Acta Montanistica Slovaca
ISSN 1335-1788
actamont.tuke.sk

A New Hybrid MCDM Model for Personnel Selection in the Mining Industry Based on the PIPRECIA-S, CRITIC, and WISP Methods

Maja STANUJKIĆ[1], *Vuk MIRČETIĆ*[2], *Dragiša STANUJKIĆ*[3], *Darjan KARABAŠEVIĆ*[2,4]*, *Gabrijela POPOVIĆ*[2], *Muzafer SARAČEVIĆ*[5] and *Pavle BRZAKOVIĆ*[2]

Authors' affiliations and addresses:
[1] ReMade DOO, Industrijska 3b, 21000 Novi Sad, Serbia
e-mail: maja.stanujkic@gmail.com

[2] Faculty of Applied Management, Economics and Finance, University Business Academy in Novi Sad, Belgrade, Serbia, Jevrejska 24, 11000 Belgrade, Serbia
e-mail: vuk.mircetic@mef.edu.rs
e-mail: gabrijela.popovic@mef.edu.rs
e-mail: pavle.brzakovic@mef.edu.rs

[3] Technical Faculty in Bor, University of Belgrade, Vojske Jugoslavije 12, 19210 Bor, Serbia
e-mail: dstanujkic@tfbor.bg.ac.rs

[4] Division of Convergence Business, College of Global Business, Korea University, Sejong 30019, Republic of Korea
e-mail: darjankarabasevic@korea.ac.kr

[5] Department of Computer Sciences, University of Novi Pazar, Dimitrija Tucovica bb, 36300 Novi Pazar, Serbia
e-mail: muzafers@uninp.edu.rs

***Correspondence:**
Darjan Karabašević, Division of Convergence Business, College of Global Business, Korea University, Sejong 30019, Republic of Korea
tel.: +381 60 0006282
e-mail: darjankarabasevic@korea.ac.kr

How to cite this article:
Stanujkić, M., Mirčetić, V., Stanujkić, D., Karabašević, D., Popović, G., Saračević, M. and Brzaković, P. (2025). A New Hybrid MCDM Model for Personnel Selection in the Mining Industry Based on the PIPRECIA-S, CRITIC, and WISP Methods. *Acta Montanistica Slovaca,* Volume 30 (3), 787-801

DOI:
https://doi.org/10.46544/AMS.v30i3.18

Abstract
A myriad of factors impact various areas of the contemporary mining environment, making it more challenging. As in other industries, the ultimate goal in mining is optimising organisational operations and achieving the best results. A prerequisite to effectively achieving organisational goals is hiring the best personnel. Different innovative methods are implemented for optimisations in various areas of the mining industry. Numerous researches have been conducted so far on the use of various Multi-criteria decision-making (MCDM) methods in different areas of the mining industry. However, despite the plenitude of significant research in this context, a particular gap exists regarding personnel selection in the mining industry. This paper endeavours to narrow a current gap by providing a systematic literature review regarding MCDM methods in the mining industry. Therefore, the aim of the paper is to provide a novel hybrid integrated MCDM approach that is based on the PIPRECIA-S, CRITIC, and WISP methods for personnel selection in the mining industry. The weights of the criteria are determined by one subjective method (PIPRECIA-S) and by one objective method (CRITIC). Whereas, the final ranking is determined by the WISP method. The proposed integrated MCDM model shows itself as a very suitable technique for use in the process of evaluation of personnel in the mining industry.

Keywords
MCDM, PIPRECIA-S, CRITIC, WISP, Mining Industry, Human Resources Management, Personnel Selection

Introduction

The contemporary business environment's disruptiveness is further enhanced by globalisation and its challenges, hyper-competition, periodic crises, both financial and health, migrations, wars, internal organisational changes, and changes in people, both employees and clients, as well as the development of information and communication technologies (ICT). Situational factors imply that uncertainty is the only certainty in the contemporary business environment (Mirčetić et al., 2022). Contemporary challenges and persisting changes impact all modern and traditional industry spheres. As a traditional industry, mining represents one of the earliest activities in human history, it is fundamental to the development of civilisation (Bell & Donnelly, 2006), and contemporary trends also influence it. Because the ultimate goal in every industry is to optimise business and achieve the best results, the mining industry is also particularly interesting for different analyses, innovational approaches, and developments.

As in other industries, the contemporary mining environment, with all the challenges, drives organisations to innovate if they want to maintain or achieve a comparative and competitive advantage. Innovations improve the performance of organisations by enhancing productivity, decreasing costs and opening new markets (Crespi & Pianta, 2008). Jurgelevicius and Tvaronaviciene (2021) underlined that technological innovations are crucial for traditional industries because they can add value and improve productivity. Innovations have become an integral part of the mining industry for all organisations that seriously approach today's challenges. Numerous scholars have conducted various research studies in this context. For example, Polishchuk et al. (2021) proposed an improved fuzzy mathematical model for assessing the creditworthiness of enterprises, Gupta et al. (2021) constructed an optimisation model for sustainable transportation in the mining industry, and Baloyi & Meyer (2020) conducted research for the best mining method selection.

One of the popular innovative approaches in the mining industry, used in academic frameworks and practice, is the multi-criteria decision-making (MCDM) method. Multi-criteria decision-making aims to enable decision-makers to analyse possible decisions and determine the most adequate one from the set of available alternatives (Özdağoğlu et al., 2021; Karamaşa, 2021). Roy (1981) underlines that MCDM is developed to tackle different problematics: choice (selecting the best option from a set of alternatives), sorting (assigning a set of alternatives to the categories created before), ranking (partially or completely ranking alternatives), and description (elaborating alternatives, building a set of criteria, and determining the performance of alternatives). MCDM is now a well-established, determined and thoroughly explored area of operational research used in many different areas (Urošević et al., 2021).

Many MCDM methods are widely used in different areas of the mining industry. The Analytical Hierarchy Process (AHP) method, developed by Saaty (1980), has been the most used MCDM method in the mining industry (Sitorus, Cilliers & Brito-Parada, 2019). The AHP method is used for selection of the proper storage location for mines waste (Straka, Bindzár & Kaduková, 2014), selecting mining equipment or technology such as a loading-hauling system (Basçetin, 2004), appropriate roadheaders (Acaroglu, Ergin & Eskikaya, 2006), an alternative energy-delivery system for stopping in narrow-reef hard rock mines (Petit & Fraser, 2013), or the most suitable fan for an underground coal mine (Kursunoglu & Onder, 2015). The AHP method has an application also in different suitable mining method selection (Ataei et al., 2008; Mohsen et al., 2009), or even more precise, selecting an appropriate stopping method in underground mining (Gupta & Kumar, 2012), and also techno-economic optimisation of the level and raise spacing in a platinum mine (Musingwini, 2010).

Apart from the AHP method, other MCDM methods have also been implemented in the mining industry. For example, ELECTRE III (Roy, 1978), from Elimination et choix traduisant la realit (ELECTRE) family method, is used for the selection of the off-highway dump truck in opencast mining (Bodziony, Kasztelewicz & Sawicki, 2016) and selection of sustainability criteria of equipment (Patyk, Bodziony & Krysa, 2021). The Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE) method, initially proposed by Brans (1982), is used for the selection of the most appropriate underground ore transport system (Elevli & Demirci, 2004) and the technological system in an open pit mine (Vujić, Hudej & Miljanović, 2013). The technique for order of preference by similarity to ideal solution (TOPSIS) method, presented by Chen and Hwang (1992), with reference to Hwang and Yoon (1981), is used for maintenance strategy (Pourjavad, Shirouyehzad & Shahin, 2013) and green supply chain practices evaluation (Kusi-Sarpong et al., 2015). Multi-criteria optimisation and compromise solution (VIKOR) method, developed by Opricović (1998), for selection of the optimal mining block size (Hayati, Rajabzadeh & Darabi, 2015). The Analytic Network Process (ANP) method, proposed by Saaty and Vargas (2001), is used to examine alternative planning scenarios for mining activities in a particular region (Assumma et al., 2020). Step-wise Weight Assessment Ratio Analysis (SWARA) method, developed by Keršuliene et al. (2010), analyse the risks in coal supply chain management (Sivageerthi et al., 2022) and evaluation of risks impeding sustainable mining (Deveci et al., 2023). Scholars periodically introduce new MCDM methods in various areas of mining, such as multiple criteria ranking by alternative trace (MCRAT) method and ranking alternatives by perimeter similarity (RAPS) method (Urošević et al., 2021).

