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Utilization of mathematical models in complex work environment assessment method

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Využitie matematických modelov pri tvorbe metód komplexného posúdenia pracovného prostredia

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pracovní prostředí pracovní rizika hodnocení rizik modelování metody

Abstract

This paper deals with possible approaches to complex work environment assessment. It is known that individual factors of work environment can significantly affect human behavior. Ensuring suitable work environment is a basic requirement for complex assessment of risk factors. This article defines the possibility of using mathematical methods which could enable complex assessment of risk factors and their effects on employees in the work environment.

Keywords: risk, complex assessment, work environment, mathematical models

Abstrakt

Príspevok sa zaoberá možnými prístupmi ku komplexnému posudzovaniu rizikových faktorov pracovného prostredia. Je všeobecne známe, že jednotlivé faktory pracovného prostredia môžu významne ovplyvniť ľudské správanie. Zabezpečenie vhodnej kultúry pracovného pros tredia je základným predpokladom pre komplexné posudzovanie. Uvedený príspevok definuje možnosti využitia matematických metód, pomocou ktorých by bolo možné komplexne posúdiť pôsobenie rizikových faktorov pracovného prostredia na človeka.

Klíčová slova: riziko, komplexné hodnotenie, pracovné prostredie, matematické modely

Introduction

Every company tries to ensure maximum productivity and effectiveness, which cannot be achieved without optimizing working conditions. Optimization has to be applied to the process of creating the work environment, mainly in the production stage. The production stage is affected by the technological factor, which makes it difficult to achieve the required optimal work conditions. Individual steps to achieving optimal conditions can be executed in many ways, the pick of which depend on the extent of available information on the technological and work process, work factors and the state of the work environment, risk assessment purpose, the nature of the exposure or risk, etc.

Underestimating the importance of one of the risk factors leads to degradation of working conditions and lowering of work safety (Hnilica and Dado, 2009), health damages occur, the probability of accidents increases and psychic comfort is disturbed, which results in increase of error rate, productivity and quality of work decline.

The employee represents human factor of the ergonomic system. Its impact on the system is not negligible, because it represents a source of errors. About 90% of all serious industrial accidents are the outcome of human failure (Buchancová at al., 2003). The level of capability to not cause an unwanted incident is the reliability of the human factor. Its assessment presents an inseparable, but demanding task in risk assessment. When carrying out this task, one can utilize many available methods, which take the qualitative and quantitative reliability into account (Sablik, 1990).

Every human activity, including work activities bears risk. This risk is an expression of combination of probabilities and outcomes of certain undesirable incidents. It is therefore necessary in work environment assessment to determine the intensity and duration of the risk factors effect, whether the impact of the work environment is harmful or not. Quantifying the impact of individual risk factors on human health is very difficult. Every person is a unique individuality, which tolerates the risks in his own way. One of the key factors entering the process is the duration of the particular risk factors. This makes it even more difficult to find mathematical dependence between the work environment as a whole and its effects on humans.

Complex assessment of the work environment is composed from the qualitative and quantitative analysis of the work environment factors.

Qualitative analysis of the work environment parameters presents execution of these main operations:

- Determining the simplest condition, the so called comparative basis,
- Determining the main attributes, through which the level of individual factors will be distinguished (determining the assessment criteria),
- The comparative analysis, that is determining by what extent the level of a factor deviates from the comparative basis.

Qualitative analysis of work environment parameters is oriented on determining the quantity or extent of the given factor (Sablik, 1990).

Qualitative and quantitative assessments create a system of risk parameters assessment, which will take into account:

- The nature of work environment parameters effect,
- The duration of the effect,
- The number of factors occurring simultaneously,
- The severity of individual factors of the work environment.

The present state of the work environment, regarding the effect of the environment factors, suggests the need for increase in care for the work environment. The confrontation of work environment assessment by subjective and objective methods is an optimal way of managing companies in this area. It is necessary to aim on com plex work environment assessment too (Hnilica and Dado, 2009). It is necessary to ensure that the chemical, physical, biological, psychological and social factors do not pose a threat for the health of the employees (Dado, 2008).

Materials and methods

Risk assessment is a process of evaluating the probability and severity of the harmful effect on humans as a result of exposure to the risk factor in defined conditions, from defined sources. It consists of defining the hazard, defining the exposure, evaluation of the relation between the dose and the effect, definition of the risk and determining the uncertainty of the assessment.

