Selection of candidates in the mining industry based on the application of the SWARA and the MULTIMOORA methods

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The goal of this manuscript is to provide an efficient approach to the process of the recruitment and selection of candidates in the mining industry. The proposed approach is based on the use of MCDM models for personnel selection in the mining industry; the approach will provide an MCDM model for the personnel selection based on the SWARA ant the MULTIMOORA methods. The efficiency and usability of the proposed approach are considered on the numerical example of the selection of a candidate for the position of the mining engineer for underground mining.

***Key words**: recruitment and selection of candidates, mining engineer for underground mining, MCDM, SWARA, MULTIMOORA*

Introduction

Today's business conditions are certainly characterized by rapid and unpredictable changes in both the environment and the Company. In these business conditions, companies primarily need to remain flexible in order to manage to follow up changes in the environment, maintain their competitive advantage and remain competitive. Therefore, human resources in a company are strategically managed by defining a strategy of the development of human resources in the company, so it can be said that human resources in a company unquestionably become a part of the strategic management of the company.

The recruitment and selection of personnel are a part of human resources and play an extremely important role in the management of human resources. Recruitment as a process is aimed at attracting and acquiring qualified candidates in a number which allows the company to select the best ones amongst them with the aim to fill the vacant positions. Candidate selection represents a process in which the final selection of the best candidates is performed with the aim to fill a certain position. During the recruitment and selection process different methods and techniques helping decision makers to predict how successful a candidate will be in his/her future workplace are applied. (Bogićević Milikić, 2006; Petkovic et al.; Urošević and Sajfert, 2012).

According to Cook and Cripps (2005), the personnel recruitment and selection process represents a very complex and demanding process primarily due to the fact that, in the hiring process, decision makers are forced to select candidates who will be hired for a period of up to 10 years in a very short period of time, which usually ranges from 30 minutes to 3 days, and to do so on the basis of the information obtained in this short period of time.

The personnel recruitment and selection process always first begin by determining the characteristics of a particular job, i.e. a job analysis is carried out, upon completion of which, the process of the recruitment, selection and evaluation of candidates who best meet the requirements of a particular job follows. We should bear in mind the fact that, today, modern companies fill part of their vacant positions by conducting an internal selection that includes finding personnel within the company i.e. among their employees. However, if there is an insufficient number of qualified candidates for filling the job positions that are expected to be vacant, employers predict an offer of external candidates who are not the employees of the organization (Desler, 2007).

A significant number of studies and researches into the problem of the recruitment and selection of personnel have been approached by using psychometric-test-, cognitive-test-, personality-test- and intelligence-test- and structured interviews (Campion et al., 1988; Wright et al., 1989; Morgeson et al., 2007; Kline, 2000; Kruyen et al., 2012; Robertson and Smith, 2001).

Noe et al. (2006) provide an overview of nine different types of the selection methods currently used in organizations: the interview, checking references, the physical ability test, the test of cognitive ability, personality tests, samples of work tests, honesty tests and tests for drug use. Based on one of these methods, many candidates can be rejected for the job. These methods can be used as a guide in deciding which test to use

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for certain purposes. It is important to note that decision makers do not need to use one test only; in fact, the department for the assessment of human resources already uses many different forms of tests lasting for a period of two to three days, with the aim to learn more about candidates for important executive positions. Such tests result in highly accurate predictions.

In recent times, along with skills and personality characteristics as the key sources of individual differences in the area of professional selection, the concept of competence has been introduced. A competence could be determined as one's ability to successfully perform a job or a specific task. It is the ability of a person to demonstrate that he/she can perform jobs, tasks or activities according to the required standards. Competences represent a set of skills, knowledge and attitudes for personal development, employment and participation. They allow people to fulfill their objectives in finding suitable employment, but also to be able to keep it and take part in social life. They could be said to stand for a precondition for work performance (Urošević, 2012).

Reviewing the literature, it can be noted that many multiple criteria decision making methods (MCDM) have been proposed. Plenty of papers are devoted to the comparison and review of the MCDM methods. A good overview of the MCDM methods is presented in recent papers by Zavadskas et al. (2014) and Mardani et al. (2015), while a good overview of Professor Willem Karel M. Brewer's research in the field of input-output analysis and Multi-Objective Optimization is presented by Masri (2014). Also, there are the papers in the field of operational research that have been devoted to the application of the ordinal dominance theory for ranking such as Brauers and Zavadskas (2014).