One of the most important strategic decisions is selecting the appropriate personnel. Consequently, hiring the best individuals is crucial in the mining industry to obtain the best results and optimise work. The selection process is a critical factor in hiring and involves the systematic identification, assessment and hiring of qualified individuals for available positions within the organisation. Personnel selection represents the selection of the most adequate individuals for certain positions (Hirst et al., 2021). It is a complex process that entails planning (Armstrong & Taylor, 2023), and it begins with working position analysis and specifying the characteristics of a particular job (Karabašević et al., 2015). During selection, decision-makers use diverse methods, tests, and techniques to predict and hire the appropriate candidate.

Many researchers have confirmed that MCDM methods are innovative methods that can help select the best solution for many challenges. MCDM methods have also been used in the selection process, for example, for leader selection (Vujić et al., 2016), personnel selection (Korkmaz, 2019; Ulutaş et al., 2020; López et al., 2022; Tuğrul, 2022), more precise the selection of information technology personnel (Gelen & Demir, 2019) or selection, training and maintaining skills for the safe work of personnel (Gendler, Tumanov & Levin, 2021).

As can be observed, an abundance of research has been conducted on the use of various MCDM methods in different areas of the mining industry so far. However, despite the plenitude of considerable studies in this regard in the past decades, a particular theoretical gap exists regarding personnel selection in the mining industry. Building on the paper by Karabašević et al. (2015), this paper endeavours to narrow a current gap, provide a systematic literature review regarding MCDM methods in the mining industry and particularly elaborate on PIPRECIA-S (Simple PIvot Pairwise RElative Criteria Importance Assessment), CRITIC (CRiteria Importance Through Intercriteria Correlation), and WISP (Simple Weighted Sum Product) methods as an appropriate solution for methods regarding personnel selection in the mining industry, and discuss obtained results. Therefore, aim of the paper is to provide a hybrid integrated MCDM model based on PIPRECIA-S, CRITIC, and WISP methods for personnel selection in the mining industry. Weights of the criteria are determined by one subjective method (PIPRECIA-S) and by one objective method (CRITIC). Whereas, final ranking is determined by WISP method. The proposed integrated MCDM model shows itself as a very suitable technique for using in the process of evaluation of personnel in the mining industry.

The remainder of the article is organised as follows. The material and methods used in this paper are presented and explained in the following section. This paper analyses groundbreaking, respectable, and highly cited scientific papers from the last five years to provide a fine-grained perspective on the effectiveness of MCDM methods in different areas of the mining industry and on three MCDM methods that were used in this paper. This chapter is segmented into three subchapters, each introducing the observed MCDM method, presenting the computational procedure of the method and presenting different fields of application in which that method is used, reasoning the selection of that MCDM method for this paper. The first subchapter of this chapter examines the PIPRECIA-S method, the following segment of this chapter analyses the CRITIC method, and the third subchapter discusses the WISP method. The next chapter elaborates on the numerical illustration and results, and discusses combining subjective and objective MCDM methods and critically evaluates the results and implications, providing a holistic perspective of the study's contributions to the field of personnel selection in the mining industry. The last chapter consists of conclusions, limitations and suggestions for future analysis.

Material and Methods

This chapter presents the methodological frameworks of this article and is thematically differentiated into three subchapters that analyse the multi-criteria methods used in this paper. The subchapters explore the MCDM methods used in the research in the following order: PIPRECIA-S, CRITIC, and the WISP method.

The PIPRECIA-S method

PIPRECIA-S (Simple PIvot Pairwise RElative Criteria Importance Assessment) was developed by Stanujkić et al. (2021a) as a modification of the original PIPRECIA method (Stanujkić et al., 2017), making it more easy to use by the respondents. PIPRECIA method was based on SWARA method (Keršuliene, Zavadskas & Turskis, 2010).

The computational procedure of PIPRECIA-S method can be shown through the following steps (Stanujkić et al., 2021a):

Step 1. Determine the set of evaluation criteria.

Step 2. Set the relative significance s_j of each criterion, except the first, as follows:

$$s_j = \begin{cases} > 1 & if\ C_j \succ C_1 \\ 1 & if\ C_j = C_1. \\ < 1 & if\ C_j \prec C_1 \end{cases} \tag{1}$$

where $j \neq 1$.

Similar to the PIPRECIA method, the value of s_1 is set to 1, while values of s_j belong to the interval (1, 1.9] when $C_j \succ C_1$, that is to the interval [0.1, 1) when $C_j \prec C_1$.

Step 3. Calculate the value of coefficient k_j as follows:

$$k_j = \begin{cases} 1 & if\ j = 1 \\ 2 - s_j & if\ j > 1 \end{cases}. \tag{2}$$

Step 4. Calculate the recalculated weight q_j as follows:

$$q_j = \begin{cases} 1 & if\ j = 1 \\ \frac{1}{k_j} & if\ j > 1 \end{cases}. \tag{3}$$

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

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k}. \tag{4}$$

The PIPRECIA-S method was applied in different fields. Because of the similarity between the PIPRECIA-S and PIPRECIA methods, Table 1 presents an overview of fifteen respectable and novel studies that used the abovementioned methods in different fields.

Tab. 1. Overview of the application of the PIPRECIA-S method in different fields

Study	Field of Application
Mirčetić, Popović & Vukotić (2024)	Determining characteristics of the charismatic leaders in EU
Sarbat (2024)	Analysis of job satisfaction
Setiawansyah et al. (2024)	Personnel selection
Stanujkić et al. (2024)	Approach to the personnel selection in a group decision-making environment
Hadad et al. (2023)	Student ranking based on learning assessment
Mladenović, Đukić & Popović (2023)	Analysis of financial platforms reporting
Setiawansyah & Saputra (2023)	Selecting the head of the school organization
Stanujkić et al. (2023a)	Improvement of the decision-making process in the IT industry
Sulistiani et al. (2023)	Evaluation of employees in an educational institution
Aytekin (2022)	Vehicle tracking system
Đukić, Karabašević & Popović (2022)	Evaluation of different aspects of cognitive skills
Ivanov & Stanujkić (2022)	Evaluation of electric vehicles
Popović, Milovanović & Pucar (2022)	Choice of RFID solution provider
Ulutaş & Topal (2022)	Evaluation of the criteria used in the selection of renewable energy sources
Jauković Jocic, Karabašević & Jocić (2020)	Assessing the quality of e-learning materials

The CRITIC Method

Proposed by Diakoulaki, Mavrotas & Papayannakis (1995), CRITIC method aims to determine objective weights of relative importance in MCDM problems. The weights derived include contrast intensity and conflict contained in the structure of the decision problem. CRITIC can be applied in numerous multicriteria problems to define objective weights when a decision maker is absent, to facilitate the decision maker's voicing of his argument or belief on the relative importance of the criteria, to decrease the subjective character of the decision-making process, or to discard the non-salient attributes in a primary weighting of the evaluation criteria. (Diakoulaki et al. 1995).

The computational procedure of CRITIC method can be shown through the following steps (Diakoulaki et al. 1995):

Step 1. Form decision-making matrix D as follows:

$$D = \left[x_{ij}\right]_{mxn}. \tag{5}$$

where x_{ij} denotes ratings of alternative i according to criterioj j, m denotes number of alternatives and j denotes number of criteria.

