



# Occupational risk assessment with grey system theory

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## Abstract

The article proposes a new method of occupational risk assessment which uses the grey decision model. The method is called the grey occupational risk assessment model (GORAM). The presented method allows for combining measurable and qualitative factors in the process of occupational risk assessment through the use of expert knowledge. This method can be applied to the multifaceted occupational risk assessment of complex and uncertain sociotechnical systems. First, the article presents problems with currently used methods of occupational risk assessment in the context of the possibility of solving them using the methods of the grey system theory. Secondly, the algorithm of the GORAM method is presented. Finally, the developed GORAM model was used in a case study involving the position of a mechanic in the technical department of a production company.

**Keywords** Grey decision making (GDM) · Occupational risk assessment · Grey occupational risk assessment model (GORAM)

## 1 Introduction

Nowadays, it is recognized that the most common cause of accidents is the variability of human performance. This approach is different from the traditional human error paradigm (Stanton and Harvey 2017). However, it should be noted that despite the change of the paradigm, still, the most important factor in improving work safety is influencing employee awareness. It aims at shaping safe attitudes in the workplace

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through appropriate training and implementation of risk prevention procedures (Kariuki and Lowe 2007). Despite providing an adequate level of safety through technical means, it requires credible and reliable assessment of occupational risk. Thanks to this, it is possible to understand residual risk (Azadeh-Fard et al. 2015), and not only fulfil administrative bureaucratic requirements (Swuste 2008). In occupational risk assessment, the main problem is the high subjectivity of this procedure (Fauquet-Alekhine et al. 2018) and the resulting necessity to combine quantitative and qualitative information in safety assessments. The methods used to assess occupational risk were most often adopted from the area of quantitative risk estimation, which required adjusting their classification system for the purposes of assessing occupational risks. An example of such a method may be Risk Score (Kokangül et al. 2017; Ozdemir et al. 2017). Due to its simple construction, this method is one of the most frequently used methods in occupational risk assessments. Its simple design is also its disadvantage since in order to determine the cumulative value, individual factors are classified into qualitative measures, thereby making significant simplifications that may give a misleading picture of the resultant risk for individual hazards. This is noted by both practitioners and theoreticians of occupational safety, who search for ways to formalize the process of estimating the level of occupational risk and formulate general recommendations for the entire process of risk analysis and assessment. These recommendations indicate, among others, the need to include employees in the occupational risk assessment process, which results in both knowledge-generation and raising awareness, which are necessary to shape the organizational safety climate (Yule et al. 2007). Including employees in the analysis and assessment of occupational risk, however, requires the inclusion of diverse opinions resulting from their different (sometimes misleading) perception of occupational hazards.

The aim of the article is to present the method of occupational risk assessment which enables the integration of objective factors related to hazards present in the workplace with subjective employee evaluations. The method is called grey occupational risk assessment model (GORAM). This method will use the grey classification algorithm in combination with Risk Score. In order to determine the validity of the occupational risk estimation criteria, the AHP method was used.

The article is organized as follows. Section 1 presents current theoretical and practical issues related to the analysis and assessment of occupational risk. Section 2 describes issues related to grey uncertainty in occupational risk assessment. Section 3 shows the designed method of GORAM. Section 4 presents a case study using the developed GORAM method. Finally, Sect. 5 summarizes the obtained research results and indicates the potential directions for further research.

## 2 Grey system theory in occupational risk assessment

The essence of occupational risk assessment is the appropriate evaluation of individual hazards according to the adopted risk assessment criteria, which is not easy even in the case of relatively measurable risk factors (Kuempel et al. 2015). A characteristic feature of occupational risk and during the process of its operationalization is

the phenomenon of uncertainty (Aven 2016). Uncertainty in assessing occupational risk is compounded by a number of factors that impede the identification of events which are difficult to predict, non-linear, based on human psychological patterns. In the literature, this issue is described in the black swan theory (Aven 2015). According to this theory, events which are very unlikely to occur are usually treated by people as impossible, despite the fact that they happen and often turn out to be the most important factors in a given situation. Their significance is verified only empirically. Thus, the risk is underestimated and is considered possible only after the occurrence of a specific event, according to the principle of creeping determinism, and given a specific rank (Lybeck 2017). Therefore, there is a need to introduce mechanisms for occupational risk analysis that allow for solving the problem of unlikely scenarios and modeling the uncertainty associated with it.