Multiple methods can be assigned to complex assessment, the nature of which can meet the requirements of evaluation individual risk factors and their interaction. These methods include:

- questionnaire method,
- score method,
- method of work environment assessment through coefficients,
- mathematical methods.

In the presented paper we would like to describe the possibilities of utilizing mathematical models in complex work environment risk assessment.

Results

Mathematical modeling has made its way into various fields of natural, technical, economic and social sciences and has become an important part of simulating and modeling system, analyses and prediction of various processes, events, behavior of species and societies.

Utilization of a mathematical model brings many advantages:

- It enables to recognize information about the behavior of the system even if making assumptions from the original is impossible or complicated.
- It accelerates the process of familiarization with the objective reality. The processes which in reality happen in long-term can be observed during the computation of the model, which is dependent on the information and communication technology (ICT).
- It simplifies and rationalizes the process of familiarization. The mathematical model of a system provides transparent, brief depiction of objective reality and enables adjusting the process of problem solving to the needs of the user. Models bring new knowledge into our thinking.
- It enables various solutions, which means the calculation of numerous versions of possible outcomes. It identifies erroneous knowledge of objective reality (unlike an experiment in the real system) (Hřebíček and Škrdla, 2006).

From the information provided above it can be said that mathematical modeling is one of perspective methods of complex work environment assessment. These methods fall into objective methods and their advantage is precision and statistical basis.

Statistics is defined as a science on methods of quantitative evaluation of mass phenomena. The basic task of statistical work is setting the aim of the research. The final task is to make decisions based on the outcomes of the research. In between the basic tasks there is statistical data processing.

Depending on whether the model includes a time factor or not there are static and dynamic models. Static models do not include the time factor, dynamic models express observed changes in time. The input parameters in deterministic models are explicitly given (deterministic parameters), in stochastic models parameters are of random nature. Considering the mathematical relations between the parameters there are linear and non-linear models. In linear models all of the relations are linear, in non-linear models they have non-linear tendency. The models with restricted applicability and purely formal methods which utilize creative elements while operating on empirical data, based on the know-how (intuition, imagination and technical sense) are called heuristic models. Situations where we do not know the exact algorithm are quite common. These situations can be simulated through computers. Simulation methods constitute a special group of mathematical models applicable mainly with dynamic and stochastic models (Hřebíček and Škrdla, 2006).

Mathematical model of a complex work environment assessment shall therefore be a combination of non-statistical methods (questionnaires, score methods, or evaluation through coefficients) and statistics utilization. As it was mentioned before, the basic task of statistic work is setting the aim of the research. This condition creates the need for establishing a reference value, which will constitute the basis of the mathematical model creation.

One of possible techniques is to utilize a multicriterial method, which would be combined with the coefficient method. Various multicriterial methods exist, which have the same purpose, which is to evaluate several alternatives of solutions of the given problem with set criteria and to determine their order. Individual methods differ mainly on how the weighing of individual criteria is determined.

The whole process has two parts. In the first part it is necessary to determine the weights of individual criteria, which express the significance of the criteria. The more significant the criterion the more weight it has. To ensure the comparability of the criterion weight these are standardized so that the sum is equal to 1. Standardization is carried out so that the sum of all of the criteria is set and then the individual criterion weights are divided by the sum.

Basic methods of weight determining in multicriterial methods of assessment are:

- Score method – every criterion is given a specific number of points from a defined scale corresponding with the criterion's significance. This method is very simple and transparent;
- Fuller method – uses pair comparison of alternatives. The disadvantage of this method is that the comparison is based on "better – worse" and it does not take the size of preference of one alternative over another into account;
- Saaty method – compares the preference relation of pairs of criteria in a Saaty matrix. In contrast with the Fuller method besides noting the preferences themselves it also takes the size of the preference.

The next step is to calculate the complex load q_c according to the formula (1) and to determine its effect on the health of the employee.

$$q_c = \sum_{i=1}^{n} a_i \frac{Z_i^r}{Z_i^p} \quad (1)$$

vzorec, část vzorce do článku

where Image not found or type unknown is the weight of the criterion calculated from the Saaty matrix and the following is valid $q_c = \sum_{i=1}^{n} a_i \frac{Z_i^r}{Z_i^p}$,

$q_c = \sum_{i=1}^{n} a_i \frac{Z_i^r}{Z_i^p}$ is the real value of the observed factor,

$q_c = \sum_{i=1}^{n} q_i \frac{Z_i}{Z_i^{P}}$ is the limiting value of the observed factor.