Step 2. Construct normalized decision-making matrix R as follows:

$$R = \left[r_{ij}\right]\ . \tag{6}$$

where r_{ij} denotes normalized ratings of alternative i according to criterion j, and it is calculated as follows:

$$r_{ij} = \frac{x_{ij-min_i\, x_{ij}}}{max_i\, x_{ij-min_i\, x_{ij}}}. \tag{7}$$

Step 3. Determine the weights of criteria w_j as follows:

$$R = \frac{C_j}{\sum_{j=1}^{n} C_j}. \tag{8}$$

where C_{ij} denotes quantity of information contained in criterioj j, and it is calculated as follows:

$$C_j = \sigma_j \sum_{j=1}^{n} (1 - cr_{jj}) . \quad (9)$$

and σ_j denotes standard deviation of criterion j, cr_{jj} denotes correlation coefficient between two criteria.

The CRITIC method was used in different fields. Table 2 presents an overview of eighteen respectable and novel studies that used the CRITIC method in different fields.

Tab. 2. Overview of the application of the CRITIC method in different fields

Study	Field of Application
Chang (2024)	Design and Application of Evaluation Method for Civics Classroom
Krishnan (2024)	Research trends in CRITIC method
Saensuk, Witchakool & Choompol (2024)	Effective fake news detection
Shrinivas Balraj et al. (2024)	Optimization of machining parameters
Hassan, Alhamrouni & Azhan (2023)	Selection of a location for a solar power plant
Hosseinzadeh Lotfi et al. (2023)	Evaluation and prioritization of projects based on seven specific criteria
Mishra, Chen & Rani (2023)	Proposing a model based on Fermatian fuzzy numbers
Silva et al. (2023)	Investment portfolio selection
Zhang et al. (2023)	Evaluation of the Rock Burst Intensity
Bhadra, Dhar & Salam (2022)	Selection of natural fibers
Haktanır & Kahraman (2022)	Selection of wearable health applications
Kumari & Acherjee (2022)	Selection of an unconventional method of processing
Pamučar, Žižović & Đuričić (2022)	Modification of the CRITIC method using fuzzy rough numbers
Mukhametzyanov (2021)	Comparison of methods
Zafar, Alamgir & Rehman (2021)	Evaluation of the blockchain system
Peng & Huang (2020)	Analysis of financial risks
Peng, Zhang & Luo (2020)	5G Industry Analysis
Tuş & Aytaç Adalı (2019)	Software selection

The WISP Method

The WISP (Integrated Simple Weighted Sum Product) method, created by Stanujkić et al. (2023b), is partially based on the multiobjective optimisation by ratio analysis plus the whole multiplicative form method. It also incorporates weighted aggregated sum product assessment elements and combined compromise solution methods.

According to Stanujkić (2023), the procedure of the WISP method for evaluating alternatives in the case when all criteria are income can be presented in the following way:

Step 1. Construct a normalized decision-making matrix as follows:

$$r_{ij} = \frac{x_{ij}}{max_i\, x_{ij}} . \quad (10)$$

Step 2. Calculate the values of two utility measures, as follows:

$$u_i^s = \sum_{j=1}^{n} r_{ij} w_j \text{, and} \quad (11)$$

$$u_i^p = \prod_{j=1}^{n} r_{ij} w_j . \quad (12)$$

where: u_i^s and u_i^p denote the weighted sum and the weighted product of normalized ratings of alternative i, respectively.

Step 3. Recalculate values of two utility measures, as follows:

$$\bar{u}_i^s = \frac{1+u_i^s}{1+max_i\, u_i^s} \text{, and} \quad (13)$$

$$\bar{u}_i^p = \frac{1+u_i^p}{1+max_i\, u_i^p} . \quad (14)$$

where: $\bar{u}_i^s$and $\bar{u}_i^p$ denote recalculated values of $u_i^s$of u_i^p.

Step 4. Determine the overall utility u_i of each alternative as follows:

$$u_i = \frac{\bar{u}_i^s + \bar{u}_i^p}{2} . \quad (15)$$

Step 5. Rank the alternatives and select the most suitable one, in the same way as in the ordinary WISP method.

The WISP method, its extensions, and methods integrating this method have different fields of application. Table 3 presents an overview of nineteen respectable and novel studies that used the abovementioned methods in different fields.

Tab. 3. Overview of the application of the WISP method in different fields

Study	Field of Application
Kara et al. (2024)	Blockchain platform selection in digital projects
Rani et al. (2024)	Location selection for offshore wind power station
Altıntaş (2023)	Measuring peace performances of G7 group
Hezam et. al. (2023)	Gerontechnology selection problem for aging persons and people with disability
Kirmizi, Karakas & Uçar (2023)	Selecting the optimal naval ship drainage system design alternative
Rahman (2023)	Efficient requirement prioritization for software projects
Stanujkić (2023)	Comparative analysis of WISP method and other methods regarding candidate selection
Stanujkić, Fedajev & Santos (2023)	Investment projects evaluation
Yılmaz (2023)	Examination of the banking sector performance in a particular country
Demir & Arslan (2022)	Sensitivity analysis in multi-criterion decision-making problems
Deveci et al. (2022)	Assessing and prioritising sustainable urban transportation in metaverse
Karabašević et al. (2022)	A New Fuzzy Extension of the Simple WISP Method
Pala (2022)	Financial performance analysis in the food industry
Stanujkić (2022)	Development of the Simple WISP method and its ehtensions
Ulutaş et al. (2022a)	Pallet truck selection
Ulutaş et. al. (2022b)	Sustainable supplier selection
Zavadskas et al. (2022)	An Intuitionistic Extension of the Simple WISP Method
Gokmen (2021)	Analyse of the future educational leaders' metaphoric perceptions regarding sustainability
Stanujkić et al. (2021b)	Comparative analysis of the Simple WISP and other MCDM methods

A Numerical Illustration and Results

This chapter presents the combined use of PIPRECIA-S, CRITIC and WISP methods for evaluating personnel i.e. candidates in the mining industry, based on an example adapted from Karabašević et al. (2015).

In the given example, three candidates were evaluated based on seven criteria by one decision-maker (DM). However, in this case the example is extended so that four candidates are evaluated by three decision makers (DMs), also based on the seven criteria listed below:

- C_1 Education and knowledge EK
- C_2 Personal characteristics PC
- C_3 Organisational capability
- C_4 Physical ability PA
- C_5 Computer skills CS
- C_6 Foreign languages FL
- C_7 The research spirit RS

In the first step, criteria weights were determined by using the PIPRECIA-S method. The procedure for determining criteria weights using the PIPRECIA-S method is shown in Table 4.

Tab. 4. Criteria weights determined using the PIPRECIA-S method based on the attitudes of the first DM

Criteria	s_j	k_j	q_j	w_j
C_1		1.00	1.00	0.15
C_2	0.90	1.10	0.91	0.13
C_3	1.05	0.95	1.05	0.15
C_4	1.10	0.90	1.11	0.16
C_5	1.00	1.00	1.00	0.15
C_6	0.90	1.10	0.91	0.13
C_7	0.80	1.20	0.83	0.12
			6.82	1.00

The weights obtained from three DMs are shown in Table 5, as well as in Figure 1.

Tab. 5. Criteria weights determined using the PIPRECIA-S method based on the attitudes of three DMs

DM_s	DM_1	DM_2	DM_3
Criteria	w_j	w_j	w_j
C_1	0.147	0.144	0.129
C_2	0.133	0.144	0.117
C_3	0.154	0.160	0.184
C_4	0.163	0.131	0.161
C_5	0.147	0.144	0.143
C_6	0.133	0.160	0.143
C_7	0.122	0.120	0.123

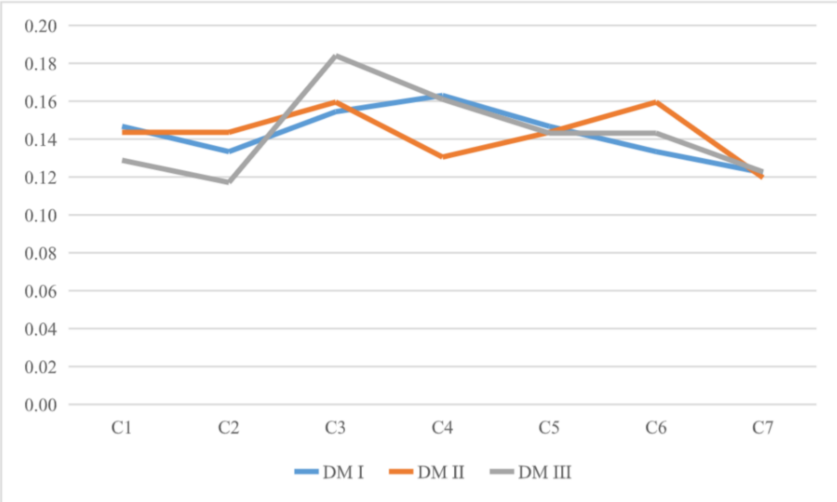

Fig. 1. Criteria weights determined using the PIPRECIA-S method based on the attitudes of three DMs

The ratings of the evaluated candidates concerning the selected evaluation criteria are shown in Tables 6 to 8.