Managers in modern organizations are forced to make decisions in conditions of increasing uncertainty (Luhmann 2018). This state of affairs is the premise for developing new methods of modeling and managing uncertainty in decision-making processes (Beach and Lipshitz 2017). The most important approaches to modeling information uncertainty include statistical methods (Berger 2013), methods based on fuzzy logic (Klir and Yuan 1995), methods based on Bayesian data analysis (Rezaei 2015), or methods based on rough sets theory (Yao 2010).

The information uncertainty in the decision-making process can be a result of two reasons. First of all, from the generating excess information about the decision-oriented situation, and secondly, because of the lack of information about it (Karr-Wisniewski and Lu 2010). In the case of information overload, the intensive methodology is currently Big Data, using, among others, statistical approach (LaValle et al. 2011). Many well-known uncertainty modeling methods remain unreliable in the case of information shortage (Liu et al. 2016).

The answer to these difficulties is the theory of gray systems. It was developed as a methodology contrary to the Big Data concept (Mierzwiak et al. 2019). A special application of GST is found in the modeling of systems with a high level of uncertainty (Liu and Yuan 2010). This uncertainty is connected with the incompleteness of information about the system (Akinci and Sadler-Smith 2012), the sparseness of information (Hodgkinson et al. 2009), or the risk of incorrect information (Xie 2017; Mierzwiak et al. 2018).

Over the past 30 years, the Grey System Theory has found a number of applications (Bouzon et al. 2018; Sun et al. 2018; Delcea 2015). The GST methods are used to solve a wide range of problems in the areas of engineering sciences, social studies and economics.

The Grey Systems Theory may be applied in the case of occupational risk assessment. This is due to the fact that in occupational risk assessment two types of hazards may be distinguished. The first of which constitutes threats that can be measured objectively. One example of such hazards is the exposure to various substances and chemicals used at a given workplace. This threat can be objectively quantified. Measures reflecting these hazards include, for example, maximum allowable concentrations (NDS) and maximum allowable levels (NDN). The second group of threats concerns threats that cannot be directly quantified. One example of this type of hazard is the risk of falling from the same level. From the point of view of

managing the occupational safety and health system at a given workplace, it is possible to use tools that quantify some variables, e.g., the use of statistical tools makes it possible to determine the likelihood of falling from a given level in a particular workplace.

However, in the face of this type of analysis, a number of objections are raised. The use of statistical tools for risk assessment (which is not always possible due to the lack of sufficient information) is alleged to exclude the natural diversity of employees. Thus, there exists a need to differentiate occupational risk assessments at a given workplace according to, for example, employee age, sex, or level of competence. At the same time, employees differ in terms of subjective assessments of parameters such as the probability of the occurrence of an undesired event or the level of exposure to the selected harmful factor. There is a common situation in which, for example, one of the employees in a given position assesses that the probability of falling from the same level is negligible, and another employee finds it quite probable.

The problem, indicated in the literature on the subject, is the necessity to individualize occupational risk assessments at a given position and to take into account the subjective perception of threats by individual employees. The described situation constitutes the theoretical basis for the application of tools which take into account subjective, difficult to quantify, and uncertain information in the process of occupational risk assessment. The presented arguments provide the basis for using the Grey Systems Theory methods in occupational risk assessment.

### **3 Foundation of the grey occupational risk assessment model**

This section presents the way of proceeding in the GORAM method. The structure of the GORAM method is presented first. This structure reflects the assumption that the analysis of occupational risk is a problem of classifying individual threats to specific groups in relation to the adopted set of criteria. Secondly, the problem of determining the validity of risk assessment criteria by the well-known AHP method is discussed. Thirdly, the principles of assessing measurable and non-measurable threats with the use of the assessment scales adopted in the GORAM method are discussed. Finally, by means of the designated weights and the assessment of threatening factors, it was subsequently possible to present the hazard classification principles using the Grey Decision Method (GDM) based on the weight whitening functions. The model functions that were defined for the presented GORAM method are shown. The classification algorithm of the GORAM method is presented.

#### **3.1 Structure of the GORAM method**

The proposed new occupational risk assessment method is based on the use of the Grey Decision Model (Ruan and Wang 2017; Wu et al. 2018) in the decision-making process related to hazards identified at a given workplace. The method was called the GORAM. The main advantage of the method is the ability

to combine objective (measurable) factors with subjective factors (qualitative, related to expert judgment) in the risk assessment process. This method can be used in multi-aspect occupational risk assessment of complex and uncertain social engineering systems. The structure of the GORAM method shows Fig. 1.