In reality we can say that if a limiting value of any factor is exceeded the situation has to be resolved immediately, because according to the current legislation every risk factor has to be within an acceptable interval. Therefore overstepping the limiting value does not need to be resolved and it will be assumed that all of the risk factors are in set boundaries. Overstepping the limiting value means that the fraction vzorec, část vzorce do článku Image not found or type unknown will have value greater than 1. If the result of the fraction is exactly 1 it means that the value of the factor is exactly the limiting value. In practice the value should be $q_c = \sum_{i=1}^{n} q_i \frac{Z_i}{Z_i^{P}}$ < 1, which means that the value of the factor is below the limit and this should be applicable to all of the risk factors. *How does this affect the overall rating q_c?* If all the factors are below the limit (all the fractions are < 1), then q_c is also < 1. If all of the factors were exactly on the limiting values (very specific case), then q_c = 1. The value q_c = 1 (other than the case in the previous sentence) or q_c > 1 this means, that at least one factor overstepped the limit. This is a situation which should not happen in reality, because comparing the q_c value with 1 in case that all of the risk factors are below the limit is meaningless.

Further possible solution (model) would consist of partial modification of the equation (1) so that the comparison would not be with the limiting value, but with some optimal value. This would mean that if the q_c = 1, all of the factors are around the optimal value. The case if q_c > 1, would mean that at least one factor is above the optimal value and it is necessary to be cautious, or that it is necessary to start making provisions to improve the state of the work environment.

Other solution (model) could be based on comparing q_c with another value. The question is "*With what value?*" The answer on this question could lay in a condition, that measurements would have to be carried out for all of the risk factors and that there would have to be measurements proving negative effects on health if the factor reached this value. It is necessary to understand what kind of measurement it should be. It could be a result of a questionnaire (based on observing the subjective feeling of exhaustion, overload, etc.). If there was a measurement available, which enabled the evaluation of health effects, a critical value q_c could be searched for. This would serve as the comparison base. "*What would the search for the q_c critical value look like?*" With different critical values q_c the measurements would be divided into two groups: group with q_c < *critical value* and a group with q_c> *critical value*. In the second group the share of measurements with negative health effects would be observed. The condition is that this share should be maximized. In the first group there would be observations of the share of measurements where there are no negative health effects and the condition is that the share should be maximized. There observed shares are contradictive and by observing them an optimal critical q_c could be found.

One the possible mathematical models can be based on the analysis of the interval variable *y* dependent on independent variables *x,* which means that there will be correlations between the values of risk factors and the value taken from the questionnaire (health assessment).

It could be based on a linear model such as this:

$$q_c = \sum_{i=1}^{n} q_i \frac{Z_i}{Z_i^{P}} \quad (2)$$

where x_1 is noise for example,

x_2 is energy expenditure for example,

y is the outcome of the questionnaire.

The values of the coefficients α_i refer to the significance of the factors and their strength. Coefficients α_1, α_2, α_3 a α_4 are computed from the measurements, their values can be arbitrary real numbers (positive and negative, small and large), α_1 in the equation (2) means the value, by which the y (the outcome of the questionnaire) would change if the x_1 changed by 1. The outcome would be a function through which it would be possible to estimate the outcome of y under selected values of the x_i factors.

This model could be used in simulations, where for example with one fixed factor the development of other factors (and their effect on health). Other models could be tested on the data as well.

Conclusion

Even if all of the hygienic limits for individual risk factors are met, complete safety and reliability of humans in the work system is not secured if exposed to multiple factors simultaneously. Because of this potential effects should be taken into account and not be neglected. A suitable tool for determining whether there can be cumulative effect of work environment factors is a well-made analysis and evaluation of risks. Based on this analysis it is possible to evaluate all of the risk factors and their effect on employees.

Presented paper is an overview of mathematical methods utilization, through which the complex assessment of the effects risk factors in the work environment have on human beings. Their usability is under further research.

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