Tab. 6. Candidate ratings obtained from the first of three DMs

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	4	3	3	4	3	2	4
A_2	3	3	4	3	5	4	4
A_3	5	4	4	5	5	3	4
A_4	3	3	4	5	4	3	5

Tab. 7. Candidate ratings obtained from the second of three DMs

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	4	4	3	4	4	3	3
A_2	4	3	3	3	4	4	4
A_3	3	4	5	4	3	5	3
A_4	3	3	4	5	4	3	5

Tab. 8. Candidate ratings obtained from the third of three DMs

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	2	3	3	4	5	4	4
A_2	4	4	5	4	3	4	3
A_3	3	4	5	4	4	3	4
A_4	4	3	4	5	4	4	4

The weights of the criteria obtained by the CRITIC method are summarised in Table 9, as well as presented in Figure 2.

Tab. 9. Criteria weights determined using the CRITIC method based on the attitudes of three DMs

DMs	DM1	DM2	DM3
Criteria	w_j	w_j	w_j
C_1	0.171	0.181	0.121
C_2	0.128	0.163	0.159
C_3	0.114	0.128	0.125
C_4	0.145	0.105	0.134
C_5	0.118	0.148	0.130
C_6	0.132	0.140	0.148
C_7	0.193	0.134	0.183

Fig. 2. Criteria weights determined using the CRITIC method based on the attitudes of three DMs

Table 10 presents the procedure for evaluating candidates using the WISP method and the subjective weights obtained from the first DMs, while Table 11 summarises the ranking order of evaluated candidates achieved using the WISP method and subjective weights based on the attitudes of the three DMs.

Tab. 10. Details of calculations using the WISP method and subjective weights based on the attitudes of the first of three DMs

	u_i^s	u_i^p	$\bar{u}_i^s$	$\bar{u}_i^p$	u_i	Ranks
A_1	0.73	0.00000013	0.884	0.999999	0.942	4
A_2	0.84	0.00000032	0.940	0.999999	0.970	3
A_3	0.96	0.00000088	1.000	1.000000	1.000	1
A_4	0.87	0.00000040	0.951	1.000000	0.976	2

Tab. 11. Ranking orders of candidates obtained using the WISP method and subjective weights

	DM1	DM2	DM3
A_1	3	4	2
A_2	1	1	3
A_3	2	1	1
A_4	3	4	2

Similarly, the procedure for evaluating candidates using the WISP method and the objective weights obtained from the first DMs is presented in Table 12.

Tab. 12. Details of calculations using the WISP method and objective weights based on the attitudes of the first ot three DMs

	u_i^s	u_i^p	$\bar{u}_i^s$	$\bar{u}_i^p$	u_i	Ranks
A_1	0.73	0.00000013	0.884	0.999999	0.942	4
A_2	0.84	0.00000032	0.940	0.999999	0.970	3
A_3	0.96	0.00000088	1.000	1.000000	1.000	1
A_4	0.87	0.00000040	0.951	1.000000	0.976	2

The ranking order of evaluated candidates achieved using the WISP method and objective weights based on the attitudes of the three DMs are summarised in Table 13.

Tab. 13. Ranking orders of candidates obtained using the WISP method and objective weights

	DM1	DM2	DM3
A1	4	3	4
A2	3	4	1
A3	1	1	2
A4	2	1	2

Finally, the rankings orders of evaluated candidates using the WISP method and the subjective and objective methods are summarised in Table 14.

Tab. 14. Ranking orders of candidates obtained using the WISP method

	Subjective weights			Objective weights		
	DM1	DM2	DM3	DM1	DM2	DM3
A1	3	4	2	4	3	4
A2	1	1	3	3	4	1
A3	2	1	1	1	1	2
A4	3	4	2	2	1	2

In Table 14, it can be seen that the candidates denoted as A_2 and A_3 are the most suitable based on the evaluation performed using the WISP method and subjective weights, i.e., using the PIPRECIA-S method, while the alternative denoted as A_3 is the most suitable based on the evaluation performed using the WISP method and objective weights, i.e., by applying the CRITIC method.

Based on the evaluation performed using subjective and objective weights, the candidate denoted as A_3 is the most suitable because, based on the theory of dominance, he has the highest number of appearances in the first position.

Conclusions

Mining is one of the earliest activities in human history, and it is fundamental to the development of civilisation. Therefore, it is crucial to optimise organisational operations to achieve best results. One of the ways to achieve that is by using different innovations because they can add value and improve productivity. One of the popular innovative approaches in the mining industry, used in academic frameworks and practice, are the MCDM methods, which can also be used for solving problem of personnel selection, as important segment in the mining industry.

Firstly, this manuscript provides a systematic literature review regarding MCDM methods in the mining industry and particularly elaborate on PIPRECIA-S (Simple PIvot Pairwise RElative Criteria Importance Assessment), CRITIC (CRiteria Importance Through Intercriteria Correlation), and WISP (Simple Weighted Sum Product) methods as an appropriate solution for methods regarding personnel selection in the mining industry, and, based on previous research, proposed different and innovative approach for personnel selection in the mining industry.

The study discusses the combined use of one subjective and one objective method for determining the importance (weights) of the criteria, namely the PIPRECIA-S and CRITIC methods, intending to evaluate candidates using the WISP method. It is known that with subjective techniques, decision-makers can directly express their preferences in terms of the importance (weight) of the criteria, while with objective techniques, the weights of the criteria are determined based on the evaluation of the alternatives concerning the criteria. In the first case, decision-makers can express their preferences more easily and precisely, while in the second case, modifying the criteria weights requires modifying the ratings of the alternatives. By combining subjective and objective techniques, decision-makers can check whether there is a significant difference in the weights of the criteria obtained by applying subjective and objective techniques and, if necessary, make proper corrections.

When it comes to the ranking results, after the applied MCDM model, it can be noted that the candidates denoted as A_2 and A_3 are the best ranked based on the conducted evaluation by using the WISP method and subjective weights, i.e., using the PIPRECIA-S method, whereas the alternative denoted as A_3 is the best ranked based on the evaluation performed by using the WISP method and objective weights, i.e., by applying the CRITIC method. Also, it is important to state that theory of dominance is applied for final ranking (highest number of apperances in the first position). By applying proposed MCDM model, it can be seen that the proposed approach is easy to use, effective and easily it can be addapted if necessary for additional criteria or sub-criteria. Also, proposed approach can be used for solving problems in other areas as well.

The proposed MCDM based PIPRECIA-S, CRITIC, and WISP model can successfully be used to resolve personnel selection issues in the mining industry. Combining subjective and objective criteria weights can achieve a more adequate selection of candidates. Therefore, the paper's particular contribution is the modification and improvement of the existing MCDM model by combining new subjective and objective MCDM methods. The proposed MCDM-based model (PIPRECIA-S, CRITIC and WISP) proved to be adequate when it comes to solving the problem of personnel selection in the mining industry. The applicability of the proposed model is reflected through the use of MCDM methods that are based on crisp numbers. Therefore, the advantage of the proposed model is its simplicity and ease of use, especially from the standpoint of the DMs.

This article is not exempt from certain limitations that may be addressed by future research. First, the proposed hybrid MCDM model is based on crisp numbers. Also, it is known that sometimes decision-making environment is characterized by vagueness, and in those cases, evaluation cannot be done via crisp numbers.