According to Fig. 1, three basic components of the decision-making process have been distinguished:

- (1) Hazardous Event—individual hazards identified at the workplace ( $n_i$ ),
- (2) Decision Making Criteria—the model assumed three decision-making criteria—Likelihood of Hazardous Event ( $j_1$ ), The Exposure Factor ( $j_2$ ), and Possible Consequence ( $j_3$ ). The indicated decision-making criteria derive from the most popular method in the risk assessment called the Risk Score method,
- (3) Grouping indicator  $k$ —it is assumed that as a result of the decision-making procedure it will be possible to obtain the following values:  $k = 1$ —very high risk (unacceptable),  $k = 2$ —high risk (remedies required),  $k = 3$ —medium risk (tolerated—monitoring required),  $k = 4$ —low risk (acceptable—remedies not required).

### 3.2 Determination of validity of risk assessment criteria in the GORAM method

The first stage of the GORAM method is to determine the importance of hazard classification criteria. Weights can be determined using a number of methods—e.g. the Thurstone's method, the modified Thurstone's method or the AHP method (Wiecek-Janka et al. 2019). In the presented method variant, the AHP

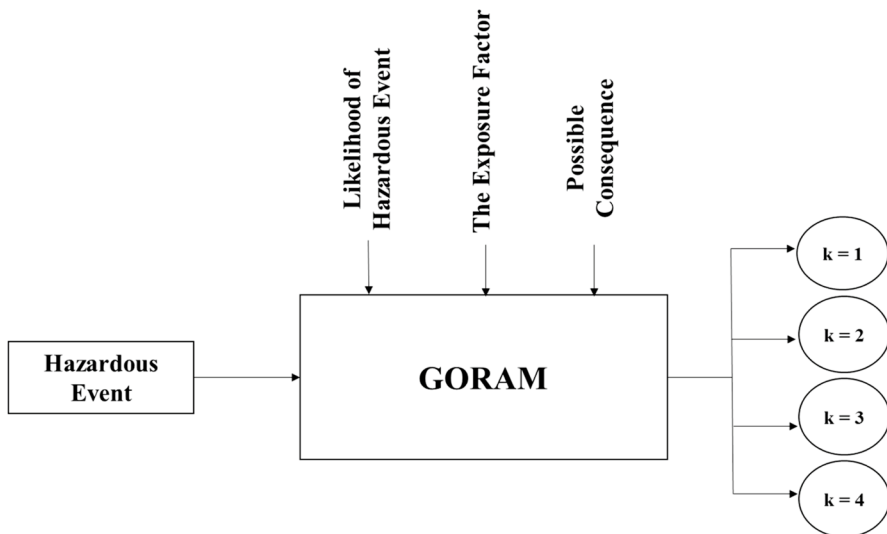


Fig. 1 Structure of the GORAM method

method was used. The choice of the AHP method was dictated by its simplicity and high popularity (Deng and Deng 2019; Vaishnavi et al. 2017; Ho and Ma 2018).

The scale of relative assessments of the validity of the decision-making criteria is presented in Table 1.

The first stage of the AHP method is to develop a matrix to compare the criteria in pairs. This operation is performed by creating a matrix in dimensions  $n \times n$ , where  $n$  is the number of criteria undergoing validation. Each  $a_{jk}$  element of the created matrix reflects the importance of  $j$ th criterion relative to the  $k$ th criterion. If the value of  $a_{jk}$  is greater than 1.00 it means that the  $j$ th criterion is more important than  $k$ th criterion. If, however,  $a_{jk}$  is less than 1.00, then the  $j$ th criterion is less important than the  $k$ th criterion.  $a_{jk}$  value of 1.00 means that both criteria have the same validity. There must be such a dependence between the elements  $a_{jk}$  and  $a_{kj}$  that  $a_{jk} \times a_{kj} = 1$ .