Part of the study to the problem of personnel selection approaches is conducted by applying MCDM methods, such as personnel selection based on computing with words and fuzzy MULTIMOORA (Baležentis et al., 2012), the fuzzy MCDM approach for personnel selection (Dursun and Karsak, 2009), a rough-set-based approach to designing an expert system for personnel selection (Akhlaghi, 2011), the GRA-based intuitionistic fuzzy multi-criteria group decision-making method for personnel selection (Zhang and Liu, 2011), the personnel selection fuzzy model (Petrovic-Lazarevic, 2001), personnel selection by applying the analytic network process and fuzzy data envelopment analysis approaches (Lin, 2010), the fuzzy AHP approach to the personnel selection problem (Güngör et al., 2009), an extension of the TOPSIS method for the R&D personnel selection problem with an interval grey number (Wang, 2009) and the fuzzy multi-criteria decision-making approach for solving the bi-objective personnel assignment problem (Huang et al., 2009).

The manuscript is aimed at providing an effective MCDM model for the selection of personnel for the position of the mining engineer for underground mining – a trainee in the mining industry. The MCDM model will be based on the application of the SWARA and the MULTIMOORA methods. The SWARA method is herein used to determine the weights of certain criteria, while the MULTIMOORA method is of use in order to rank alternatives – in our case, the candidate – for the position of the mining engineer for underground mining.

Therefore, the manuscript is structured as follows: in Section 1, a set of the evaluation criteria is presented; Section 2 shows the computational procedure of the SWARA method, whereas Section 3 is an account of the computational procedure of the MULTIMOORA method; finally, Section 4 accounts for a numerical example.

1. Set of the evaluation criteria for the position of the mining engineer

Mining engineers deal with the exploration, exploitation and refinement of metal and non-metallic mineral raw materials, special activities in building various geotechnical objects and the consolidation of objects and terrain as well as operations in terms of environmental protection and waste recycling.

In order for a person to be successful and pleased to work as a mining engineer, it is desirable that he/she should love nature and outdoor living, be dynamic and good at coping with the space. His/her capability of graphic visualization and the presentation of spatial relations, which will serve them well when drafting sketches and graphics, is of importance, too. It is desirable that they show a tendency towards the natural sciences, be interested in mechanics and general technical disciplines. They would also be considered to have an advantage should they reveal their ability to make decisions in situations of a crisis as well as their capability of working under stress. Their working habits, discipline, accuracy and precision are also welcome, as much as their communication and presentation abilities and skills are. (Grupa autora, 1999).

For the position of the mining engineer for underground mining – a trainee, the following knowledge, skills and competencies are necessary:

- the detailed knowledge of the technological process of the surface and underground exploitation of mineral resources,
- mastering the techniques of designing mines with surface and underground exploitation,
- work organization, management and the administration of the system,
- mastering the skills of designing and constructing underground spaces, traffic and utility facilities, as well as special-purpose facilities,
- familiarity with the tools for geodetic measurements, mining measurements,

- the knowledge of computer use and utilization, measurements, regulations and other ancillary pieces of equipment,
- thorough knowledge and understanding of computing, the computer-integrated technology, the systems science and systems engineering,
- the basic knowledge of creative engineering tools (method), the characteristics and possibilities of their application,
- the development of their habits of permanently being informed, monitoring and the implementation of innovations in the profession,
- the development of their skills of communication with the working environment,
- the development of their professional ethics,
- their responsibility and accuracy at work, etc.

In terms of the knowledge, competencies and personal characteristics sought by employers in the process of the selection of candidates for the position of the mining engineer, the most sought ones are:

- the possession of general engineering education,
- the ability to grasp the mechanical relations,
- the ability to use information and communication technologies,
- the possession of the knowledge of foreign languages for the purpose of communication and keeping themselves up with the world literature,

as well as many others, namely: accuracy and precision; the tendency towards fast-paced work; the tendency towards finding practical solutions; the inclination to problem solving; resourcefulness; independence; caution; research curiosity; creativity/innovativity (their ability to create); systematicity and organization; communication skills; the ability to reason; the ability to perceive spatial relationships; stress tolerance and emotional stability.