Second, the paper focuses on the microenvironment, providing insufficient information regarding possible differences in results in different industries. Future research can be conducted in another industry. Finally, because of the constant changes and challenges and the importance of new technologies, it would be beneficial for future analysis to incorporate new criteria. Adding new or adopting current criteria will help get insight in a more granular manner, and observing the industry's development can assist in achieving a more effective strategic approach to personnel selection in mining or other industries. Besides, in order to better cope with uncertainty in the decision-making process MCDM methods based on fuzzy, neutrosophic, rough numbers can be used in future.

Acknowledgement

The research presented in this article was partly financially supported by of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, within the funding of the scientific research work at the University of Belgrade, Technical Faculty in Bor, according to the contract with registration number 451-03-47/2023-01/200131.

References

Acaroglu, O., Feridunoglu, C., & Tumac, D. (2006). Selection of Roadheaders by Fuzzy Multiple Attribute Decision Making Method. *Mining Technology, 115*(3), 91–98. https://doi.org/10.1179/174328606X128723

Altıntaş, F. F. (2023). Barış Performanslarının LOPCOW Tabanlı WISP Yöntemi İle Analizi: G7 Ülkeleri Örneği. *Fenerbahçe Üniversitesi Sosyal Bilimler Dergisi, 3*(2), 215-241. https://doi.org/10.58620/fbujoss.1313949

Armstrong, M. & Taylor, S. (2023). *Armstrong's Handbook of Human Resource Management Practice*. Kogan Page.

Assumma, V., Bottero, M., Mondini, G., Zanetta, E. (2020). An Analytic Network Process (ANP)-Based Approach for Investigating Alternative Planning Scenarios of Mining Activities in Piedmont Region. In B. Murgante, S. Misra, C. Garau, I. Blečić, D. Taniar, B. O. Apduhan, A. M. A. C. Rocha, E. Tarantino, C. M. Torre, & Y. Karaca (Eds.), *Computational Science and Its Applications – ICCSA 2020. ICCSA 2020. Lecture Notes in Computer Science* (pp. 355–365). Springer. https://doi.org/10.1007/978-3-030-58814-4_25

Ataei, M., Jamshidi, M., Sereshki, F., & Jalali, S. (2008). Mining Method Selection by AHP approach. *The Journal of The Southern African Institute of Mining and Metallurgy, 108*, 741–749.

Aytekin, A. (2022). Determining Criteria Weights for Vehicle Tracking System Selection Using PIPRECIA-S. *Journal of Process Management and New Technologies, 10*(1-2), 115-124. https://doi.org/10.5937/jpmnt10-38145

Baloyi, V. D., & Meyer, L. D. (2020). The Development of a Mining Method Selection Model Through a Detailed Assessment of Multi-Criteria Decision Methods. *Results in Engineering, 8*, 100172. https://doi.org/10.1016/j.rineng.2020.100172

Basçetin, A. (2004). Technical Note: An Application of the Analytic Hierarchy Process in Equipment Selection at Orhaneli Open Pit Coal Mine. *Mining Technology, 113*(3), 192–199. https://doi.org/10.1179/037178404225004968

Bell, F. B., & Donnelly, L. J. (2006). Introduction. In F. G. Bell, & L. J. Donnelly (Eds.), *Mining and its Impact on the Environment* (pp. 1-22). CRC Press. https://doi.org/10.1201/9781482288230

Bhadra, D., Dhar, N. R., & Salam, M. A. (2022). Sensitivity Analysis of the Integrated AHP-TOPSIS and CRITICTOPSIS Method for Selection of the Natural Fiber. *Materials Today: Proceedings, 56*(5), 2618-2629. https://doi.org/10.1016/j.matpr.2021.09.178

Bodziony, P., Kasztelewicz, Z., & Sawicki, P. (2016). The Problem of Multiple Criteria Selection of the Surface Mining Haul Trucks. *Archives of Mining Sciences, 61*(2), 223–243. https://doi.org/10.1515/amsc-2016-0017

Brans, J. (1982). L'ingénièrie de la Décision; Elaboration D'instruments D'aide à la Décision. La Méthode PROMETHEE. In R. Nadeau, & M. Landry (Eds.), *L'aide à la Décision. Nature, Instruments et Perspectives D'avenir* (pp. 183-214). Québec, Canada: Presses de l'Université Laval.

Chang, Z. (2024). Design and Application of Evaluation Method for Civics Classroom Based on CRITIC Fuzzy Algorithm. *EAI Endorsed Transactions on Scalable Information Systems, 11*(1), in press. https://doi.org/10.4108/eetsis.4217

Chen, S.-J., Hwang, C.-L., & Hwang, F. P. (1992). *Fuzzy Multiple Attribute Decision Making Methods and Applications*. Springer. https://doi.org/10.1007/978-3-642-46768-4

Crespi, F., & Pianta, M. (2008). Diversity in Innovation and Productivity in Europe. *Journal of Evolutionary Economics, 18*(3), 529-545. https://doi.org/10.1007/s00191-008-0101-0

Demir, G., & Arslan, R. (2022). ÇOk Kriterli Karar Verme Problemlerinde Duyarlılık Analizi. *Ankara Hacı Bayram Veli Üniversitesi İktisadi Ve İdari Bilimler Fakültesi Dergisi, 3*(24), 1025-1056. https://doi.org/10.26745/ahbvuibfd.1103531

Deveci, M., Mishra, A. R., Gokasar, I., Rani, P., Pamucar, D. & Ozcan, E. (2022). A Decision Support System for Assessing and Prioritizing Sustainable Urban Transportation in Metaverse. *IEEE Transactions on Fuzzy Systems, 31*(2), 475-484. https://doi.org/10.1109/TFUZZ.2022.3190613

Deveci, M., Varouchakis, E. A., Brito-Parada, P. R., Mishra, A. R., Rani, P., Bolgkoranou, M., & Galetakis, M. (2023). Evaluation of Risks Impeding Sustainable Mining Using Fermatean Fuzzy Score Function Based SWARA Method. *Applied Soft Computing, 139*, 110220. https://doi.org/10.1016/j.asoc.2023.110220

Diakoulaki, D., Mavrotas, G., & Papayannakis, L. (1995). Determining Objective Weights in Multiple Criteria Problems: The CRITIC Method. *Computers & Operations Research, 22*(7), 763-770. https://doi.org/10.1016/0305-0548(94)00059-H

Đukić, T., Karabašević, D., & Popović, G. (2022). Evaluation of Aspects of Cognitive Skills Using the PIPRECIA method. *Ekonomika, 68*(4), 1-14. https://doi.org/10.5937/ekonomika2204001D

Elevli, B., & Demirci, A. (2004). Multicriteria Choice of Ore Transport System for an Underground Mine: Application of PROMETHEE Methods. *The Journal of The South African Institute of Mining and Metallurgy, 104*(5), 251–256.

Gelen, M. B., Demir, A. (2019). Selection Of Information Technology Personnel For An Enterprise In the Process Of Industry 4.0 With The Multimoora Method. *Sakarya Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 4*(23), 663-675. https://doi.org/10.16984/saufenbilder.459659

Gendler, S. G., Tumanov, M. V., & Levin, L. Y. (2021). Principles for Selecting, Training and Maintaining Skills for Safe Work of Personnel for Mining Industry Enterprises. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 2*, 156 - 162. https://doi.org/10.33271/nvngu/2021-2/156

Gokmen, A. (2021). Investigating Future Educational Leaders' Metaphoric Perceptions Regarding Sustainability According to Their Knowledge Levels. *International Online Journal of Education and Teaching, 8*(2), 1151-1171.