The second stage of the AHP method is the normalized comparison of criteria in pairs. This operation is based on such normalization of matrix elements that the sum of elements in each column is equal to one, according to the following formula:

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{l=1}^m a_{lk}} \tag{1}$$

The final stage of the AHP method is to determine the vector of weights ( $m$ -dimensional column vector) for the evaluated criteria. This vector is determined according to the following formula:

$$w_j = \frac{\sum_{l=1}^m \bar{a}_{jl}}{m} \tag{2}$$

Assuming that three decision-making criteria in the GORAM method occur, three weights  $\eta_1, \eta_2, \eta_3$  are obtained, fulfilling the following properties:

$$\eta_1 + \eta_2 + \eta_3 = 1 \tag{3}$$

### 3.3 Assessment of hazards with regard to the adopted classification criteria

The next stage of the GORAM method (after determining the weight of the decision-making criteria using the AHP method) is conducting research on the group of employees with the use of the questionnaire in terms of individual classification criteria, i.e.

**Table 1** The model of awarding individual criteria in the AHP method

Value of $a_{jk}$	Interpretation
9	$j$ is absolutely more important than $k$
7	$j$ is strongly more important than $k$
5	$j$ is more important than $k$
3	$j$ is slightly more important than $k$
1	$j$ and $k$ are equally important

**Table 2** The rating scale for individual decision-making criteria

Weight of the criterion	Criterion 1 (likelihood of hazardous event)	Criterion 2 (the exposure factor)	Criterion 3 (possible consequence)
1	Only theoretically possible	Rare	Minor (providing first aid)
2	Very unlikely	Occasionally	Moderate (absence from work)
3	Unlikely	A few times a week	Major (severe injuries)
4	Medium likelihood	Everyday	Disaster (one or several deaths)
5	Very likely	Permanent	Serious disaster (many deaths)

**Table 3** The way of rescaling a variable on a linguistic scale

Value	$V \leq 20$	$20 < V \leq 40$	$40 < V \leq 60$	$60 < V \leq 80$	$80 < V \leq 100$
Linguistic scale	Very small (1)	Small (2)	Medium (3)	High (4)	Very high (5)

Likelihood of Hazardous Event, The Exposure Factor and Possible Consequence related to particular hazards. The survey is conducted only for risk factors that are not subject to direct quantification. Table 2 presents the proposed scale of assessments for individual decision-making criteria.

For objectified elements of occupational risk assessment such as exposure to certain toxic substances (which may result from the work schedule in a given position or workplace measurements), the results should be scaled to a linguistic scale.

An example of rescaling a variable that takes values from the range 0–100 is shown in Table 3.

### 3.4 The classification of hazards using the grey decision model

The next step in the proposed method is to determine the weight whitening function for each of the hazard factors analyzed ( $n_1, n_2, \dots, n_n$ ). The concept of weight whitening function defined in grey space was used (Mierzwiak et al. 2018). These functions are intended to reflect the preferences of experts regarding the impact of occupational hazards on individual risk assessment criteria. In the method, there was adopted the following analytical form of the weight whitening function:

$$f_i^1(x_j) = \frac{x}{5} \quad \text{for } 0 \leq x \leq 5 \quad (4)$$

$$f_i^2(x_j) = \begin{cases} \frac{x}{3.33} & \text{for } 0 \leq x \leq 3.33 \\ \frac{5-x}{1.67} & \text{for } 3.33 < x \leq 5 \end{cases} \quad (5)$$

$$f_i^3(x_j) = \begin{cases} \frac{x}{1.67} & \text{for } 0 \leq x \leq 1.67 \\ \frac{5-x}{3.33} & \text{for } 1.67 < x \leq 5 \end{cases} \quad (6)$$

$$f_i^4(x_j) = \frac{5-x}{5} \quad \text{for } 0 \leq x \leq 5 \quad (7)$$

After determining the weight whitening function, a grey cluster coefficient was defined for each hazard factor using the formula (8):

$$\sigma^k = \sum_{j=1}^m f_i^k(x_j) * \eta_j \quad (8)$$

By replacing in the formula (8) the value of  $k$ , its possible realizations obtain the following formulas:

$$\sigma^1 = \sum_{j=1}^m f_i^1(x_j) * \eta_j \quad (9)$$

$$\sigma^2 = \sum_{j=1}^m f_i^2(x_j) * \eta_j \quad (10)$$

$$\sigma^3 = \sum_{j=1}^m f_i^3(x_j) * \eta_j \quad (11)$$

$$\sigma^4 = \sum_{j=1}^m f_i^4(x_j) * \eta_j \quad (12)$$

In the next stage, after calculating  $\sigma^1, \sigma^2, \sigma^3, \sigma^4$ , the maximum grey cluster coefficient was determined using the following formula:

$$\sigma^{k^*} = \max\{\sigma^k\} \quad \text{for } 1 \leq k \leq s \quad (13)$$

As a result, in the presented decision-making procedure for each hazard the value of  $k$  from the set  $\{1; 2; 3; 4\}$  is assigned. The value of  $k=1$  means that the risk is very high (unacceptable),  $k=2$ , the risk is high (required remedies),  $k=3$ , the risk is medium (tolerable—monitoring required),  $k=4$ , the risk is low (no remedies required).