Therefore, on the basis of the foregoing and the studied literature, the authors of this paper propose the following set of criteria for the position of the mining engineer for underground mining – a trainee, as displayed in Table 1 below.

Tab. 1. The set of the evaluation criteria.

	Criteria	Designation	Annotation
C_1	Education and knowledge	EK	Completed formal education in the mining orientation; the ability to overcome mechanical relations; an engineering approach to problems.
C_2	Personal characteristics	PC	Autonomy; carefulness; communicativeness; ability to perceive spatial relationships; stress tolerance; emotional stability.
C_3	Organizational capability	OC	The tendency towards finding practical solutions; resourcefulness; systematicity; organizational ability.
C_4	Physical ability	PA	The physical capability of and stamina for hard work; a good health condition.
C_5	Computer skills	CS	The capability of using ICT; the knowledge of the SW packages intended for mining.
C_6	Foreign languages	FL	Communication and the study of the world literature, with a special emphasis on the English language.
C_7	The research spirit	RS	The creative ability; research curiosity.

2. The computational procedure of the SWARA method

The Step-wise Weight Assessment Ratio Analysis (SWARA) method was proposed by Kersuliene et al. (2010). The SWARA is a newly-proposed method; however, it is also used for solving many problems, such as: a rational dispute resolution (Kersuliene et al., 2010), an architect selection (Kersuliene and Turskis, 2011), the design of products (Zolfani et al., 2013), the selection of a packaging design (Stanujkic et al., 2015), a machine tool selection (Aghdaie et al., 2013), the prioritizing of the sustainability assessment indicators of the energy system (Zolfani and Saparauskas 2013), personnel selection (Zolfani and Banihashemi 2014)), investments (Hashemkhani Zolfani and Bahrami, 2014) and choosing the optimal method of the mechanical longitudinal ventilation of tunnel pollutants (Hashemkhani Zolfani et al., 2013).

Based on Kersuliene et al. (2010) and Stanujkic et al. (2015), the process of determining the relative weights of the criteria by applying the SWARA method can accurately be shown through the following steps:

Step 1. Sort the evaluation criteria in descending order, based on their expected significances.

Step 2. Starting from the second criterion, make the respondent express the relative importance of the criterion j in relation to the previous (j-1) criterion, and do this for each particular criterion. According to Kersuliene et al. (2010), this ratio is called the Comparative importance of average value, s_j.

Step 3. Determine the coefficient k_j as follows:

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases}. \tag{1}$$

Step 4. Determine the recalculated weight q_j as follows:

$$q_j = \begin{cases} 1 & j = 1 \\ \dfrac{k_{j-1}}{k_j} & j > 1 \end{cases}. \tag{2}$$

Step 5. Determine the relative weights of the evaluation criteria as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k}, \tag{3}$$

where w_j denotes the relative weight of the j-th criterion, n denotes the number of such criteria.

3. The computational procedure of the MULTIMOORA method

The Multi-Objective Optimization by Ratio Analysis plus Full Multiplicative Form (MULTIMOORA) method was proposed by Brauers and Zavadskas (2010a), based on the previous researches (Brauers, 2004; Brauers and Zavadskas, 2006). This method has been proposed in order to cope with subjectivity problems arising from the use of weights in a number of the known MCDM methods (Balezentis et al., 2010).

The usability of the MULTIMOORA method has been successfully demonstrated and applied in numerous studies for the solving of a wide range of problems, such as those related to economics and regional development (Brauers and Zavadskas, 2010b; Brauers and Zavadskas, 2011; Brauers and Ginevicius, 2010; Brauers et al., 2014; Brauers and Ginevicius 2013), mining (Stanujkic et al., 2014) a choice of a bank loan (Brauers and Zavadskas, 2011), personnel selection (Balezentis et al., 2012a; Balezentis et al., 2012b), the prioritization of energy crops (Balezentiene et al., 2013), construction (Kracka and Zavadskas, 2013; Zavadskas et al., 2013a; Brauers et al. 2013; Lazauskas et al., 2015), sustainability and corporate social responsibility (Stankeviciene et al., 2014; Stankeviciene and Cepulyte, 2014) and the assessment of heating technologies in the heating sector (Streimikiene and Balezentiene, 2014) and so on.