Gupta, P., Mehlawat, M. K., Aggarwal, U., & Charles, V. (2021). An Integrated AHP-DEA Multi-Objective Optimization Model for Sustainable Transportation in Mining Industry. *Resources Policy, 74*, 101180. https://doi.org/10.1016/j.resourpol.2018.04.007

Gupta, S., & Kumar, U. (2012). An Analytical Hierarchy Process (AHP)-Guided Decision Model for Underground Mining Method Selection. *International Journal of Mining, Reclamation and Environment, 26*(4), 324–336. https://doi.org/10.1080/17480930.2011.622480

Hadad, S. H., Darwis, D., Qurania, A., Aldino, A. A., Mehta, A. R., Rahmanto, Y., & Setiawansyah, S. (2023). Student Ranking Based on Learning Assessment Using the Simplified PIPRECIA Method and CoCoSoMethod. *Journal of Computer System and Informatics, 5*(1), 30-39. https://doi.org/10.47065/josyc.v5i1.4544

Haktanır, E., & Kahraman, C. (2022). A Novel Picture Fuzzy CRITIC & REGIME Methodology: Wearable Health Technology Application. *Engineering Applications of Artificial Intelligence, 113*, 104942. https://doi.org/10.1016/j.engappai.2022.104942

Hassan, I., Alhamrouni, I., & Azhan, N. H. (2023). A CRITIC–TOPSIS Multi-Criteria Decision-Making Approach for Optimum Site Selection for Solar PV Farm. *Energies, 16*(10), 4245. https://doi.org/10.3390/en16104245

Hayati, M., Rajabzadeh, R., & Darabi, M. (2015). Determination of Optimal Block Size in Angouran Mine Using VIKOR Method. *Journal of Materials and Environmental Science, 6*(11), 3236–3244.

Hezam, I. M., Pratibha Rani, Arunodaya Raj Mishra, Ahmad M. Alshamrani. A Combined Intuitionistic Fuzzy Closeness Coefficient and a Double Normalization-Based WISP Method to Solve the Gerontechnology Selection Problem for Aging Persons and People With Disability. *AIMS Mathematics, 2023*, 8(6): 13680-13705. http://doi.org/10.3934/math.2023695

Hirst, G., Curtis, S., Nielsen, I., Smyth, R., Newman, A., & Xiao, N. (2021). Refugee Recruitment and Workplace Integration: An Opportunity for Human Resource Management Scholarship and Impact. *Human Resource Management Journal, 33*(4), 783–805. https://doi.org/10.1111/1748-8583.12349

Hosseinzadeh Lotfi, F., Allahviranloo, T., Pedrycz, W., Shahriari, M., Sharafi, H., Razipour GhalehJough, S. (2023). The Criteria Importance Through Inter-Criteria Correlation (CRITIC) in Uncertainty Environment. In F. Hosseinzadeh Lotfi , T. Allahviranloo, W. Pedrycz, M. Shahriari, H. Sharafi, & S. R. GhalehJough (Eds.), *Fuzzy Decision Analysis: Multi Attribute Decision Making Approach. Studies in Computational Intelligence* (pp. 309–324). Springer. https://doi.org/10.1007/978-3-031-44742-6_13

Hwang, C.-L., & Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications A State-of-the-Art Survey*. Springer. https://doi.org/10.1007/978-3-642-48318-9

Ivanov, B., & Stanujkić, D. (2022). Evaluation of Electric Vehicles Using the Simplified WISP method. *Proceedings of the International Scientific Conference-UNITECH* (pp. 18-19). Technical University of Gabrovo.

Jauković Jocić, K., Karabašević, D., & Jocić, G. (2020). The Use of the PIPRECIA Method for Assessing the Quality of E-Learning Materials. *Ekonomika, 66*(3), 37-45. https://doi.org/10.5937/ekonomika2003037J

Jurgelevicius, A., & Tvaronaviciene, M. (2021). Assessing the Impact of Human Capital's Structure on High Value-Added Economic Sectors in European Countries: Illustration of Mining Industry. *Acta Montanistica Slovaca, 26*(1), 106-116. https://doi.org/10.46544/AMS.v26i1.09

Kara, K., Yalçın, G. C., Simić, V., Korkuç, Ç., Çiçek, İ., Afacan, E., & Pamučar, D. (2024). An Interval-Valued Spherical Fuzzy CIMAS-WISP Group Decision-Analytic Model for Blockchain Platform Selection in Digital Projects. *Applied Soft Computing, 162*, 111810. https://doi.org/10.1016/j.asoc.2024.111810

Karabašević, D., Stanujkić, D., Urošević, S., & Maksimović, M. (2015). Selection of Candidates in the Mining Industry Based on the Application of the SWARA and the MULTIMOORA Methods. *Acta Montanistica Slovaca, 20*(2), 116-124.

Karabašević, D., Ulutaş, A., Stanujkić, D., Saračević, M., & Popović, G. (2022). A New Fuzzy Extension Of the Simple WISP Method. Axioms, 7(11), 332. https://doi.org/10.3390/axioms11070332

Karamaşa, Ç. (2021). Ranking Service Quality Using Multi-Criteria Decision-Making Methods: Example of Erzurum Province. *Journal of Process Management and New Technologies, 9*(3-4), 1-12. https://doi.org/10.5937/jouproman2103001K

Keršuliene, V., Zavadskas, E. K., & Turskis, Z. (2010). Selection of Rational Dispute Resolution Method by Applying New Step-Wise Weight Assessment Ratio Analysis (SWARA). *Journal of Business Economics and Management, 11*(2), 243-258. https://doi.org/10.3846/jbem.2010.12

Kirmizi, M., Karakas, S., & Uçar, H. (2023). Selecting the Optimal Naval Ship Drainage System Design Alternative Based on Integer Linear Programming, TOPSIS, and Simple WISP Methods. *Journal of Ship Production and Design 39*(2), 63–74. https://doi.org/10.5957/JSPD.01220003

Korkmaz, O. (2019). Personnel Selection Method Based On Topsis Multi-criteria Decision Making Method. *Uluslararası İktisadi Ve İdari İncelemeler Dergisi, 23*, 1-16. https://doi.org/10.18092/ulikidince.468486

Krishnan, A. R. (2024). Research Trends in Criteria Importance Through Intercriteria Correlation (CRITIC) Method: A Visual Analysis of Bibliographic Data Using the Tableau Software. *Information Discovery and Delivery*, in press. https://doi.org/10.1108/IDD-02-2024-0030

Kumari, A., & Acherjee, B. (2022). Selection of Non-Conventional Machining Process Using CRITIC-CODAS Method. *Materials Today: Proceedings, 56*(1), 66-71. https://doi.org/10.1016/j.matpr.2021.12.152

Kursunoglu, N., & Onder, M. (2015). Selection of an appropriate fan for an underground coal mine using the Analytic Hierarchy Process. *Tunnelling and Underground Space Technology, 48*, 101–109. https://doi.org/10.1016/j.tust.2015.02.005

Kusi-Sarpong, S., Bai, C., Sarkis, J., & Wang, X. (2015). Green Supply Chain Practices Evaluation in the Mining Industry Using a Joint Rough Sets and Fuzzy TOPSIS Methodology. *Resources Policy, 46*(1), 86-100. https://doi.org/10.1016/j.resourpol.2014.10.011

López, J. C., Solano-Noriega, J. J., Gastelum-Chavira, D. A., Gaxiola-Valenzuela, T. (2022). A Personnel Selection Model for a Software Development Company Based on the ELECTRE III Method and a Variant Of NSGA-II. *Innovar, 85*(32), 117-132. https://doi.org/10.15446/innovar.v32n85.100657

Mirčetić, V., Ivanović, T., Knežević, S., Bogojević Arsić, V., Obradović, T., Karabašević, D., Vukotić, S., Brzaković, T., Adamović, M., Milojević, S., Milašinović, M., Mitrović, A., & Špiler, M. (2022). The Innovative Human Resource Management Framework: Impact of Green Competencies on Organisational Performance. *Sustainability, 14*(5), 2713. https://doi.org/10.3390/su14052713

Mirčetić, V., Popović, G., & Vukotić, S. (2024). Unveiling the Characteristics of the EU Charismatic Leaders Using PIPRECIA-S Method. *Journal of Process Management and New Technologies, 12*(1-2), 99-109. https://doi.org/10.5937/jpmnt12-51159

Mishra, A. R., Chen, S. M., & Rani, P. (2023). Multicriteria Decision Making Based on Novel Score Function of Fermatean Fuzzy Numbers, the CRITIC Method, and the GLDS Method. *Information Sciences, 623*, 915-931. https://doi.org/10.1016/j.ins.2022.12.031

Mladenović, M., Đukić, T., & Popović, G. (2023). Analysis of Financial Reporting Platforms Based on the PIPRECIAS Method. *Journal of Process Management and New Technologies, 11*(3-4), 95-104. https://doi.org/10.5937/jpmnt11-48186

Mohsen, J., Mohammad, A., Farhang, S., & Esmaeil, J. S. M. (2009). The Application of AHP Approach to Selection of Optimum Underground Mining Method, Case Study: Jajarm Bauxite Mine (Iran). Archives of Mining Sciences, 54(1), 103–117.