## 4 Case study

The GORAM will be presented on the example of a risk assessment at the workplace of a mechanic in the technical department of the selected manufacturing enterprise. The nature of the activities performed means that the mechanic spends most of the day in the serviced department and works in the conditions present in these workplaces. The mechanic also performs workshop work. Work in this position is



performed on one's own and under supervision. While performing the activities, the mechanics cooperate with the management of the departments. Mechanics use individual and collective protection equipment. Personal protective equipment includes gloves, footwear and work clothes. The collective protection measures include basic mechanical ventilation and fire alarm system. Table 4 presents the scope of tasks performed as a mechanic.

When working as a mechanic, sets of hand tools are used, such as spanners, screwdrivers, hammers, clamps, etc., hydraulic expander, bearing pullers, etc. The materials used in this position include spare parts, lubricants, oils, cleaning agents, paints, varnishes as well as hazardous substances and mixtures according to the list in the department. Table 5 presents a set of hazards occurring at the mechanic's workstation.

The first stage of the GORAM method is to determine the weight of the decision-making criteria, i.e. for Likelihood of Hazardous Event, The Exposure Factor and for Possible Consequence. In the presented example of occupational risk assessment for a mechanic in the technical department of the selected production enterprise, the procedure of determining the weight of the decision-making criteria using the AHP method was carried out. The assessment of the validity of the criteria in pairs relative to each other was carried out on the basis of the expert knowledge of the technical department manager, in which the mechanic's positions are located.

The pairwise comparison matrix is shown in Table 6.

In accordance with the conducted analysis of the importance of the decision-making criteria relative to each other, it turned out that the expert assigned the greatest importance to the Possible Consequence criterion, and the lowest to the Exposure Factor criterion. In Table 7, the normalized pairwise comparison matrix is presented.

The result of weighing the decision-making criteria of the grey occupational risk assessment model for the position of a mechanic in the technical department of the manufacturing enterprise is presented in Table 8.

As a result of the conducted procedure for weighing the decision-making criteria using the AHP method, Possible Consequence ( $\eta_3=0.5736$ ) was considered the most important criterion, the second criterion was Likelihood of Hazardous Event

**Table 4** The scope of tasks performed as a mechanic

No.	The scope of tasks performed
1	Repairs of machines and devices
2	Manual and mechanical transport of machine parts and assemblies
3	Disassembly and assembly of machine parts and assemblies
4	Performing dangerous work at a height above 1 m
5	Inspections and maintenance of subordinate machines and devices
6	Operating forklift trucks, cranes, and self-propelled lifting equipment, machines and power tools in the department's equipment
7	Computer skills and data processing
8	Operating power tools

**Table 5** Hazards occurring at the mechanic's workstation

No.	Possible hazards at the workplace
1	Tripping, slipping—falling on the same level
2	Electric shock when operating power tools and other machines under voltage, repairs and maintenance
3	Working in a standing position and on the move, variable positions
4	Hot metal particle burns during welding
5	Falling from a height—working on landings, platforms, ladders and elevators
6	Dust in eyes—grinding and assembly work
7	Contact with chemicals—oils, greases, rust removers
8	Injuries caused by used hand tools, cuts, pricks, abrasions
9	Traffic accidents—driving a forklift
10	A non-ergonomic computer workstation
11	Noise
12	Possible toxic action of the substance through the respiratory tract
13	Possible eye, respiratory tract and skin irritation
14	Possible carcinogenic effects
15	Possible sensitizing effects, by inhalation and in contact with the skin

**Table 6** Pairwise comparison matrix

	Likelihood of hazardous event	The exposure factor	Possible consequence	Overall
Likelihood of hazardous event	1.00	3.00	0.33	4.33
The exposure factor	0.33	1.00	0.33	1.67
Possible consequence	3.00	3.00	1.00	7.00
Overall	4.33	7.00	1.67	13.00