The MULTIMOORA method is also characteristic for its integrating the following three specific approaches named as:

- Ratio System approach,
- Reference Point approach, and
- Full Multiplicative Form.

Based on Zavadskas et al. (2013b) and Stanujkic et al. (2012a, 2012b), these approaches can be presented in the following manner:

The Ratio System approach. The basic idea of the Ratio System (RS) approach of the MULTIMOORA method is to determine the overall performance index of an alternative as the difference between its sums of the weighted normalized performance ratings of the benefit and cost criteria, as follows:

$$Q_i = \sum_{j \in \Omega_{\max}} w_j r_{ij} - \sum_{j \in \Omega_{\min}} w_j r_{ij}, \tag{4}$$

where Q_i denotes the ranking index of the i-th alternative, w_j denotes weight of the j-th criterion, r_{ij} denotes the normalized performance of the i-th alternative with respect to the j-th criterion, $\Omega_{\max}$ and $\Omega_{\min}$ denotes the sets of the benefit and cost criteria, respectively; i = 1,2, … m; m is the number of the compared alternatives, j = 1,2, ..., n; n is the number of the criteria.

Based on the RS approach, the compared alternatives are ranked on the basis of their Q_i in ascending order, and the alternative with the highest value of Q_i is the best-ranked one. The best-ranked alternative, A_{RS}^* can be determined as follows:

$$A_{RS}^* = \left\{ A_i = \max_i Q_i \right\}. \tag{5}$$

The Reference Point approach. For the optimization based on the Reference Point (RP) approach, Brauers and Zavadskas (2006) proposed the following form:

$$\min_i \left\{ \max_j \ (w_j \mid r_j - r_{ij} \mid) \right\}, \tag{6}$$

where r_j denotes the normalized performance of the j-th coordinate of the reference point, and it can be determined as follows:

$$r_j = \begin{cases} \max_i r_{ij} \ ; & j \in \Omega_{\max} \\ \min_i r_{ij}; & j \in \Omega_{\min} \end{cases}. \tag{7}$$

The best-ranked alternative, based on the RP approach A^*_{RP}, can be determined as follows:

$$A^*_{RP} = \left\{ A_i = \min_i \left\{ \max_j \ (w_j \mid r_j - r_{ij} \mid) \right\} \right\}. \tag{8}$$

The Full Multiplicative Form. The Full Multiplicative Form (FMF) embodies the maximization as well as minimization of the purely multiplicative utility function (Balezentis et al., 2010). The overall utility of the i-th alternative, based on the FMF, can be determined as follows:

$$u_i = \frac{A_i}{B_i}, \tag{9}$$

where:

$$A_i = \prod_{j \in \Omega_{\max}} w_j r_{ij} \text{, and} \tag{10}$$

$$B_i = \prod_{j \in \Omega_{\min}} w_j r_{ij} \ . \tag{11}$$

In the particular case of decision-making problems where the cost criteria are not included, B_i is set to 1.

Based on the FMF, the compared alternatives are ranked on the basis of their u_i in ascending order, and the alternative with the highest value of u_i is the best-ranked one. The best-ranked alternative, A^*_{FMF} can be determined as follows:

$$A^*_{FMF} = \left\{ A_i = \max_i u_i \right\}. \tag{12}$$

The normalized performance ratings, used in all the above-considered parts of the MULTIMOORA method, are calculated as follows:

$$r_{ij} = \frac{x_{ij}}{\left(\sum_{i=1}^{n} x_{ij}^2 \right)^{1/2}}, \tag{13}$$

where x_{ij} denotes the performance ratings of the i-th alternative with respect to the j-th criterion.

4. Numerical example

In this section, in order to briefly demonstrate the efficiency and usability of the above considered approach, an example of the selection of candidates in the mining industry for the position of the mining engineer for underground mining – a trainee is considered.