Mukhametzyanov, I. (2021). Specific Character of Objective Methods for Determining Weights of Criteria in MCDM Problems: Entropy, CRITIC and SD. *Decision Making: Applications in Management and Engineering, 4*(2), 76-105. https://doi.org/10.31181/dmame210402076i

Musingwini, C. (2010). Techno-Economic Optimization of Level and Raise Spacing in Bushveld Complex Platinum Reef Conventional Breast Mining. *The Journal of The Southern African Institute of Mining and Metallurgy, 110*(8), 425–436.

Opricović S. (1998). *Multicriteria optimization of civil engineering systems*. Faculty of Civil Engineering, University of Belgrade.

Özdağoğlu, A., Keleş, M. K., Altınata, A., & Ulutaş, A. (2021). Combining Different MCDM Methods With the Copeland Method: An Investigation on Motorcycle Selection. *Journal of Process Management and New Technologies, 9*(3-4), 13-27. https://doi.org/10.5937/jpmnt9-34120

Pala, O. (2023). Sd ve Wisp Yaklaşimlari Ile Gida Sektöründe Finansal Performans Analizi. *Doğuş Üniversitesi Dergisi, 24*(1), 59-79. https://doi.org/10.31671/doujournal.1118061

Pamučar, D., Žižović, M., & Đuričić, D. (2022). Modification of the CRITIC Method Using Fuzzy Rough Numbers. *Decision Making: Applications in Management and Engineering, 5*(2), 362–371. https://doi.org/10.31181/dmame0316102022p

Patyk, M., Bodziony, P., & Krysa, Z. (2021). A Multiple Criteria Decision Making Method to Weight the Sustainability Criteria of Equipment Selection for Surface Mining. *Energies, 14*, 3066. https://doi.org/10.3390/en14113066

Peng, X., & Huang, H. (2020). Fuzzy Decision Making Method Based on CoCoSo with Critic for Financial Risk Evaluation. *Technological and Economic Development of Economy, 26*(4), 695-724. https://doi.org/10.3846/tede.2020.11920

Peng, X., Zhang, X., & Luo, Z. (2020). Pythagorean Fuzzy MCDM Method Based on CoCoSo and CRITIC with Score Function for 5G Industry Evaluation. *Artificial Intelligence Review, 53*(5), 3813-3847. https://doi.org/10.1007/s10462-019-09780-x

Petit, P., & Fraser, P. (2013). What is the best energy-delivery system for hand-held stope drilling and associated equipment in narrow-reef hard rock mines? *The Journal of The Southern African Institute of Mining and Metallurgy, 113*(3), 243–249.

Polishchuk, V., Kelemen, M., Povkhan, I., Kelemen, jr., M., & Liakh, I. (2021). Fuzzy Model for Assessing the Creditworthiness of Ukrainian Coal Industry Enterprises. *Acta Montanistica Slovaca, 26*(3), 444-454. https://doi.org/10.46544/AMS.v26i3.05

Popović, G., Milovanović, G., & Pucar, Đ. (2022). A Multiple-Criteria Approach to RFID Solution Provider Selection. *Proceedings of the IV Virtual International Conference Path to a Knowledge Society-Managing Risks and Innovation - PaKSoM 2022* (pp. 457-464). Research and Development Center "IRC ALFATEC", & Complex System Research Centre, Serbia.

Pourjavad, E., Shirouyehzad, H., & Shahin, A. (2013). Selecting Maintenance Strategy in Mining Industry by Analytic Network Process and TOPSIS. *International Journal of Industrial and Systems Engineering, 15*(2), 171–192. https://doi.org/10.1504/IJISE.2013.056095

Rahman, A. (2023). MEREC-WISP(S) Integration Extended with Fermatean Fuzzy Set for Requirement Prioritization. *Foundation University Journal of Engineering and Applied Sciences, 4*(1), 37-60. https://doi.org/10.33897/fujeas.v4i1.868

Rani, P., Mishra, A. R., Cavallaro, F., & Alrasheedi, A. F. (2024). Location Selection for Offshore Wind Power Station Using Interval-Valued Intuitionistic Fuzzy Distance Measure-RANCOM-WISP Method. *Scientific Reports, 14*, 4706. https://doi.org/10.1038/s41598-024-54929-6

Roy, B. (1978). ELECTRE III: Un Algorithme de Classements Fondé Sur Une Représentation Floue des Préférences en Présence de Critères Multiples. *Cahiers du Centre d'Etudes de Recherche Opérationnelle, 20*(1), 3–24.

Roy, B. (1981). The Optimisation Problem Formulation: Criticism and Overstepping. *The Journal of the Operational Research Society, 32*(6), 427–436. https://doi.org/10.1057/jors.1981.93

Saaty, L. T., & Vargas, L. G. (2001). *Models, Methods, Concepts & Applications of the Analytical Hierarchy Process*. Kluwer Academic Publishers: Boston, MA, USA. https://link.springer.com/book/10.1007/978-1-4615-1665-1

Saaty, T. (1980). *The Analytic Hierarchy Process*. McGraw-Hill, New York. https://doi.org/10.1016/0270-0255(87)90473-8

Saensuk, M., Witchakool, S., & Choompol, A. (2024). A Hybrid Method Based on CRITIC Method and Machine Learning Models for Effective Fake News Detection in Thai Language. *Journal of Current Science and Technology, 14*(2), 24. https://doi.org/10.59796/jcst.V14N2.2024.24

Sarbat, I. (2024). A MCDM-Based Measurement Proposal of Job Satisfaction Comprising Psychosocial Risks. *Ergonomics*, 1-16. https://doi.org/10.1080/00140139.2024.2361301

Setiawansyah, S., & Saputra, V. H. (2023). Kombinasi Pembobotan PIPRECIA-S dan Metode SAW dalam Pemilihan Ketua Organisasi Sekolah. *Jurnal Ilmiah Informatika Dan Ilmu Komputer (JIMA-ILKOM), 2*(1), 32-40. https://doi.org/10.58602/jima-ilkom.v2i1.16

Setiawansyah, S., Sintaro, S., Saputra, V. H., & Aldino, A. A. (2024). Combination of Grey Relational Analysis (GRA) and Simplified Pivot Pairwise Relative Criteria Importance Assessment (PIPRECIA-S) in Determining the Best Staff. *Bulletin of Informatics and Data Science, 2*(2), 57-66. https://doi.org/10.61944/bids.v2i2.67

Shrinivas Balraj, U., Uyala, S., Jannu, S., & Gadakh, V. S. (2024). Multi-Objective Optimization Of Machining Parameters for EDM Of Magnesium Alloy- ZE41 Using Marcos Algorithm AND Different Weighing Methods: SD, CRITIC and MEREC. *International Journal of Modern Manufacturing Technologies, 16*(1), 124-140. https://doi.org/10.54684/ijmmt.2024.16.1.124

Silva, N. F., dos Santos, M., Gomes, C. F. S., & de Andrade, L. P. (2023). An Integrated CRITIC and Grey Relational Analysis Approach for Investment Portfolio Selection. *Decision Analytics Journal, 8*, 100285. https://doi.org/10.1016/j.dajour.2023.100285

Sitorus, F., Cilliers, J. J., & Brito-Parada, P. R. (2019). Multi-Criteria Decision Making for the Choice Problem in Mining and Mineral Processing: Applications and Trends. *Expert Systems With Applications, 121*, 393-417. https://doi.org/10.1016/j.eswa.2018.12.001

Sivageerthi, T., Bathrinath, S., Uthayakumar, M., & Bhalaji, R. K. A. (2022). A SWARA Method to Analyze the Risks in Coal Supply Chain Management. *Materials Today: Proceedings, 50*(5), 935-940. https://doi.org/10.1016/j.matpr.2021.06.338

Stanujkić, D. (2022). Development of the Simple WISP method and its ehtensions. Proceedings of XVIII International May Conference on Strategic Management - IMCSM22 (pp. 15-25). Technical Faculty in Bor, University of Belgrade, Serbia.