**Table 7** The normalized pairwise comparison matrix

	Likelihood of hazardous event	The exposure factor	Possible consequence	Weight
Likelihood of hazardous event	0.2308	0.4286	0.2000	0.2864
The exposure factor	0.0769	0.1429	0.2000	0.1399
Possible consequence	0.6923	0.4286	0.6000	0.5736
Overall	1.0000	1.0000	1.0000	1.0000

**Table 8** Determining the weights for decision-making criteria

Criterion ( <i>j</i> )	Likelihood of hazardous event	The exposure factor	Possible consequence
Weight of the criterion ( $\eta_j$ )	0.2864	0.1399	0.5736

( $\eta_1=0.2864$ ), and the Exposure Factor turned out to be the least important criterion ( $\eta_2=0.1399$ ).

The next step in the GORAM method is to determine the value (on a scale of 1–5) for each of the decision-making criteria assigned to all hazards occurring in the workplace. Taking into consideration the fact that the company in question has been operating for only 3 years, it is impossible to statistically determine the Likelihood of Hazardous Event for individual hazards. The situation of the impossibility of applying statistical tools is typical for many enterprises, which may result from the short period of the company's operation on the market (and thus the company does not have a sufficiently large empirical base regarding accidents at individual workplaces to conduct statistical surveys), relatively frequent reorganization or improvement of workplaces or companies do not keep this kind of statistics. The GORAM method finds a special application in this situation because it excludes the necessity of using statistical tools. In the situation of the absence of a sufficiently broad empirical base in the GORAM method, the opinions of respondents working at a given workplace are used. At the same time, it emphasizes the possibility of differentiating the employees' assessment in accordance with the probability of the occurrence of individual hazards—e.g. due to sex, age, or competences. In the case of the Exposure Factor criterion for some of the hazards, it can be objectively determined. For example, the work schedule shows the level of exposure to possible toxic effects of the substance through the respiratory tract or dust in eyes. The level of noise can be determined objectively by performing a workplace measurement. Only for some of the hazards, The Exposure Factor is subjective—respondents working as mechanics in the technical department were asked to identify them. In the case of the Possible Consequence criterion, there are a number of factors affecting its value for each of the hazards. In the presented example, this criterion was treated as subjective and it was included in the survey sheet.

Ten respondents working as mechanics participated in the survey. The respondents' task was to assess the validity for each of the subjective criteria for each of the analyzed hazards.

Table 9 presents the results of the conducted survey for individual hazards.

The next stage of the GORAM method was to determine the value of grey cluster coefficient  $\sigma^1$ ,  $\sigma^2$ ,  $\sigma^3$ ,  $\sigma^4$  for each of the hazards based on the weighting weight function determined by formulas (4), (5), (6), (7).

Table 10 presents the results of the grey cluster coefficient for all hazards present at the position of a mechanic in the technical department of the examined production enterprise.

The final stage of the GORAM method is the calculation of the maximum value of the Grey Cluster Coefficient for each hazard. The upper index of the maximum value  $\sigma^k$  for each hazard determines the classification of a given hazard to the group  $k=1, 2, 3$  or 4. The results of the occupational risk assessment carried out among mechanics in the examined enterprise using the GORAM method are presented in Table 11.

As a result of the occupational risk assessment carried out among mechanics using the GORAM method, it was found that in case of seven hazards ( $n_3, n_6, n_7, n_{12}, n_{13}, n_{14}, n_{15}$ ) no remedies are required—the classified risks belong to the low

**Table 9** The juxtaposition of survey results carried out among mechanics

No.	Hazardous event ( $n_i$ )	Likelihood of hazardous event	The exposure factor	Possible consequence
1	Tripping, slipping—falling on the same level	2	4	2
2	Electric shock when operating power tools and other machines under voltage, repairs and maintenance	2	1	3
3	Working in a standing position and on the move, variable positions	1	2	1
4	Hot metal particles burns during welding	2	1	2
5	Falling from a height—working on landings, platforms, ladders and elevators	1	1	2
6	Dust in eyes—grinding and assembly work	1	1	1
7	Contact with chemicals—oils, greases, rust removers	1	1	1
8	Injuries caused by used hand tools, cuts, pricks, abrasions	1	1	2
9	Traffic accidents—driving a forklift	2	2	3
10	A non-ergonomic computer workstation	2	3	1
11	Noise	1	1	2
12	Possible toxic action of the substance through the respiratory tract	1	1	1
13	Possible eye, respiratory tract and skin irritation	1	1	1
14	Possible carcinogenic effects	2	1	1
15	Possible sensitizing effects, by inhalation and in contact with skin	1	2	1

