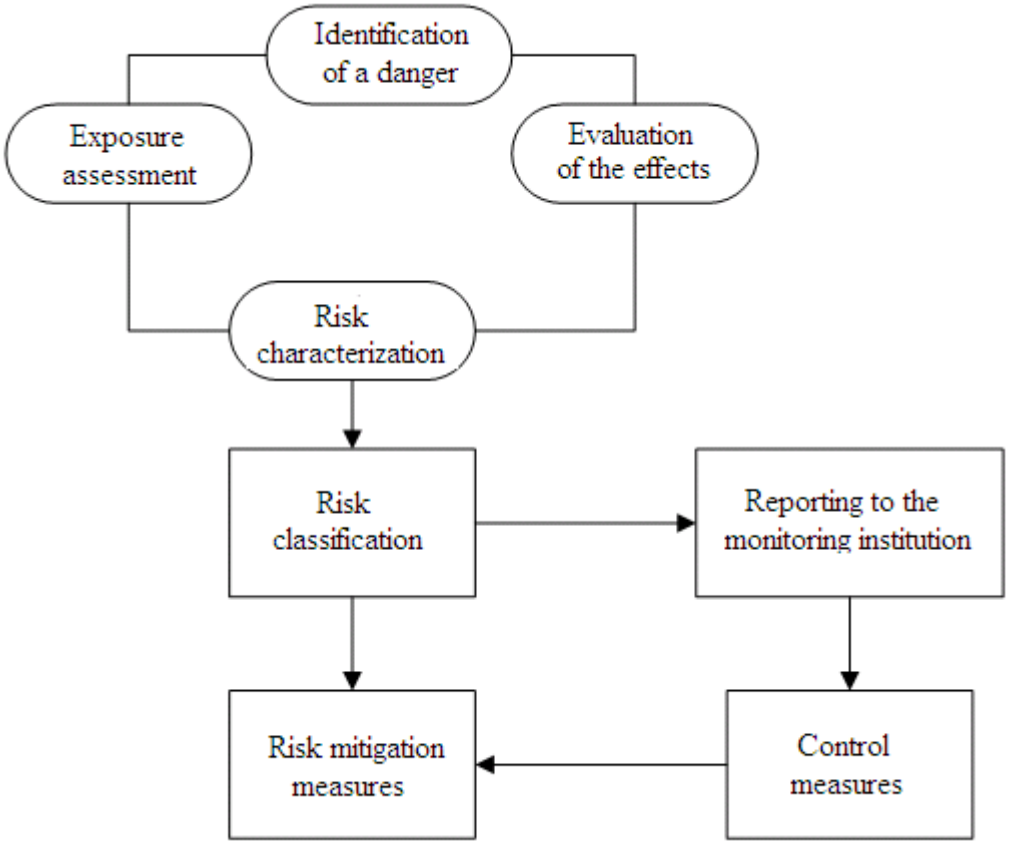

Fig. 3. The collection and control scheme of the risk index

It means that by using the information of the risk index, one can create a common security controls and risk management system and ensure the human security monitoring. In this case, the risk index is composed of several indices, which would include the necessary information:

1. the occupational health and safety system,
2. the environmental safety,
3. hazardous chemical substances,
4. the safety of the technological systems.

Implementing the control measures, the competent body or authority is determined, which is competent to carry out a risk index and compliance audits. It is tested to comply with the specific circumstances of the company. Cases of non-compliance assessment are carried out by a competent organization.

The risk index value is expressed as a percentage and it is a numerical value, which can be easily used in statistics and it allows the information processing and analysis. Risk assessment for the simplified scheme [7] is supplemented by an additional procedure – submission of a report (Fig. 3) to the controlling department and control measures; thus, we get the risk assessment, the information gathering and the schematic representation of the indexing. In this way we ensure the risk index assessment and the information gathering.

Advantages or benefits of the method:

1. All companies are rated by risk index.
2. The changes of the risk index show the changes in the labor protection system and safety throughout the facility.
3. It is simply and clearly to understand, which are the weaknesses in the company's labor protection system compared to other companies.
4. It is possible for the enforcement authority to monitor and control the risk assessment of each company or site.
5. Partners can easily and clearly understand the details and the level of risk of the object.
6. The risk index (R_i) provides primary information not only on labor protection system, but also on the risk of technological operations.
7. It is easy to assemble and to follow the changes of the risk indices of companies.
8. Indices can be analyzed either at the field level, or by region, or by company size.
9. The level of the risk index can be used in regional planning according to technogenic objects.
10. The state can establish support programs to reduce the risk index for those companies, which are important to the economy.

Security index allows accessing the information about the company and the evaluation index, as well as security systems

of the company. This information is centralized and collected from all enterprises. In this way it is possible:

1. To obtain an assessment of the company's security systems during the inspection;
2. To quickly obtain information on security systems and hazardous chemicals in the case of technological disaster.
3. In case of emergency this information is needed operatively, because any delay may affect possible solutions and other related events.

Using a risk index method, one can create the common index of security systems of companies, which includes the assessment of all systems related to human security and ensuring safe operation.

CONCLUSIONS

Nowadays, people are exposed to a combination of several risk factors simultaneously. In such cases, a combination of factors is reflected in the synergy or in the mutually reinforcing effect. The risk identification and analysis of the workplace is a comprehensive procedure, which is necessary to effectively address health and safety.