Suppose that the human resources decision makers have evaluated the criteria and competences for the total of three candidates. The evaluation process can be accurately expressed through the following steps:

Step 1. The human resources decision makers (HR DM) have evaluated the criteria and competences for the total of three candidates.

Step 2. Determine the evaluation criteria. In this step, the HR DM has determined the set of the evaluation criteria on the basis of which candidates will further be evaluated.

Step 3. Determine the weights of such evaluation criteria. In this step, the HR DM has determined the weights of the evaluation criteria based on the application of the SWARA method. The resulting weights, obtained on the basis of one HR DM, are shown in Table 2.

Tab. 2. The responses obtained from one HR DM and the relative weights of the criteria.

Criteria	s_j	k_j	q_j	w_j
C1		1.00	1	0.215
C2	0.00	1.00	1.000	0.215
C3	0.35	1.35	0.741	0.159
C4	0.20	1.20	0.617	0.133
C5	0.30	1.30	0.475	0.102
C6	0.00	1.00	0.475	0.102
C7	0.40	1.40	0.339	0.073
			4.647	1.00

Step 4. Evaluate the candidates in relation to the chosen criteria. The ratings of the three candidates as well as the corresponding weights of the evaluation criteria are shown in Table 3.

Tab. 3. The initial decision-making matrix for the candidates selection.

Criteria Candidates	C1	C2	C3	C4	C5	C6	C7
w_j	0.215	0.215	0.159	0.133	0.102	0.102	0.073
K1	4	3	3	4	3	2	4
K2	3	3	4	3	5	4	4
K3	5	4	4	5	5	5	4

Step 5. Construct a normalized decision-making matrix. The normalized decision-making matrix obtained by applying Eq. (9) is shown in Table 4.

Tab. 4. The normalized decision-making matrix.

Criteria Candidates	C1	C2	C3	C4	C5	C6	C7
K1	0.566	0.514	0.469	0.566	0.391	0.298	0.577
K2	0.424	0.514	0.625	0.424	0.651	0.596	0.577
K3	0.707	0.686	0.625	0.707	0.651	0.745	0.577

Step 6. Rank the candidates on the basis of the three approaches of the MULTIMOORA method.

RS approach. The ranking indexes of the considered candidates, obtained by using Eq. (4), are shown in Column II of Table 5. In Column III, the ranks of the candidates obtained on the RS approach are accounted for.

RP approach. The values obtained by using Eq. (6) are shown in Column IV of Table 5. The ranking order of the candidates, on the basis of the RP approach, is shown in Column V.

FMF approach. The overall utility for each of the considered candidates, obtained by using Eq. (9), is presented in Column VI. The ranking order of the candidates, on the basis of the FMF, is shown in Column VII.

Tab. 5. The ranking orders of the candidates obtained on the three parts of MULTIMOORA.

I	II	III	IV	V	VI	VII
Candidates	RS	Rank	RP	Rank	FMF	Rank
K1	0.495	3	0.046	2	3.876E-09	3
K2	0.528	2	0.061	3	9.689E-09	2
K3	0.678	1	0.000	1	4.486E-08	1

The final ranking order of the considered candidates, based on the dominance theory (Brauers and Zavadskas, 2010a), is shown in Table 6.

Tab. 6. The final ranking order of the considered candidates

Criteria	Rank
K1	3
K2	2
K3	1

As it can be seen from Table 6, based on the conducted numerical example, the Candidate designated as K_3 is the best candidate in terms of the evaluated criteria.

Conclusions

In this manuscript, one approach for personnel selection in the mining industry has been proposed. Based on the studied literature and according to experts in the field of human resources and the mining industry, this paper makes a special contribution to defining the criteria necessary for a mining engineer for underground mining – a trainee, who is included in the workflow for the first time. From the above conducted numerical example, it can be concluded that the proposed MCDM model can successfully be used for resolving problems in terms of personnel selection in the mining industry. The proposed model is efficient, adjustable and easy-to-use; so, for a better evaluation of candidates, additional criteria or sub-criteria can be added as well. The proposed model is also generally applicable and, together with additional criteria or criteria modification as well as their importances, the proposed MCDM model can be used for the selection of personnel in other areas or for solving similar problems.

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