**Table 10** The values of the grey cluster coefficient for all examined hazards at the position of a mechanic

Hazardous event ( $n_i$ )	$\sigma^1$	$\sigma^2$	$\sigma^3$	$\sigma^4$
1	0.456	0.600	0.817	0.544
2	0.487	0.731	0.686	0.513
3	0.228	0.342	0.641	0.772
4	0.372	0.559	0.859	0.628
5	0.315	0.473	0.772	0.685
6	0.200	0.300	0.599	0.800
7	0.200	0.300	0.599	0.800
8	0.315	0.473	0.772	0.685
9	0.515	0.773	0.729	0.485
10	0.313	0.470	0.686	0.687
11	0.315	0.473	0.772	0.685
12	0.200	0.300	0.599	0.800
13	0.200	0.300	0.599	0.800
14	0.257	0.386	0.685	0.743
15	0.228	0.342	0.641	0.772

**Table 11** The results of the occupational risk assessment at the position of a mechanic

No.	Hazardous event ( $n_i$ )	$k$	Risk category
1	Tripping, slipping—falling on the same level	3	Medium risk
2	Electric shock when operating power tools and other machines under voltage, repairs and maintenance	2	High risk
3	Working in a standing position and on the move, variable positions	4	Low risk
4	Hot metal particles burns during welding	3	Medium risk
5	Falling from a height—working on landings, platforms, ladders and elevators	3	Medium risk
6	Dust in eyes—grinding and assembly work	4	low risk
7	Contact with chemicals—oils, greases, rust removers	4	low risk
8	Injuries caused by used hand tools, cuts, pricks, abrasions	3	Medium risk
9	Traffic accidents—driving a forklift	2	High risk
10	A non-ergonomic computer workstation	3	Medium risk
11	Noise	3	Medium risk
12	Possible toxic action of the substance through the respiratory tract	4	Low risk
13	Possible eye, respiratory tract and skin irritation	4	Low risk
14	Possible carcinogenic effects	4	Low risk
15	Possible sensitizing effects, by inhalation and in contact with skin	4	Low risk

risk category. Six hazards ( $n_1, n_4, n_5, n_8, n_{10}, n_{11}$ ) were classified in the medium risk category, which should be monitored. Two hazards ( $n_2, n_9$ ) were classified as high risk and require remedial measures. None of the hazards were classified in the very high risk category, which would be unacceptable.

## 5 Conclusions

In the article, the authors proposed a new method of risk assessment using the theoretical achievements of the theory of grey systems. The method, based on the grey decision model (GDM), was named the grey occupational risk assessment model (GORAM). The proposed method is a response to the problem identified in the literature regarding the lack of risk assessment methods enabling a joint, multi-criteria assessment of quantifiable risk factors with difficult to quantify subjective employee assessments.

The GORAM method can be used in occupational risk assessment in every enterprise and in every workplace. Its use will be particularly useful in enterprises that do not function for a long time on the market (they do not have extensive empirical observation databases regarding risk at individual workplaces). Furthermore, the high practical usefulness of the GORAM method can be demonstrated in situations of diverse employee characteristics, especially in terms of sex, age, condition or competence. Especially then, it becomes important to include employee with their subjective and uncertain assessments in the development of the occupational risk assessment. Thus, the GORAM method is a response to the need to appreciate the human factor in the process of developing an occupational risk assessment.

At the same time, the GORAM method has some limitations. In the situation of enterprises operating on the market for a long time, which have an extensive empirical base of observations regarding risk factors at individual workplaces, the GORAM method will only fulfill a complementary function to the commonly used methods of occupational risk assessment.

The GORAM method will be even more useful in case of information insecurity regarding individual components of occupational risk assessment. The greater the information insecurity, the more useful the method is.

The instrumentation of the grey systems theory used in the GORAM method shows the potential for further improvement. This improvement may refer to the concept of greyspace developed by the authors of this article, or applications in the grey numbers algebra method.

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