Stanujkić, D., Fedajev, A., & Santos, M. (2023). Investment Projects Evaluation in a Fuzzy Environment Using the Simplified WISP Method. *Serbian Journal of Management, 18*(2), 225-235. https://doi.org/10.5937/sjm18-44522

Stanujkić, D., Karabašević, D., Popović, G., & Sava, C. (2021a). Simplified Pivot Pairwise Relative Criteria Importance Assessment (PIPRECIA-S) Method. *Romanian Journal of Economic Forecasting, 24*(4), 141-154.

Stanujkić, D., Karabašević, D., Popović, G., Zavadskas, E. K., Saračević, M., Stanimirović, P. S., Ulutaş, A., Katsikis, V. N., & Meidute-Kavaliauskiene, I. (2021b). Comparative Analysis of the Simple WISP and Some Prominent MCDM Methods: A Python Approach. *Axioms, 10*, 347. https://doi.org/10.3390/axioms10040347

Stanujkić, D., Popović, G., Karabašević, D., Meidute-Kavaliauskiene, I., & Ulutaş, A. (2023b). An Integrated Simple Weighted Sum Product Method—WISP. *IEEE Transactions on Engineering Management, 70*(5), 1933-1944. https://www.doi.org/10.1109/TEM.2021.3075783

Stanujkić, D., Zavadskas, E. K., Karabašević, D., Smarandache, F., & Turskis, Z. (2017). The Use of The Pivot Pairwise Relative Criteria Importance Assessment Method for Determining the Weights of Criteria. *Romanian Journal of Economic Forecasting, 20*(4), 116-133.

Stanujkić, M. (2023). Comparative Analysis of MULTIMOORA, WASPAS and WISP Methods: The Case of Candidate Selection. *Journal of Process Management and New Technologies, 11*(3-4), 79-88. https://doi.org/10.5937/jpmnt11-47703

Stanujkić, M., Popović, G., Karabašević, D., Šarčević, M., Stanujkić, D., & Novaković, S. (2024). Approach to the Personnel Selection in a Group Decision-Making Environment Based on the Use of the MULTIMOORA and PIPRECIA-S Methods. *BizInfo (Blace) Journal of Economics, Management and Informatics, 15*(1), 19–26. https://doi.org/10.5937/bizinfo2401019S

Stanujkić, M., Popović, G., Vukotić, S., Karabašević, D., & Stanujkić, D. (2023a). Improvement of Business Decision Making in IT Industry Using the MCDM Approach. *Industrija, 51*(3/4), 73-88. https://doi.org/10.5937/industrija51-48118

Straka, M., Bindzár, P., & Kaduková, A. (2014). Utilization of the Multicriteria Decision-Making Methods for the Needs of Mining Industry. *Acta Montanistica Slovaca, 19*(4), 199-206.

Sulistiani, H., Setiawansyah, Palupiningsih, P., Hamidy, F., Sari, P. L., & Khairunnisa, Y. (2023). Employee Performance Evaluation Using Multi-Attribute Utility Theory (MAUT) with PIPRECIA-S Weighting: A Case Study in Education Institution. In *2023 International Conference on Informatics, Multimedia, Cyber and Informations System (ICIMCIS)* (pp. 369-373). IEEE. https://doi.org/10.1109/ICIMCIS60089.2023.10349017

Tuğrul, F. (2022). Personnel Selection Utilizing the Decision Making Mechanism Created With The Intuitionistic Fuzzy Topsis Method. *Mugla Journal of Science and Technology, 8*(2), 16-21. https://doi.org/10.22531/muglajsci.1158599

Tuş, A., & Aytaç Adalı, E. (2019). The New Combination with CRITIC and WASPAS Methods for the Time and Attendance Software Selection Problem. *Opsearch, 56*, 528-538. https://doi.org/10.1007/s12597-019-00371-6

Ulutaş, A., & Topal, A. (2022). Evaluation of the Criteria Used in the Selection of Renewable Energy Sources With the Plithogenic PIPRECIA Method. In F. Balo, A. Topal, E. Demir, & A. Ulutaş (Eds.), *Optimization and Decision-Making in the Renewable Energy Industry* (pp. 109-125). https://doi.org/10.4018/978-1-6684-2472-8.ch005

Ulutaş, A., Popović, G., Stanujkić, D., Karabašević, D., Zavadskas, E. K., & Turskis, Z. (2020). A New Hybrid MCDM Model for Personnel Selection Based on a Novel Grey PIPRECIA and Grey OCRA Methods. *Mathematics, 8*(10), 1698. https://doi.org/10.3390/math8101698

Ulutaş, A., Stanujkić, D., Karabašević, D., Popović, G., & Novaković, S. B. (2022a). Pallet Truck Selection With MEREC and WISP-S Methods. *Strategic Management, 27*(4), 23-29. https://doi.org/10.5937/StraMan2200013U%20

Ulutaş, A., Topal, A., Pamučar, D., Stević, Ž., Karabašević, D., & Popović, G. (2022b). A New Integrated Multi-Criteria Decision-Making Model for Sustainable Supplier Selection Based on a Novel Grey WISP and Grey BWM Methods. *Sustainability, 24*(14), 16921. https://doi.org/10.3390/su142416921

Urošević, K., Gligorić, Z., Miljanović, I., Beljić, Č., & Gligorić, M. (2021). Novel Methods in Multiple Criteria Decision-Making Process (MCRAT and RAPS)—Application in the Mining Industry. *Mathematics, 9*, 1980. https://doi.org/10.3390/math9161980

Vujić, D., Stanujkić, D., Urošević, S., Karabašević, D. (2016). An Approach to Leader Selection in the Mining Industry Based on the Use of Weighted Sum Preferred Levels of the Performances Method. *Mining and Metallurgy Engineering Bor, 4*, 53-62. https://doi.org/10.5937/mmeb1604053V

Vujić, S., Hudej, M., & Miljanović, I. (2013). Results of the Promethee Method Application in Selecting the Technological System at the Majdan Iii Open Pit Mine / Wyniki Zastosowania Metody Promethee Do Wyboru Systemu Technologicznego W Kopalni Odkrywkowej Majdan III. *Archives of Mining Sciences, 58*(4), 1229– 1240. https://doi.org/10.2478/amsc-2013-0084

Yılmaz, N. (2023). An Integrated LOPCOW-WISP Model for Analyzing Performance of Banking Sector in Romania. In H. Akgün, S. Sağlik, & U. Inan (Eds.), *Academic Studies in Social, Human and Administrative Sciences* (pp. 161-178). Gece Kitaplığı.

Zafar, S., Alamgir, Z., & Rehman, M. H. (2021). An Effective Blockchain Evaluation System Based on Entropy CRITIC Weight Method and MCDM Techniques. *Peer-to-Peer Networking and Applications, 14*(5), 3110-3123. https://doi.org/10.1007/s12083-021-01173-8

Zavadskas, E. K., Stanujkić, D., Turskis, Z., & Karabašević, D. (2022). An Intuitionistic Extension Of the Simple WISP Method. *Entropy, 2*(24), 218. https://doi.org/10.3390/e24020218

Zhang, Q., Liu, C., Guo, S., Wang, W., Luo, H., & Jiang, Y. (2023). Evaluation of the Rock Burst Intensity of a Cloud Model Based on the CRITIC Method and the Order Relation Analysis Method. *Mining, Metallurgy & Exploration, 40*, 1849–1863. https://doi.org/10.1007/s42461-023-00838-7