In Latvia, the indoor air pollution by dust, microorganisms, allergens and volatile organic compounds cause serious problems for workers' physical and mental well-being. The number of people doing sedentary work has also increased. The body is suffering from hypoactivity, forced state, stereotypic movements and rapid work pace. The number of jobs, which require high accuracy and visual tension, has increased. This leads to rapid fatigue of congested parts of the body and the total organism.

As elsewhere in Europe, there is evidence of the aging workforce problem in Latvia, as well. Healthy working environment enables workers of all ages to work according to requirements.

As technology evolves, a number of work processes have become more secure; harmful substances are used less; there is more information available on topic how to protect your health, and the range of personal protective equipment is available, but with every year the number of recorded occupational diseases continues to increase in Latvia. In order to achieve reduction of the number of occupational illnesses, it is important to ensure that preventive measures are used and working conditions are improved. One of the most important conditions to effectively address the health and safety problems is the risk identification and assessment.

Quantitative and qualitative evaluation methods are the most widely used for the risk assessment. Semi-quantitative or combined methods are difficult and often require additional resources and expertise. One of the most popular methods for qualitative risk assessment in Latvia is the Finland's five-point method. Evaluation methods, which are used by expert, depend on the evaluator's expertise. Currently, there are not any common risk assessment models or risk indicators. In the existing models, the risk is evaluated analytically and is often expressed in terms of ‘high risk’ or ‘negligible risk’, but these terms are not clear indicators. Degree of risk, which is expressed in such a way, is difficult to use in statistics and planning.

Using the Finland's five-point method as the basement model, it is possible to create a framework for risk assessment which is relatively simple and easy to assess the risks quantified by risk index. Such a model can be used in small and medium-sized enterprises, as well in enterprises, which do not have complex technological process. Assessment data can be used to create an overview of the risks in the company or site, as well as for comparing objects and for planning.

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Ansis Meļko, Jānis Ieviņš, Ženija Roja. Darba vides risku analīzes un novērtēšanas metodes riska indeksa modificētā metode

Pētījumā par darba vides risku novērtēšanas un analīzes metodēm ir analizēta zinātniskā literatūra, noteiktas biežāk lietotās risku novērtēšanas metodes un paņēmieni. Risku novērtēšanas metodes pētījumā ir iedalītas trijās kategorijās. kvalitatīvās, kvantitatīvās un puskvantitatīvās jeb hibrīda metodes. Pētījuma rezultātā ir secināts , ka nav vienotu kopēju riska novērtēšanas modeļu un riska rādītāju.

Pašlaik risku novērtēšanai tiek izmantotas dažādas metodes un paņēmieni. Risku novērtēšanai Latvijā un Pasaulē visplašāk tiek izmantotas kvantitatīvās un kvalitatīvās novērtēšanas metodes, Novērtēšanas metodes izvēle ir atkarīga no speciālista, kas veic novērtēšanu zināšanām un pieredzes. Puskvantitativo jeb apvienoto metožu pielietošana ir sarežģīta un bieži vien prasa papildus resursus un specifiskas zināšanas. Esošajos modeļos tiek novērtēts analītiski un bieži vien tiek izteikts ar apzīmējumiem liels risks vai maznozīmīgs risks, kas nav skaidri saprotams rādītājs. Šādi izteiktus riska rādītājus grūti izmantot statistikā un plānošanā. Nav izveidoti arī vienoti modeļi dažādām zinātnes nozarēm un virzieniem. Pēc autora domām ir nepieciešams izveidot kopēju, vienotu modeli, kurā apvienotas dažādu risku novērtēšanas metodes, un paņēmieni. Izmantojot vienotu modeli var veidot efektīvu risku kontroles un vadības sistēmu, lai samazināto kaitīgo darba vides faktoru iedarbību. Izmantojot risku indeksācijas metodi, var izveidot kopēju uzņēmuma drošības sistēmu indeksu, kas ietver sevī novērtējumu visam sistēmām saistītām ar cilvēka drošību, un drošas darbības nodrošināšanu.

Ансис Мелько, Янис Иевиньш, Зения Роя. Анализ рисков и методы оценки, модифицированный метод индекса риска

В исследовании наиболее часто применяемых методов оценки и анализа рисков рабочей среды проведён анализ научной литературы, выявлены наиболее часто используемые методы и приёмы оценки рисков. Методы оценки рисков в исследовании разделены на три категории: качественные, количественные и полуколичественные или гибридные методы. Созданных единых общих моделей оценки риска и показателей риска не существует.

В настоящее время для оценки рисков применяются различныне методы и приёмы. Для оценки рисков в Латвии и в мире самое широкое применение имеют качественные и количественные методы оценки. Выбор метода оценки зависит от знаний и опыта специалиста, осуществляющего оценку. Применение полуколичественных или объединённых методов является сложным и часто требует дополнительных ресурсов и специфических знаний. Существующими методами степень риска аналитично оценивается и часто определяется при помощи обозначений как крупный либо малозначимый риск, что не является чётко внятным показателем. Данным образом определённые показатели трудно используемы для статистики и планирования. Не создано и единых моделей для различных отраслей и направлений науки. По мнению автора, необходимо создать общую единую модель, объединяющую различные методы и приёмы оценки рисков. Применяя единую модель, можно создать эффективную систему контроля и управления рисками, чтобы уменьшить вредное воздействие факторов рабочей среды. Применяя метод по индексации рисков, можно создать общий индекс безопасности предприятия, включающий оценку всех систем, связанных с безопасностью человека и обеспечением безопасной деятельности.